USAID
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The National Academies of SCIENCES ENGINEERING MEDICINE

PARTNERSHIPS FOR ENHANCED ENGAGEMENT IN RESEARCH

Funded Project Summaries

2012 - 2024

Introduction

Partnerships for Enhanced Engagement in Research (PEER) was a competitive grants program that invited scientists in low and middle-income countries (LMICs) to apply for awards of up to $300,000 to support research and capacity-building activities on topics with strong potential development impacts. Funded by the U.S. Agency for International Development (USAID) and implemented by the National Academies of Sciences, Engineering, and Medicine (NASEM), from 2011 to 2024, PEER supported over 463 scientists in 60 USAID-partner countries. These researchers partnered with U.S. government-supported scientists in mutually beneficial collaborations that produced scientific breakthroughs, trained future scientists, built capacity at local higher education institutions, and translated evidence into policy. Funded researchers examined international development topics such as environmental resilience, global health, and digital development, among others. PEER's core objectives were (1) advancing high quality research to improve programs and policies; (2) building partnerships between local research institutions and in-country and global entities; and (3) strengthening the research capacity in developing countries to generate solutions to local challenges.

PEER Structure

Each PEER project started as an application, where local scientists and their U.S.-based partners outlined in detail their proposed research topic, project goals, and how the topic aligned with USAID priorities. Projects were then rated by a panel of scholars convened by NASEM and ultimately selected for funding by NASEM and USAID. PEER researchers partnered with U.S.-based researchers funded or employed by the National Aeronautics and Space Administration, the National Institutes of Health, the National Oceanic and Atmospheric Administration, the National Science Foundation, the U.S. Department of Agriculture, the U.S. Geological Survey, or the Smithsonian Institution. PEER projects generally lasted up to three years, though many received no-cost extensions. PEER grantees used their flexible funding to conduct research, purchase equipment, provide training and stipends for students, travel to visit U.S. partners, attend conferences, and other relevant expenses.

Impact

Over 13 years, PEER strengthened the capacity of local institutions while producing research that influenced policy and programs. PEER created or supported research partnerships involving 325 low and middle-income institutions and 153 U.S. institutions in 60 states. In total, over 2,700 students were part of PEER teams; 51 percent of the students were women. PEER Principal Investigators have published over 1500 peer-reviewed journal articles to date.

Due to the complex and long-term nature of research for development, USAID staff designed a Program and Policy Change (PPC) Framework that measures the social and economic impact of research projects across various sectors. USAID and NASEM staff measured the extent to which PEER project results were used as evidence to inform local, regional, or national policies, programs, or behavior changes by external stakeholders. At the end of the program, PEER delivered 188 program and policy changes at the local, national, and regional levels. A few examples of high-impact PEER projects include:

- A group of researchers in Kenya and Tanzania teamed up to sequence, catalog, and document the DNA of endangered wildlife into barcodes now used by East African law enforcement agencies to track and prosecute illegal wildlife traffickers.

- PEER researchers worked with community members to address forest degradation and illegal gold mining and logging in the Peruvian Amazon using remote sensing technology. With research team training, park rangers and Indigenous community members co-designed methods to monitor the region and respond to illegal activity while ensuring the safety of community members.
- A group of researchers in Malawi and Mozambique worked with U.S. universities to study Cervical Cancer Screening and Preventive Therapy, which informed national cervical cancer screening and treatment guidelines in both countries.
- Indian researchers worked to develop, pilot, patent, and market the Farm SunFridge, a batteryless, off-grid solar-refrigerator that allows farmer groups to cool their produce and reduce spoilage. As a result, farmers and governments hope to build Sunfridges in Ethiopia, Kenya, Bangladesh, and Bhutan.
- Throughout Africa and Asia, the PEER Women in Science Mentoring Program provided opportunities for early career women scientists to build skills in topics such as work-life balance, networking, proposal writing, publishing research papers, and access to small grants to kick start their research.

The longevity of the PEER program speaks to the support of numerous global partners, including multiple U.S. government agencies and USAID Missions. PEER PIs and their teams collectively received more than $133 million in additional funding to continue and expand their research as a result of working with PEER. On the U.S. side, PEER projects leveraged more than $580 million in U.S. science agency funding that went to U.S. partners. However, what is most unique about PEER is its focus on local research teams tackling local and regional problems in partnership with U.S. partners.

This Book

USAID and NASEM are proud to present the following “PEER Funded Project Summaries” book, a culmination of thirteen years of hard work, dedication, and research by hundreds of scientists across the globe. In this book, you will find a comprehensive summary of every project conducted between 2011 and 2024. By compiling an aggregate list of achievements made by the PEER scientists, we hope to elevate the work of these research teams who are changing the development landscape.

AFRICA

BENIN

Benin - Project 8-211: Entomopathogenic nematodes and plant resistance for the control of sweet potato weevils (Cylas spp.) in Benin and in South Africa
PI: Hugues Kossi Baimey, University of Parakou
U.S. Partner: David Shapiro-Ilan, United States Department of Agriculture/Agricultural Research Service, Southeast Fruit and Tree Nut Research Lab

BOTSWANA

Botswana - Project 9-452: Long-term impacts of land-use/land-cover dynamics on surface water quality in Botswana's reservoirs using satellite data and artificial intelligence methods: case study of the Botswana's Limpopo River Basin (1984-2019)
PI: Yashon Ouma, University of Botswana
U.S. Partner: Jiaguo Qi, Michigan State University (funded by the National Aeronautics and Space Administration)

Botswana - Project 9-477: livelihood change in the context of community conservation - Chobe, Botswana
PI: Lin Cassidy, Okavango Research Institute, University of Botswana
U.S. Partner: Andrea Gaughan, University of Louisville, Kentucky (funded by the National Science Foundation)

BURKINA FASO

Burkina Faso - Project 8-116: Increasing access to sanitation services integrated with resource recovery in rural Burkina Faso
PI: Ynoussa Maiga, University of Ouaga I Pr Joseph Ki-Zerbo
U.S. Partner: James Mihelcic, University of South Florida (funded by the National Science Foundation)

CAMEROON

Cameroon - Project 4-360: Using geospatial tools to investigate how deforestation affects the transmission of malaria in birds
PI: Anong Damian Nota, University of Buea
U.S. Partner: Thomas Smith, University of California, Los Angeles (funded by the National Science Foundation)

Cameroon - Project 3-12: Biochar and compost from cocoa pod husk: opportunities for crop fertilization and suppression of black pod disease
PI: Njukeng Nkengafac, Institute of Agricultural Research for Development
U.S. Partner: Bin Gao, University of Florida (funded by the National Science Foundation)

ETHIOPIA

Ethiopia - Project 6-400: Promoting Resource- Oriented Sanitation in Peri-urban Ethiopia throughthe Production of Struvite from Digested Sludge Filtrate
PI: Adey Desta, Addis Ababa University
U.S. Partner: Nancy Love, University of Michigan (funded by the National Science Foundation)

Ethiopia - Project 5-610: Improved access and uptake of maternal and child health services in rural Ethiopia through collaborative community and health systems partnership
PI: Getahun Asres Alemie, University of Gondar
U.S. Partner: Judd Walson, University of Washington (funding by the National Institutes of Health)

Ethiopia - Project 5-194: Bringing seasonal forecasts to the farmer: participatory climate smart villages for Green Growth in Ethiopia
PI: Belay Simane, Addis Ababa University
U.S. Partner: Benjamin Zaitchik, Johns Hopkins University (funded by the National Aeronautics and Space Agency)

Ethiopia - Project 4-315: Enhancing food security through improved productivity, nutrition, and marketing of chickpeas in central and western Ethiopia
PI: Kassahun Tesfaye Geletu, Institute of Biotechnology, Addis Ababa University
U.S. Partner: Douglas Cook, University of California, Davis (funded by the National Science Foundation)

Ethiopia - Project 3-94: Development of a Microgrid Research Center in Ethiopia to support USAID's Power Africa program
PI: Belachew Gessesse with co-PI Nigus Gabbiye Habtu, Bahir Dar University
U.S. Partner: Suman Banerjee, University of Wisconsin-Madison (funded by the National Science Foundation)

Ethiopia - Project 2-333: Development and field testing of high-performance aluminium oxide-based technologies for fluoride removal in the Ethiopian Rift Valley
PI: Feleke Zewge Beshah, Addis Ababa University
U.S. Partner: David Sabatini, University of Oklahoma (funded by the National Science Foundation)

Ethiopia - Project 1-289: Reducing soil loss through effective soil and water conservation practices using hydrologic considerations and farmers' participation in Blue Nile Basin
PI: Seifu Tilahun, Bahir Dar University
U.S. Partner: Christopher Barrett, Cornell University (funded by the National Science Foundation)

Ethiopia - Project SG1-003: Unlock the potential of Begait cattle: genome wide assessment of genetic diversity, population structure and association study using high density single nucleotide polymorphism (SNP) marker
PI: Selam Meseret, Ethiopian Biotechnology Institute

GHANA

Ghana - Project 9-518: Community and Hospital-based obstetrics WhatsApp triage, referral, and transfer (WAT-RT) system
PI: Veronica Millicent Dzomeku, Kwame Nkrumah University of Science And Technology, Kumasi- Ghana
U.S. Partner: Jody Lori, University of Michigan (funded by the National Institutes of Health)

Ghana - Project 9-117: Agrivoltaic technology in drylands of West Africa: Strengthening national innovation systems for diffusion and market development at the water-energy-food nexus
PI: Francis Kemausuor, The Brew-Hammond Energy Centre, Kwame Nkrumah University of Science and Technology, with co-PI Patricia Amankwaa-Yeboah, CSIR-Crops Research Institute
U.S. Partner: Efthymios Nikolopoulos, Florida Institute of Technology(fundedby the National Science Foundation)

Ghana - Project 4-40: Development of high-yielding Aflatoxin-resistant maize hybrids for improved nutrition and health in Ghana
PI: Allen Oppong, CSIR, Crops Research Institute
U.S. Partner: Marilyn Warburton, USDA ARS Corn Host Plant Resistance Research Unit

Ghana - Project 3-186: PRESSA: Photovoltaic Reliability Evaluation in Sub-Sahara Africa
PI: Gabriel Takyi, Kwame Nkrumah University of Science & Technology
U.S. Partner: Christiana Honsberg and Mani G. TamizMani, Arizona State University (funded by the National Science Foundation)

Ghana - Project 2-251: Development of edible and medicinal mushrooms as functional foods in Ghana
PI: Mary Obodai, Council for Scientific and Industrial Research, Food Research Institute
U.S. Partner: Steven J. Schwartz, The Ohio State University (funded by the National Science Foundation)

Ghana - Project 1-142: Possible causes of the contraction of West Africa's rainfall season under global warming: implications for agriculture
PI: David Cudjoe Adukpo, University of Cape Coast
U.S. Partner: William Gutowski, Jr., Iowa State University (funded by the National Science Foundation)

Ghana – Project SG1-002: The gut microbiome composition and its implication for hypertension
PI: Adjoa A. Boakye, University of Health and Allied Sciences

KENYA

Kenya - Project 9-69: Enhancing capacity of local communities in Laikipia County, Kenya: Increasing preparedness and response to emerging infectious diseases in parallel with preservation of biodiversity
PI: Joseph Kamau, University of Nairobi
U.S. Partner: Dawn Zimmerman, Smithsonian Institution (funded by the Smithsonian Institution)

Kenya - Project 8-105: Distribution and species diversity of bats (Mammalia: Chiroptera) in Kenya
PI: Paul Webala, Maasai Mara University
U.S. Partner: Dawn Zimmerman, Smithsonian Institution

Kenya - Project 8-66: Deploying *Striga* smart sorghum: The last mile
PI: Steven Runo, Kenyatta University
U.S. Partner: Emily Bellis, Arkansas State University (funded by the National Science Foundation)

Kenya - Project 8-56: Application of partitioned woody and herbaceous forage estimates in index-based livestock insurance, a better alternative to NDVI as a proxy for forage index
PI: Milkah Kahiu, International Livestock Research Institute, in partnership with Jomo Kenyatta University of Agriculture and Technology
U.S. Partner: Niall Hanan, New Mexico State University (funded by the National Aeronautics and Space Administration)

Kenya - Project 5-93: Remote sensing and GIS mapping for land use changes in Laikipia ecosystem, Kenya: a tool to explore patterns of biodiversity and emergence of vector-borne zoonoses and enhance environmental management and community health
PI: Nancy Moinde, Institute of Primate Research-National Museums of Kenya
U.S. Partner: Peter Leimbruger, Smithsonian Institution

Kenya - Project 4-494: Enhancing conservation of African buffalo and rangeland habitat through molecular investigations of foot-and-mouth disease at the wildlife-livestock interface
PI: Francis Gakuya, Kenya Wildlife Service
U.S. Partner: Andres Perez, University of Minnesota (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Kenya - Project 4-457: Using an integrated modeling framework to evaluate the impact of human-induced land use/land cover change on carbon dynamics in the Upper Ewaso Ngiro River Basin, Kenya
PI: Stephen Kiama, Kenya Forestry Research Institute
U.S. Partner: Scott Goetz, Woods Hole Research Cente (funded by the National Aeronautics and Space Agency)

Kenya - Project 4-428: Enhancing elephant conservation and protection in East Africa with molecular genetic tools
PI: Moses Otiende, Kenya Wildlife Service
U.S. Partner: Samuel Wasser and David Schindel, Smithsonian Institution

Kenya - Project 4-365: DNA barcoding to combat wildlife crime
PI: Henry Ndithia, National Museums of Kenya
U.S. Partner: David Schindel, Smithsonian Institution

Kenya - Project 4-342: Use of DNA technology in combating illegal trade and promoting conservation and sustainable use of plants in Kenya and Tanzania
PI: Beatrice Khayota, National Museums of Kenya
U.S. Partner: David Schindel, Smithsonian Institution

Kenya - Project 4-192: End of the road for illegal bushmeat trade in East Africa: establishing transboundary surveillance by high resolution melting analysis of vertebrate molecular barcodes
PI: Lilian Wambua, International Center for Insect Physiology and Ecology
U.S. Partner: Scott Miller, Smithsonian Institution

Kenya, Ethiopia, and Tanzania - Project 3-233: GeoPower Africa
PI: Nicholas Mariita, Dedan Kimathi University of Technology, Kenya, with co-PIs Jacques Varet, Dedan Kimathi University of Technology (DeKUT); Tesfaye Kidane Birke, Addis Ababa University; and Gabriel Mbogoni, Geological Survey of Tanzania
U.S. Partner: Cynthia Ebinger, University of Rochester (funded by the National Science Foundation)

Kenya - Project 3-210: Development and implementation of a solar PV outreach training module for capacity building in East Africa
PI: Izael Da Silva, Strathmore University
U.S. Partner: Benjamin L. Ruddell, Arizona State University (funded by the National Science Foundation)

Kenya - Project 3-154: Mwangaza project on science, technology, engineering, and mathematics and computing education for students in Kenya with vision loss
PI: Marguerite Miheso O'Connor, Kenyatta University
U.S. Partner: Bruce N. Walker, Georgia Institute of Technology (funded by the National Science Foundation)

Kenya - Project 2-447: Capacity building in fish biodiversity discovery in Kenya
PI: Dorothy Wanja Nyingi, National Museums of Kenya
U.S. Partner: Henry Bart Jr., Tulane University (funded by the National Science Foundation)

Kenya - Project 2-349: Derailing witchweed (*Striga*) virulence in rice to achieve durable and broad-spectrum resistance
PI: Steven Runo, Kenyatta University
U.S. Partner: Mike P. Timko, University of Virginia (funded by the National Science Foundation)

Kenya - Project 2-335: Unlocking agricultural potential in drylands: enhancing efficient utilizationof soil moisture for improved smallholder farm productivity in ASALs of Kenya
PI: Mary Baaru, Kenyatta University
U.S. Partner: Ethan Allen, Pacific Resources for Education and Learning (funded by the National Science Foundation)

Kenya - Project 2-219: Strengthening institutional capacity for participatory action research in sustainable aquaculture

PI: Joyce Gichiku Maina, University of Nairobi

U.S. Partner: Irene Kimaru, St. John Fisher College (funded by the National Science Foundation)

Kenya - Project 2-135: Harnessing genomics of edible African *Solanaceae* plants for improved nutritional and food security

PI: Willis Owino, Jomo Kenyatta University of Agricultureand Technology, with co-PI Jane Ambuko, University of Nairobi

U.S. Partner: James Giovannoni, USDA-ARS, Boyce Thompson Institute for Plant Research, Cornell University (funded by the National Science Foundation)

Kenya - Project 1-382: Natural resources interacting with health outcomes: understanding fishery resource use and improving nutrition in western Kenya

PI: Richard Magerenge, Organic Health Response-Ekialo Kiona Center

U.S. Partner: Justin Brashares, University of California, Berkeley (funded by the National Science Foundation)

Kenya - Project 1-207: Addressing drinking water quality challenges in developing countries: case study of Lake Victoria Basin

PI: Shem Wandiga, University of Nairobi

U.S. Partner: Benito Mariñas, University of Illinois Urbana-Champaign, formerly Mark Shannon (funded by the National Science Foundation)

Kenya - Project 1-198: Natural pest and weed suppression functions by birds as incentives to conserve a globally threatened bird species and enhance livelihoods in an agricultural landscape

PI: Peter Njoroge, National Museums of Kenya

U.S. Partner: Matthew Johnson, Humboldt State University (funded by the National Science Foundation)

Kenya - Project H1-175: Impact of PRONTO training in emergency obstetric and newborn care on 24-hour neonatal mortality

PI: Onesmus Gachuno, University of Nairobi

U.S. Partner: James Kiarie, University of Nairobi (funded by the National Institutes of Health)

Kenya - Project H1-120: Feasibility and effectiveness of the baby friendly community initiative (BFCI) in Kenya: a pilot community trial in a rural setting

PI: Judith Kimiywe, Kenyatta University

U.S. Partner: Stephen McGarvey, Brown University (funded by the National Institutes of Health)

Kenya – Project SG1-001: Evaluationof nutritional and pharmacological potential of Kenyan Doum Palm: towards improved livelihoods

PI: Cecilia Mbithe Mweu, Jomo Kenyatta University

Kenya – Project SG1-004: Towards improving nutritional outcomes through adoption of biofortified orange fleshed sweet potato climate smart technologies in Isiolo County, Kenya

PI: Agnes Kavoo, Jomo Kenyatta University

Kenya – Project SG1-005: Development of a visual detection microarray-based method for the detection of multiple Aflatoxin producing *Aspergillus* species

PI: Lilian W. Kamau-Gatogo, Kenyatta University

MADAGASCAR

Madagascar - COV-164: Resilient food systems and biodiversity under future crises in Madagascar
PI: O. Sarobidy Rakotonarivo, University of Antananarivo
U.S. Partner: Randall Kramer, Andrew Bell, and James Herrera, Duke University (funded by National Institutes of Health)

Madagascar - Project 9-232: Improving human livelihoods through holistic conservation of Malagasy orphaned plants, the iconic Baobab trees
PI: Seheno Andriantsaralaza, University of Antananarivo
U.S. Partner: Onja Razafindratsima, University of California, Berkeley(fundedby the United States Department of Agriculture/ National Institute of Food and Agriculture)

Madagascar - Project 8-168: Improving mangrove forest carbon and socioeconomic data to improve management in Madagascar
PI: Herintsitohaina Razakamanarivo, University of Antananarivo Laboratory of Radioisotopes
U.S. Partner: Richard MacKenzie, U.S. Forest Service Institute of Pacific Islands Forestry

Madagascar - Project 7-477: Building a reference collection for Malagasy rosewood, palissander and ebony identification
PI: Bako Harisoa Ravaomanalina, University of Antananarivo
U.S. Partner: John Hermanson and Michael Wiemann, United States Department of Agriculture, Forest Service, Forest Products Laboratory

Madagascar - Project 6-134: Community-based monitoring and management of Madagascar's National Park protected areas
PI: Lalatiana Randriamiharisoa, Madagascar National Parks
U.S. Partner: Brett Scheffers, University of Florida (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Madagascar - Project 6-125: Wild and edible insects to sustain forests and fight malnutrition.
PI: Andrianjaka Ravelomanana, Madagascar Biodiversity Center
U.S. Partner: Brian Fisher, California Academy of Sciences (funded by the National Science Foundation)

MALAWI

Malawi - Project 9-493: Bridging higher education and practice: Addressing gender inequity in STEM and sanitation in Malawi
PI: Brighton Chunga, Mzuzu University
U.S. Partner: Francis L. de los Reyes III, North Carolina State University (funded by the National Science Foundation)

Malawi - Project 1-307: Soil carbon distribution and dynamics in Malawi: a unique opportunity to optimize sustainable land use and enhance food security
PI: Jimmy Namangale, Chancellor College
U.S. Partner: G. Philip Robertson, Michigan State University (funded by the National Science Foundation)

Malawi - Project H1-5: Introducing "Option B+" in Malawi: impact on child outcomes
PI: Frank Chimbwandira, Malawi Ministry of Health
U.S. Partner: Matthias Egger, University of Bern

MALI

Mali - Project 8-207: Development of hay production techniques for livestock fattening and agro-pastoral resilience in the western Sahel of Mali
PI: Moussa Karembe, University of Sciences, Techniques, and Technologies of Bamako
U.S. Partner: Niall Hanan, New Mexico State University (funded by the National Aeronautics and Space Administration)

Mali - Project 8-102: Production of commercial bioplastic-based biopesticide to control aflatoxin contamination in crops
PI: Amadou Hamadoun Babana, University of Sciences, Techniques, and Technologies of Bamako
U.S. Partner: Hamed K. Abbas, United States Department of Agriculture/ Agricultural Research Service

Mali - Project 6-157: Evaluation study of the use of digital technologies for agriculture and food security in Mali
PI: Amadou Sidibé, Institute Politechnique Rural Katibougou
U.S. Partner: Laura Schmitt Olabisi, Michigan State University (funded by the National Science Foundation)

Mali - Project 6-142: Improving Parkland Management and Agriculture Using UAV Technology in Mali
PI: Fadiala Dembele, Institute Politechnique Rural Katibougou
U.S. Partner: Paul Laris, California State University, Long Beach (funded by the National Science Foundation)

Mali – Project 5-148: More rice for Africa: enhancing smallholder farmers' rice yields in Africa throughthe use of efficient and low cost endophytic *Actinomycetes* biopesticide
PI: Amadou Babana, University of Sciences, Techniques and Technologies of Bamako (USTTB)
U.S. Partners: David Weller, U.S. Department of Agriculture/ Agricultural Research Service, and Dr. Linda Kinkel, University of Minnesota

Mali - Project H1-85: Optimization of SMC delivery and its effects on the acquisition of malaria immunity
PI: Alassane Dicko, University of Bamako
U.S. Partner: Patrick Duffy, National Institute of Allergy and Infectious Diseases (NIAID) (funded by the National Institutes of Health)

MOZAMBIQUE

Mozambique - Project 8-173: Understanding interactions between people, elephants and fires in the miombo woodlands of Niassa National Reserve in support of biodiversity conservation action
PI: Natasha Ribeiro, Eduardo Mondlane University
U.S. Partner: Fernando Sedano, University of Maryland, College Park (funded by the National Aeronautics and Space Administration)

Mozambique - Project 2-156: Ecosystem carbon analytical laboratory
PI: Salomao Bandeira, Universidade Eduardo Mondlane
U.S. Partner: Ilka C. Feller, Smithsonian Environmental Research Center

Mozambique - Project H1-64: Reducing loss-to-follow-up among HIV-exposed infants in central Mozambique
PI: Lucia da Costa Vieira, Beira Operations Research Center (CIOB)
U.S. Partner: James Pfeiffer, University of Washington (funded by the National Institutes of Health)

NIGERIA

Nigeria - Project 3-208: Systems engineering perspective on power transmission for Nigeria
PI: Adegoke Melodi with co-PI Olatubosun Olabode, The Federal University of Technology, Akure
U.S. Partner: Kevin Tomsovic, University of Tennessee (funded by the National Science Foundation)

Nigeria - Project 2-504: Improving Yam (*Dioscorea spp.*) seed systems through production of dormancy-controlled seed tubers in temporary immersion bioreactors
PI: Morufat Balogun, University of Ibadan
U.S. Partner: Wayne Curtis, The Pennsylvania State University (funded by the National Science Foundation)

Nigeria - Project 2-463: Renewable energy: desktop learning module for gasification processes
PI: Idris Bugaje, National Research Institute for Chemical Technology
U.S. Partner: Bernard J. Van Wie, Washington State University (funded by the National Science Foundation)

Nigeria – Project SG1-008: Food neophobia and willingness to try fortified foods among Nigerians
PI: Folake Idowu-Adebayo, Federal University Oye-Ekiti

SIERRA LEONE

Sierra Leone - Project H1-17: Lassa fever pathobiology in children and during pregnancy
PI: Donald Grant, Lassa Fever Program Kenema Government Hospital
U.S. Partner: Robert Garry, Tulane University School of Medicine (funded by the National Institutes of Health)

SENEGAL

Senegal - COV-053: Designing and evaluating a wastewater pathogen monitoring tool for sewered and non-sewered sanitation systems to prevent disease outbreaks in Dakar, Senegal
PI: Nouhou Diaby, Université Cheikh Anta Diop
U.S. Partner: William Tarpeh, Stanford University (funded by National Science Foundation)

Senegal - Project 2-432: Rhizosphere biology of shrub created resource islands of Sahelian agroecosystems: optimization and adaptation to climate change
PI: Yacine Badiane Ndour, Institut Senegalais de Recherches Agricoles
U.S. Partner: Richard P. Dick, Ohio State University (funded by the National Science Foundation)

Senegal - Project 2-344: Impact of climate change on freshwater availability for Senegal: modeling future changes in hydro-climatology of Lake of Guiers
PI: Mouhamadou Bamba Sylla, Ecole Supérieure Polytechnique de l'Université Cheikh Anta Diop
U.S. Partner: Jeremy Pal, Loyola Marymount University (funded by the National Science Foundation)

SOUTH AFRICA

South Africa - COV-100: Impact of COVID-related disinfectants in the food processing sector on the downstream impact of antimicrobial resistant pathogens and endocrine disrupting chemicals into wastewater systems
PI: Lise Korsten, University of Pretoria, South Africa
U.S. Partner: Charles Gerba, University of Arizona (funded by United States Department of Agriculture/ National Institute of Food and Agriculture)

South Africa - COV-079: Friction and flows: understanding COVID-19 impacts on the wildlife economy in southern Africa
PI: Annette Hübschle, University of Cape Town
U.S. Partner: Meredith Gore, University of Maryland (funded by National Science Foundation)

South Africa - COV-060: Early child development duringa global pandemic: Indirect effects of COVID-19 in South Africa
PI: Roisin Elizabeth Drysdale, University of the Witwatersrand
U.S. Partner: Chris Desmond, University of KwaZulu-Natal (funded by National Institutes of Health)

South Africa - COV-054: YouthCAN - Co-design African Needs: Exploring strategies to increase the uptake of a SARS-CoV-2 vaccine in youth: A co-designed study with youth
PI: Janan Dietrich, Perinatal HIV Research Unit, Division of the University of the Witwatersrand
U.S. Partner: Avy Violari, Perinatal HIV Research Unit, Division of the University of the Witwatersrand (funded by National Institutes of Health)

South Africa - COV-041: Understanding the impact of COVID-19 and the national lockdown restrictions on sex worker uptake of health services in four sites in Gauteng, South Africa: A retrospective record review
PI: Khuthadzo Hlongwane, Perinatal HIV Research Unit (PHRU), a Division of the University of the Witwatersrand and co-PI Jenny Coetze, African Potential Foundation
U.S. Partner: Glenda Gray, South African Medical Research Council and Perinatal HIV Research Unit, Division of the University of the Witwatersrand (funded by National Institutes of Health)

South Africa - Project 6-450: Water Security and Social-Hydrological Resilience for Rural Small-scale Crop Value Chains
PI: Marizvikuru Manjoro nee Mwale, University of Venda
U.S. Partner: Brian Chaffin, University of Montana, Missoula (funded by the National Science Foundation)

South Africa - Project 6-448: Design of metal-oxide nanoparticle reinforced Nano-fibrous biopolymer composites for water treatment
PI: Wilson Gitari, University of Venda
U.S. Partner: James Smith, University of Virginia (funded by the National Science Foundation)

South Africa - Project 6-447: Effectiveness of point-of-use water treatment technologies to prevent child stunting in South Africa
PI: Pascal Bessong, University of Venda
U.S. Partner: James Smith, University of Virginia (funded by the National Science Foundation)

South Africa - Project 5-432: Developing exposure and toxicity data for trace organic chemicals in wastewater, biosolids, and soils
PI: Bice Martincigh, University of KwaZulu-Natal
U.S. Partner: Natalie Mladenov, San Diego State University (funded by the National Science Foundation)

South Africa - Project 5-48: Characterizing and tracking of antimicrobial resistance in the water-plant-food public health interface: an emerging water, sanitation and hygiene issue
PI: Liza Korsten, University of Pretoria
U.S. Partner: Manan Sharma, Environmental Microbial and Food Safety Laboratory, United States Department of Agriculture/ Agricultural Research Service

South Africa - Project 4-153: GRECHLIM
PI: Tamiru Abiye, University of the Witwatersrand
U.S. Partner: Richard Healy, United States Geological Survey

South Africa - Project 4-149: Promoting community and regional food systems in the Eastern Cape, South Africa
PI: Michael Aliber, University of Fort Hare
U.S. Partner: Stephen Ventura, University of Wisconsin-Madison (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

South Africa - Project 3-120: Managing fire and grazing to maximize carrying capacity in African rangelands
PI: Sally Archibald, University of Witwatersrand
U.S. Partner: Todd M. Anderson, Wake Forest University (funded by the National Science Foundation)

South Africa - Project 2-512: Mammal MAP: The African Mammal Atlas Project
PI: Lesley Gordon Underhill, University of Cape Town, with co-PI Robert Peter Millar, University of Pretoria
U.S. Partners: Walter Jetz, Yale University, and Robert Guralnik, University of Colorado at Boulder (funded by the National Science Foundation)

South Africa - Project 2-445: Application of cosmic ray probes for the validation of hydrometeorolgical and remote sensing models
PI: Colin Everson, University of KwaZulu-Natal
U.S. Partner: Marek Zreda, University of Arizona (funded by the National Science Foundation)

South Africa - Project 2-181: Climate change and arid-zone birds: validation of a behavioral index for assessing species' relative vulnerabilities to rising temperatures
PI: Andrew McKechnie, University of Pretoria
U.S. Partner: Blair Wolf, University of New Mexico (funded by the National Science Foundation)

South Africa - Project 2-176: Development of advanced composite materials and geopolymers for the removal of uranium and toxic elements from gold mine-polluted water
PI: Hlanganani Tutu, University of the Witwatersrand
U.S. Partner: Edward Rosenberg, University of Montana (funded by the National Science Foundation)

TANZANIA

Tanzania - Project 9-456: Morogoroyouth empowerment throughestablishment of social innovation (YEESI) lab for problem-centered training in machine vision
PI: Kadeghe Fue, Sokoine University of Agriculture
U.S. Partner: Glen Rains, University of Georgia (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Tanzania - Project 9-257: Solar dryer integrated with energy storage system: An energy efficient and environmentally friendly technology for drying biomaterials in Tanzania
PI: Thomas Kivevele, Nelson Mandela African Institution of Science and Technology (NM-AIST)
U.S. Partner: Sunghwan Lee, Purdue University (funded by the National Science Foundation)

Tanzania - Project 8-81: Enhancing postharvest technologies and food safety innovations in fresh tomato value chain
PI: Yasinta Muzanila, Sokoine University of Agriculture
U.S. Partner: Yaguang Luo, United States Department of Agriculture/ Agricultural Research Service

Tanzania - Project 6-263: Exploring the fate of mercury in artisanal gold mining of the Lake Victoria Gold Field
PI: Clavery Tungaraza, Sokoine University of Agriculture
U.S. Partner: Mark Cohen, National Oceanic and Atmospheric Administration (NOAA)

Tanzania and Kenya - Project 3-80: Waste to renewable energy: biogas cleanup (upgrading) in Tanzania and Kenya
PI: Cecil King'ondu, Nelson Mandela African Institution of Science and Technology, with co-PI Owino Joseph Hazael Odero, South Eastern Kenya University
U.S. Partner: Puxian Gao, University of Connecticut (funded by the National Science Foundation)

Tanzania - Project 3-17: Cooperation and compromise in developing rural communities—Case study: solar-electric mini-grids for the Maasai
PI: Kisioki Moitiko and co-PI Robert Lange, The International Collaborative for Science, Education, and the Environment (Tanzania)
U.S. Partner: Krister Andersson, University of Colorado (funded by the National Science Foundation)

Tanzania - Project 2-343: Computational mathematics, modeling and analysis of biological, bio-inspired and engineering systems
PIs: Madundo Mtambo and Burton Mwamila, The Nelson Mandela African Institute of Science and Technology
U.S. Partner: Padmanabhan Seshaiyer**,** George Mason University (funded by the National Science Foundation)

Tanzania - Project 1-232: Characterizationof cassava mosaic gemini viruses and their satellites in cassava at the cellular level
PI: Joseph Ndunguru, Mikocheni Agricultural Research Institute
U.S. Partner: Linda Hanley-Bowdoin, North Carolina State University (funded by the National Science Foundation)

UGANDA

Uganda - COV-096: The impact of the COVID-19 pandemic on GBV among women and girls in informal settlements in Kampala
PI: Juliet Kiguli, Makerere University, School of Public Health
U.S. Partner: Julia Dickson-Gomez, Medical College of Wisconsin (funded by National Institutes of Health)

Uganda - COV-027: The impact of COVID-19 on school enrollment and mental healthof children in the Manafwa watershed area in Uganda
PI: Charles Batte, Makerere University
U.S. Partner: Trishul Siddharthan, University of Miami (funded by National Institutes of Health)

Uganda - COV-012: Scaling cost-effective, safe, and quality black soldier fly insect larvae enterprise for COVID-19 livelihood resilience in Uganda
PI: Deborah Ruth Amulen, Makerere University
U.S. Partner: Jennifer Pechal, Michigan State University (funded by National Science Foundation)

Uganda - Project 8-187: Improving hand hygiene practice among healthcare workers through health and environmental cues in Kampala metropolitan area
PI: Richard Kibirango Mugambe, Makerere University School of Public Health
U.S. Partner:: Christine Moe, Emory University (funded by National Institutes of Health)

Uganda - Project 8-186: Promoting hand hygiene throughproduction and use of locally produced alcohol hand-rub in health facilities in Uganda
PI: Esther Buregyeya, Makerere University School of Public Health
U.S. Partner: Christine Moe, Emory University (funded by National Institutes of Health)

Uganda - Project 7-471: Reproductive Health Empowerment through Telehealth (REHEAT)
PI: Agnes Kiragga, Infectious Diseases Institute, Kampala, Uganda
U.S. Partner: Keith Horvath, University of Minnesota (funded by National Institutes of Health)

Uganda - Project 6-158: Scaled deployment of smart-phone agro-applications for field based diagnosis and real-time surveillance data collection.
PI: Ernest Mwebaze, Makerere University
U.S. Partner: Jesse Poland, Kansas State University (funded by the National Science Foundation)

Uganda - Project 5-450: mHealth for TB-Tobacco: An approach to reduce tobacco use among TB patients
PI: Elizeus Rutebemberwa, Makerere University
U.S. Partner: Robert Pack, East Tennessee State University (funded by the National Institutes of Health)

Uganda - Project 5-37: Delivering crop yield nowcasts and forecasts by integrating satellite data and crop modelling in Sub-Saharan Africa
PI: Ejiet John Wasige, Makerere University
U.S. Partner: Forrest Melton, California State University Monterey Bay, and the NASA Ames Research Center Cooperative for Research in Earth Science and Technology (NASA ARC-CREST)

Uganda - Project 5-19: A multi-sensor hydrologic modeling framework to assess the impacts of small-scale water storage practices to water resources over Uganda
PI: Jamiat Nanteza, Makerere University
U.S. Partner: Mathew Rodell, NASA Goddard Space Flight Center

Uganda - Project 2-253: Sustainable coffee-banana agroforestry systems to adapt to climate change, enhance food security, and alleviate poverty in Uganda
PI: Godfrey H. Kagezi, Coffee Research Center, National Agricultural Organization
U.S. Partner: Ivette Perfecto, University of Michigan (funded by the National Science Foundation)

Uganda - Project H1-61: Development and evaluation of strategies to foster implementation of guidelines for diagnosis of childhood tuberculosis
PI: Achilles Katamba, Makerere University
U.S. Partner: Adithya Cattamanchi, University of California at San Francisco (funded by the National Institutes of Health)

Uganda - Project H1-54: Assessing the effect of strengthening the referral of children from the private health sector and its impact on child survival in Uganda
PI: Anthony Mbonye, Makerere University
U.S. Partner: Philip LaRussa, Columbia University (funded by the National Institutes of Health)

ZAMBIA

Zambia - Project 8-174: Increased availability of fast cooking yellow dry beans rich in bioavailable iron to Zambia consumers and farmers
PI: Kelvin Kamfwa, University of Zambia
U.S. Partner: Karen Cichy, United States Department of Agriculture/ Agricultural Research Service

Zambia - Project 7-109: Applicationof GIS and geospatial analysis in understanding charcoal production, supply and demand in selected sites of Lusaka; Central, Copperbelt and North Western provinces of Zambia
PI: Stephen Syampungani, Copperbelt University
U.S. Partner: Andrew Hudak, USDA Forest Service

Zambia - Project 7-100: Adoption and scale-up of charcoal alternatives in Zambia
PI: Francis Yamba, Centre for Energy, Environment and Engineering Zambia
U.S. Partner: Robert Bailis, Stockholm Environment Institute - US Center (funded by the National Science Foundation)

BENIN

BENIN - PROJECT 8-211: ENTOMOPATHOGENIC NEMATODES AND PLANT RESISTANCE FOR THE CONTROL OF SWEET POTATO WEEVILS (CYLAS SPP.) IN BENIN AND IN SOUTH AFRICA

PI: Hugues Kossi Baimey, University of Parakou
U.S. Partner: David Shapiro-Ilan, United States Department of Agriculture/ Agricultural Research Service, Southeast Fruit and Tree Nut Research Lab
Dates: March 2020 – February 2022

PROJECT OVERVIEW

Sweet potato (SP, *Ipomoea batatas)* is one of the most widely cultivated root and tuber crops worldwide, but its production and storage are badly affected by SP weevils, *Cylas* spp. This can lead to yield losses as high as 100%, especially in storage during dry seasons. In addition, the terpenes produced by the pest while feeding greatly reduce the quality of affected tubers. To control the pests, most African SP farmers resort to expensive synthetic chemical insecticides with significant environmental and health risks.

This PEER project studied the use of entomopathogenic nematodes (EPNs) of the families *Heterorhabditidae* and *Steinernematidae* and plant resistance as an efficient, cost-effective, fast, and environmentally safe pest control method. In addition to assessing the severity of damage caused by *Cylas* spp. to SP in Benin and South Africa, the researchers screened EPN isolates provided by a South African partner lab to assess their efficacy to control SP weevils. The two best EPN isolates were identified through such screening and will be stabilized through the development of inbred lines to prevent deterioration over time. The U.S. partner Dr. Shapiro-Ilan provided training on this process.

Women were key stakeholders in the project, as they are frequently involved in SP production, storage, processing, and commercialization in Africa. The Development Leaders NGO in Benin and the Small Grain Institute of the Agricultural Research Council in South Africa have indicated that they are willing to produce the nematodes for farmers using the technique studied in this project.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team began by conducting socioeconomic and farmer opinion surveys in both Benin and South Africa. More than 150 SP farmers across the two countries were surveyed on their knowledge and opinion of EPNs. During the diagnostic survey, researchers also located two SP fields infested naturally with Cylas spp. for future trials. Under laboratory conditions, the researchers mixed isolates of Heterorhabditis, as well as Steinernema nematodes. Each set of hybridized and stabilized isolates was compared with base populations for efficacy in controlling SPW and larvae. In a separate study, the researchers selected eleven isolates of indigenous EPNs from the collection at the Agricultural Research Council (South Africa) and screened them for efficacy against SPW. One was selected for field testing.

The PEER team undertook field tests of the EPN hybrids in South Africa and Benin in newly planted SP fields and existing fields infested with SPW, comparing them against fields with no treatments and those with chemical insecticides applied. The researchers collected data monthly on SPW population density, plant flowering, and damages caused by weevils to SP plants. At harvest, SP plant biomass, tuberous root weight, and damage caused by weevils were assessed visually. Soil samples were also collected from each mound for assessment of the persistence of nematodes previously applied in the soil after planting. Harvested tuberous roots were stored and the population of emerged weevils assessed daily for 10 weeks. Their results showed that entomopathogenic nematodes could serve as a potential biological control method for the control of sweet potato weevils.

The project helped train two undergraduate and two graduate students and supported smallholder farmers with planting materials and training. The PI's lab was also outfitted with equipment for molecular work on nematodes so that they will be able to continue field experiments in the future. The researchers on the project received five separate grants worth nearly $1.2 million for future related work on their own projects and through collaborations with international teams.

PUBLICATION

Guidi, J. A. A., Adjovi, I. S. M., Nouatin, G. S., N'tcha Sema, J., Ramakuwela, T., Shapiro-Ilan, D., & Baimey, H. 2021. Regards croisés pratiques paysannes et introduction d'innovations : Cas des nématodes comme méthode de lutte biologique contre les charançons de la patate douce au Nord-Ouest du Bénin. [Cross-views of farming practices and introduction of innovations: case of nematodes as a biological control method against sweet potato weevils in northwest Benin]. Annales de l'Université de Parakou - Série Sciences Naturelles et Agronomie, 11(1), 1–12. https://doi.org/10.56109/aup-sna.v11i1.18

BOTSWANA

BOTSWANA - PROJECT 9-477: LIVELIHOOD CHANGE IN THE CONTEXT OF COMMUNITY CONSERVATION - CHOBE, BOTSWANA

Pi: Lin Cassidy, Okavango Research Institute, University of Botswana
U.S. Partner: Andrea Gaughan, University of Louisville, Kentucky (Funded by the National Science Foundation
Dates: April 2021 – January 2024

PROJECT OVERVIEW

Community conservation areas (CCAs) with tourism partnerships in the southern African savanna area are touted as a mechanism to support alternative livelihoods and reduce vulnerability while increasing wildlife protection in a landscape. Yet the claim that CCAs effectively support adaptive capacity is tenuous. Revenue is mostly returned at the community level, while economic variation occurs at the household level, where costs of living with wildlife differ according to land and natural resource use—a challenging scale mismatch. Within rural communities, socioeconomic conditions are not homogeneous, and aggregate descriptions may not be representative of all households. It is important to investigate alternative vulnerability models to capture the sources of adaptive capacity and resilience.

This PEER project sought to assess changes in socioeconomic conditions in the same five communities over time—a rare opportunity for longitudinal research on rural household vulnerability. This study explored the validity of the sustainable livelihoods' framework approach in an understudied, semi-arid African context and also tested if linking different capital types to concepts of adaptive capacity and vulnerability can provide a link between context-specificity and generalizable principles.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project data involved surveys exploring livelihood change in five villages in northern Botswana that have had a community conservation project for about 30 years. The initial sample was both statistically randomized and anonymous, so following up with the exact same households was not possible. The PEER team's analysis of this dataset brought empirical evidence to the ongoing critiques and evaluations of community-based conservation, identifying shortcomings and providing suggestions for improvement. It has also clarified the relationship between natural resource use and poverty and brought a clearer understanding to what "relying" on natural resources actually means for rural households.

The research outputs include one academic journal article, three policy briefs, and one community feedback report, written in the national language, Setswana (Tswana). The team presented their results at the FLARE (Forests & Livelihoods: Assessment, Research, and Engagement Network) annual conference. The policy briefs, which contain recommendations for policy actions, included discussion on how to correctly identify how natural resources are being used and the history and future of tourism concession areas in northern Botswana.

PUBLICATION

Lin Cassidy, Narcisa G. Pricope, Forrest R. Stevens, Jonathan Salerno, David C. Parry, Michael Murray-Hudson, Joel Hartter, and Andrea E. Gaughan. 2023. Assessing long-term conservation impacts on adaptive capacity in a flagship community-based natural resources management area in Botswana. Ecology and Society 28(4):12. https://doi.org/10.5751/ES-14487-280412

BOTSWANA - PROJECT 9-452: LONG-TERM IMPACTS OF LAND-USE/LAND-COVER DYNAMICS ON SURFACE WATER QUALITY IN BOTSWANA'S RESERVOIRS USING SATELLITE DATA AND ARTIFICIAL INTELLIGENCE METHODS: CASE STUDY OF THE BOTSWANA'S LIMPOPO RIVER BASIN (1984-2019)

Pi: Yashon Ouma, University of Botswana
U.S. Partner: Jiaguo Qi, Michigan State University (Funded by the National Aeronautics and Space Administration)
Dates: May 2021 - March 2024

PROJECT OVERVIEW

The rising demand for water, food, and energy due to increasing population continues to create immense pressure on water resources. In particular, water quality around the globe is systematically degrading, primarily due to climate change and agricultural intensification associated with rapid population growth and urbanization. In-depth assessments of the inter-linkages between land–water resources that combine land-use and water quality and availability within the catchment supply chains such as the Limpopo River Basin (LRB) in southern Africa are still lacking. Semi-arid Botswana relies on the reservoirs within the LRB for water supply, which are particularly susceptible to the negative impacts of land-use and land-cover (LULC) activities and runoff because of their complex dynamics, relatively longer water residence times, and their role as an integrating sink for pollutants from their drainage basins.

This PEER project used data-driven artificial intelligence for quantitative determination of the relationships between LULC change, together with socioeconomic development indicators and climate change and their impacts on water quality and availability within the basin, both for 1984-2019 and to predict future scenarios (2020-2050). To advance data acquisition for LULC analysis and climate change, the study used optical Earth-observation and meteorological satellite data. To provide near real-time and cost-effective approach for continuous monitoring of reservoir water quality within the basin, the study sought to develop empirical models for water quality estimation and water quality index mapping using 35-years of in-situ water quality measurements and water spectral observations using drone-borne spectrometer and optical satellite imagery through regression modeling and geospatial methods.

FINAL SUMMARY OF PROJECT ACTIVITIES

In a joint field work campaign with the Water Utilities Corporation (Botswana), the PI and his team successfully carried out their planned water quality sampling for the Bokaa and Gaborone dams, including simultaneous drone imaging. The researchers downloaded data from Sentinel-2 MSI and Landsat-8 ETM+ satellite sensors and modeled their water quality predictions with data from the sensors. The field work also involved LULC classification ground-truth campaigns within the dam catchments.

The researchers developed machine-learning models for mapping and quantifying the spatial-temporal LULC change patterns in the Botswana LRB from 1984-2019, modeling water quality and quantity in the dam catchments under climate variability and socio-economic factors. They also developed a Land-Water Nexus (LWN) for the LRB, using climate factors, socioeconomic factors, and WEAP hydrological modeling software, establishing the interactions and relationships between land use and water demand and supply-indifferent regions. The resulting monitoring tools and models are freely available for replication and will be made available after all the publications of the results in peer-reviewed journals.

Five undergraduate students were part of the PEER project as research assistants/interns and acquired advanced skills in imaging using Earth Observation analytics (drones and satellites) and machine-learning algorithms. Three postgraduate students are continuing with different components of the research project, and the PI and other staff participated in training on advanced imaging using drones for resource mapping. Through the project funding for infrastructure upgrades (drone, RTK Base Station, computers, and computer accessories), the Hydroinformatics Engineering Research Group (HERG) now has a well-equipped laboratory. PEER support has also bolstered the research activities of the academic staff and the postgraduate students in the areas of water resources, climate change and land-use studies, and the application of GeoAI technologies, including Earth Observation analytics and machine-learning/AI.

As the key stakeholder on dam water resources monitoring and management, the project established a working Memorandum of Agreement with WUC (Botswana) on water quality sampling and testing for dams in Botswana. The collaboration extends to technology transfer for planning of water quality sampling protocols for monitoring dams, and as of May 2024 WUC was in the process of evaluating and adopting the use of drone technology for water quality monitoring. The PEER team also received a $200,000 grant from the Alliance for African Partnership for work on sensors and smart infrastructure in community health.

PUBLICATIONS

Y.O. Ouma, B. Nkwae, P. Odirile, D.B. Moalafhi, G. Anderson, B. Parida, and J. Qi. 2024. Land-Use Change Prediction in Dam Catchment Using Logistic Regression-CA, ANN-CA and Random Forest Regression and Implications for Sustainable Land–Water Nexus. *Sustainability* 16(4): 1699. https://doi.org/10.3390/su16041699

Y.O. Ouma, A. Keitsile, B. Nkwae, P. Odirile, D. Moalafhi, and J. Qi. 2023. Urban land-use classification using machine learning classifiers: comparative evaluation and post-classification multi-feature fusion approach. *European Journal of Remote Sensing* 56(1): 2173659. https://doi.org/10.1080/22797254.2023.2173659

Y.O. Ouma, D.B. Moalafhi, G. Anderson, N. Boipuso, P. Odirile, B.P. Parida, and J. Qi. 2022. Dam Water Level Prediction Using Vector AutoRegression, Random Forest Regression and MLP-ANN Models Based on Land-Use and Climate Factors. *Sustainability* 14(22): 14934. https://doi.org/10.3390/su142214934

Y.O. Ouma, M. Ditiro, G. Anderson, B. Nkwae, P. Odirile, B.P. Parida, N. Sebusang, T. Nkgau, and J. Qi. 2022. Predicting the variability of dam water levels with land-use and climatic factors using Random Forest and Vector AutoRegression models. *Proceedings of SPIE Remote Sensing 2022: Remote Sensing for Agriculture, Ecosystems, and Hydrology XXIV*, 122620J. September 6-9, 2022, Berlin, Germany. https://doi.org/10.1117/12.2635933

Y.O. Ouma, B. Nkwae, D. Moalafhi, P. Odirile, B. Parida, G. Anderson, and J. Qi. 2022. Comparison of machine learning classifiers for multitemporal and multisensor mapping of urban LULC features. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLIII-B3-2022: 681-689. XXIV ISPRS Congress, June 6-11, 2022, Nice, France. https://doi.org/10.5194/isprs-archives-XLIII-B3-2022-681-2022

Y.O. Ouma et al. 2022. Land-Water (L-W) Nexus Project: Impacts of Land-Use & Climate Change on Water Quality and Quantity in Botswana's Limpopo River Basin (BLRB). United Nations/Ghana/PSIPW - 5th International Conference on the Use of Space Technology for Water Resources Management. Accra, Ghana, May 10-13, 2022. https://www.youtube.com/watch?v=YXjWnaxTXDg

BURKINA FASO

BURKINA FASO - PROJECT 8-116: INCREASING ACCESS TO SANITATION SERVICES INTEGRATED WITH RESOURCE RECOVERY IN RURAL BURKINA FASO

Pi: Ynoussa Maiga, University of Ouaga I Pr Joseph Ki-Zerbo
U.S. Partner: James Mihelcic, University of South Florida (Funded by the National Science Foundation)
Dates: October 2020 – January 2023

PROJECT OVERVIEW

The development of efficient sanitation technologies and practices can enhance the resilience of local populations from adverse consequences related to the lack of appropriate sanitation. Many imported water and sanitation technologies have failed because they were not adapted to local conditions or did not correspond to the needs of end users. This project aimed to develop, under real conditions, sanitation technologies and resource recovery technologies in a participatory way to increase their robustness and acceptability by local beneficiaries. The PI and his team worked to develop a greywater treatment unit to collect and treat household wastewater for reuse in gardening. A Slanted Soil Treatment System (SSTS) had been previously designed and tested for greywater treatment at the household level, but the quality of the treated greywater was not sufficient to allow its safe reuse in gardening. The project tested modifications made to the treatment system, including the configuration of the SSTS, the characteristics of the filter bed, and addition of plants to enhance its efficiency, making possible the safe reuse of the treated water for food crop irrigation. In addition, a composting toilet with urine diversion had been developed previously for rural households. However, concerns related to the biodegradability of the organic matter, hygiene, and maturation of the compost emerged. The PI and researchers in this project therefore tested test new strategies by mixing urine and feces in the dry toilet. In addition, they designed a composting pit for use as an additional step for the maturation and sanitization of the compost collected from the composting toilet, including through mixture with agricultural waste. The team also worked to identify the most efficient operating conditions allowing for the production of hygienic and nutrient-rich compost by testing several mixtures. They also studied the potential for thermal inactivation of pathogens using sunlight with the aim of making the compost safer and more acceptable to users.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Maiga and his team developed two models of a complex shower room/greywater treatment system and constructed them for eight beneficiary households in two rural settlements. The greywater treatment system is a subsurface horizontal flow constructed wetland in the first model and a hybrid system (vertical flow filter followed by a subsurface horizontal flow wetland) in the second model. The treatment systems are designed to allow direct collection of shower greywater (including urine) into the upper basin of the pre-treatment stage. Dishwashing and laundry greywater are collected via a receiving basin (located inside the yard) and pass through the same piping to the treatment system (located outside the courtyard and close to the shower room). Two plants were tested: *Chrysopogon zizanioides* and *Andropogon gayanus*. Visual observations of the treatment systems indicated they performed as expected. *Chrysopogon zizanioides* seemed more adapted to the greywater conditions than *Andropogon gayanus*. The results obtained from four households showed that the treatment systems perfomed well, reducing organic matter, nutrients, and fecal bacterial significantly. The residual concentration of fecal bacteria was compliant with the WHO reuse guidelines for restricted irrigation.

The composting toilet intended for the recovery of nutrient-rich compost for gardening was developed and constructed in eight beneficiary households, and the PEER team evaluated its performance. The excreta under maturation was transferred into composting pits in some of the households, and the sanitization is still ongoing. The households are using the facility, and it is contributing to reducing open defecation, which should reduce the dissemination of excreta related diseases.

The researchers also developed training manuals on the construction and operation of greywater and excreta recovery and treatment facilities. These materials will allow individuals or communities to understand the technical and operational aspects of the construction and operation of the facilities. The conditions for recovering sanitation by-products from a composting toilet or a treated greywater storage tank are also explained. The team also trained the beneficiary households on the operation and maintenance of the greywater and excreta recovery and treatment facilities developed under the project and how to collect and reuse treated water in gardening. During the training, the researchers also collected the views of the households on the sanitation facilities, the difficulties encountered, and suggestions for improvements.

Dr. Maiga had originally hoped that the outputs from both the greywater treatment and composting toilets could be used in gardening. For greywater, the results obtained from four households allow the reuse of the water in restrictive irrigation according to WHO standards. However, further improvements in the removal of microbial contamination are still required to make treated greywater even safer. The elimination of pathogens from the composting toilets was not so successful and took a long time, with the results varying seasonally. The team is still working to optimize the compositing pits and then test vegetables grown with such compost to ensure their safety before the compost could be promoted for this purpose.

In conclusion, the sanitation facilities developed in the project are very promising, but additional tests are needed to have definitive models. To know the real impact of this project, Dr. Maiga hopes to be able to conduct the compost reuse experiment for vegetable production, evaluate the associated risks, conduct an associated socioeconomic study, and increase the number of beneficiary households.

PUBLICATIONS

Cheik Omar Tidiane Compaoré, Ynoussa Maiga, Sandrine G. Zongo, Mamady Sawadogo, Mahamadi Nikiema, Oumarou Mien, Amidou S. Ouili, Iliassou Mogmenga, Cheik Amadou Tidiane Ouattara, James R. Mihelcic, and Aboubakar Sidiki Ouattara. 2024. Occurrence of antibiotic-resistant bacteria in household greywater discharged into the environment in Burkina Faso's Sahel region. Journal of Water & Health. https://doi.org/10.2166/wh.2024.344

Y. Maiga, C.O.T. Compaoré, M. Diallo/Koné, S.K. Sossou, H. YempalaSomé, M. Sawadogo, I. Nagalo, J.R. Mihelcic, and A.S. Ouattara. 2024. Development of a Constructed Wetland for Greywater Treatment for Reuse in Arid Regions: Case Study in Rural Burkina Faso. Water 16: 1927. https://doi.org/10.3390/w16131927

C.O.T. Compaoré, Y. Maiga, I. Nagalo, M. Sawadogo, S.G. Zongo, O. Mien, M. Nikièma, A.S. Ouili, I. Mogmenga, C.A.T. Ouattara, J.R. Mihelcic, and A.S. Ouattara. 2024. Effect of greywater treated by horizontal subsurface flow wetlands planted with *Chrysopogon zizanioides* and *Andropogon gayanus* on the germination of tomato (Lycopersicon esculentum Mill.) seeds under Sahelian climate. Ecological Engineering, 199, 107165. https://doi.org/10.1016/j.ecoleng.2023.107165

C.O.T. Compaoré, Y. Maiga, M. Nikiéma, O. Mien, I. Nagalo, H.T. Panandtigri, J.R. Mihelcic, and A.S. Ouattara. 2023. Constructed wetland technology for the treatment and reuse of urban household greywater under conditions of Africa's Sahel region. Water Supply 23(6), 2505–2516. https://doi.org/10.2166/ws.2023.121

C.O.T. Compaoré, Y. Maiga, A.S. Ouili, M. Nikiema, and A.S. Ouattara. 2022. Purification Potential of Local Media in the Pre-Treatment of Greywater Using Vertical Biofilters under Sahelian Conditions. Journal of Agricultural Chemistry and Environment 11(02), 117–131. https://doi.org/10.4236/jacen.2022.112008

Ynoussa Maiga, Cheik Omar Tidiane Compaoré, Martine Diallo/Koné, Seyram Sossou, Herman Somé, Mamady Sawadogo, Issa Nagalo, James R. Mihelcic and Aboubakar S. Ouattara. 2022. Development of a constructed wetland for greywater treatment for reuse in arid regions: case study in rural Burkina Faso. Proceedings of the 17th International Conference on Wetland Systems for Water Pollution Control. Lyon, France, November 6-10, 2022. ISBN: 978-2-9585706-0-6. pp33-36.

CAMEROON

CAMEROON - PROJECT 4-360: USING GEOSPATIAL TOOLS TO INVESTIGATE HOW DEFORESTATION AFFECTS THE TRANSMISSION OF MALARIA IN BIRDS

Pi: Anong Damian Nota, University of Buea
U.S. Partner: Thomas Smith, University of California, Los Angeles (Funded by the National Science Foundation)
Dates: November 2015 – October 2019

PROJECT OVERVIEW

This project addressed an unsolved problem in the field of emerging diseases: What are the proximal effects of large-scale deforestation on the transmission of vector-borne infectious diseases? The principal investigator and his team approached this problem by studying malaria in natural populations of rainforest birds threatened by rapid environmental degradation in Cameroon. It is well established that deforestation poses a major threat to biodiversity in tropical regions; however, its effects on the spread of pathogens are largely uncharacterized. The team has previously identified malaria parasites, both generalists and specialists, in African rainforest birds, and they have found that it is the generalists that have the potential to jump to naïve hosts and develop as emerging diseases. They have also identified mosquito vectors of avian malaria and demonstrated that patterns of malaria diversity are significantly affected by habitat. With their knowledge of sectors presently zoned for logging, they thus had in place an unprecedented model system for investigating the effects of environmental change on disease transmission. The team aimed to test the hypotheses that (1) deforestation promotes an increase in the prevalence of generalist parasites and (2) vector species distributions change with deforestation, and account for differences in prevalence of generalist vs. specialist parasites. The ultimate goal of this research was to discern the interplay among hosts, habitat, and vector ecology on the potential spread of novel pathogen strains. Another important objective was to determine how human-altered environments affect the feeding patterns of insect vectors and what environmental factors are important in determining likelihood of transmission. By applying the same type of relations before and after logging, the researchers were able to predict where the vectors are likely to occur, where disease is likely to occur, and the patterns may change.

This work was intended to capitalize on the U.S. Government-supported partner's expertise in molecular biology, parasitology, entomology, and fieldwork and leverages the archive of blood samples that the he and his collaborators have accrued over nearly 30 years from African rainforest birds.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ended in October 2019, sought to address an unsolved problem in the field of emerging diseases: what are the proximal effects of large-scale deforestation on the transmission of vector-borne infectious diseases. The principal investigator Dr. Nota and his team approached this problem by studying malaria in natural populations of rainforest birds threatened by rapid environmental degradation in Cameroon. They gauged the effects of deforestation on the diversity and host specificity of avian malaria parasites in Talangaye Forest.

Although the civil war in Cameroon prevented them from doing the most crucial part of the work, which was to get samples from the deforested areas for the before and after control-impact pairs (BACIP) experimental design, they were able to capture 2,658 bird species from Talangaye that belonged to 30 families. They subsequently used microscopic and PCR techniques to analyze blood samples collected for the identification of parasites. Out of the 2,658 birds collected, 1,195 were found to be infected with parasites (Plasmodium, Haempoproteus, Leucocytozoon, Micrrofilariae, and Trypanosomes). More than 1,000 sequences of parasites have been done on Plasmodium, and two PhD students are still carrying out blasting to identify avian malaria parasites in Cameroon.

In order to measure the effects of deforestation on mosquito communities, the PI and his team collected 12,272 mosquitoes belonging to 12 mosquito genera. More than 20 new potential species of mosquitoes not previously described have been named, and this number may increase as the students continue to use dichotomous keys and PCR to look at the various species.

The project was meant to have only one PhD student but ended up having 13 students at both the Master's and PhD level. Five have defended their MSc degrees in the project. One of the students has enrolled in a PhD program in the Department of Vector Biology and Parasitology to continue to look at vectors collected in Talangaye. Four other students are currently pursuing their PhDs and should be able to graduate in 2020. The project has increased the capacity of students in this area who will later join the university as faculty members or move to other conservation projects. In addition, the PI reports that the PEER project had a good impact on science and led to several academic awards. During the grant period, three of his students won the "Idea Wild Award" for equipment in the field. These are international awards that were awarded for the PEER work done in Talangaye. Lastly, one PhD student, Mayi Audrey, won the National Geographic Travel grant to visit the United States in 2019 for further training on vector biology with Dr. Anton Cornel, a medical entomologist at the University of California, Los Angeles (UCLA).

U.S. partner Dr. Tom Smith runs a weekly one-hour seminar course every quarter as part of his teaching curriculum at UCLA. The course is based on discussion of readings selected from current literature. This opportunity was offered to all the PEER-selected students from the three institutions in Cameroon beginning in the fall of 2015 and continuing to date. This has created opportunities for building relationships between African and U.S. students. This course also provides opportunities for participating faculty and students to build lasting international collaborations.

CAMEROON - PROJECT 3-12: BIOCHAR AND COMPOST FROM COCOA POD HUSK: OPPORTUNITIES FOR CROP FERTILIZATION AND SUPPRESSION OF BLACK POD DISEASE

Pi: Njukeng Nkengafac, Institute of Agricultural Research for Development
U.S. Partner: Bin Gao, University of Florida (Funded by the National Science Foundation)
Dates: September 2014 – October 2016

PROJECT OVERVIEW

Soil depletion, pests, and diseases have been identified as some of the main causes of low production in smallholder farms, which depend on agriculture to make a living and feed their families. Cocoa (*Theobroma cacao*), 80 percent of which is cultivated by smallholders, is an export crop for many countries in Africa, and black pod disease caused by *Phytophthora* spp. is a major constraint to its production. While cocoa pod husk has been identified as a major source of inoculum of *P. megakarya* and is often left in farmers' fields as waste, it can be used for crop fertilization in the form of compost or biochar, thus improving soil fertility, promoting plant growth and resistance to biotic stresses, and, in turn, helping mitigate climate change.

This research study focused on cocoa pod husk conversion into compost and biochar and aimed to characterize the converted product, evaluate its effects on soil physicochemical properties and black pod disease suppression, and assess crop growth and yield. Farmers and students also received training on composting and biochar preparation and application.

FINAL SUMMARY OF PROJECT ACTIVITIES

Cocoa pod husks are often left in farmers` fields as waste. Converting this material to biochar and compost for soil amendment has multiple benefits as they have been evaluated globally as a means to improve soil fertility, promote plant growth and resistance to biotic stresses, and to mitigate climate change. Therefore, biochar and compost are alternatives to control the black pod disease and cocoa yields in small holder farmers. This will result in reduced spending in buying chemicals for the treatment of the disease as well as time spent to take care of the farms and will leave the farmers with more time to indulge in other income generating activities that will improve their standard of living. Converting cocoa pod husk into biochar and compost provides a cheap source of fertilizer to improve food security and reduce hunger and malnutrition and will help the farmers to produce more without depleting their soils.

The project was based on cost manure and biochar, produced from cocoa pod husks and then the mature compost was dried and preserved for usage. Samples of the compost and biochar were analyzed and found to be very rich in potassium and nitrogen. The team also conducted a study on the microbial communities to determine microbial populations associated with disease suppression in the compost. The results this study showed that fluorescent pseudomonads were not present in the compost, with heterotrophic bacteria and actinomycetes dominating, as well as the presence of fungi were present in lower density. A second study looking into the in vitro antagonistic effects of biochar and compost on *P. megakarya* to evaluate the effect of compost and biochar on mycelial growth of *P.*

megakarya and detect possible suppressive effects (microbes, lethal effect of chemical component). The compost water extract consistently reduced the growth of *P. megakarya* compared to the control and the water extract from biochar. Autoclaving compost resulted in loss in growth suppressiveness.

Using the compost and biochar, greenhouse studies were also carried out. These greenhouse experiments aimed to determine the influence of compost and biochar on cocoa plantlets growth, induced resistance against *P. megakarya* using detached leaf assay, and microbial populations and activities associated with disease suppression in the substrates. The results showed that compost and biochar induced some resistance against *P. megakarya*. The team also germinated traditional African leafy vegetable seeds as well as to grow the seedlings using varying concentrations of compost. Results showed that mixing the soil media with biochar or compost manure improved seed germination compared to the control. The seedlings were latter transplanted into beds with different levels of biochar, compost and inorganic fertilizer applications which showed some improvement in marketable vegetable production with supplementation.

Beyond experiments, the team sensitized famers to the use of cocoa pod husk for soil fertility and disease suppression. A questionnaire was administered to evaluate the knowledge of cocoa famers on soil nutrient, pests and disease management. Preliminary analysis of the questionnaire data showed that farmers' knowledge on soil nutrient pest and disease management was very limited, but that many were interested in using biochar and compost manure as it was a cheap source of fertilizer. Training on compost manure preparation from cocoa pod husk was carried out in the four chosen sites. This was followed by several follow up visits to reinforce the trainings as, in most cases, farmers are reluctant to use a technology they haven't mastered. As of the end of the project, farmers were practicing composting and/or biochar production in their farms and more were willing to learn the techniques of producing these organic materials.

Two students, Martha Mounongo and Longue Morela were supported by the project and graduated after defending their theses, while Nkenganyi Felix, a student from the higher technical teachers training college, was in the process of preparing his thesis when the project ended. A draft article on the preparation and characterization of compost and biochar was prepared.

ETHIOPIA

ETHIOPIA - PROJECT 6-400: PROMOTING RESOURCE- ORIENTED SANITATION IN PERI-URBAN ETHIOPIA THROUGH THE PRODUCTION OF STRUVITE FROM DIGESTED SLUDGE FILTRATE

PI: Adey Desta, Addis Ababa University
U.S. Partner: Nancy Love, University of Michigan (Funded by the National Science Foundation)
Dates: December 2017 – February 2022

PROJECT OVERVIEW

Ethiopia has become one of the fastest growing economies in Africa, with an increasing rate of urbanization and demand for phosphate-based fertilizer to increase productivity in the agriculture sector. Phosphate rock, the starting material for phosphate fertilizer, is a finite resource, and Ethiopia is entirely dependent on importing different kinds of phosphate fertilizers and therefore is vulnerable to market fluctuations in fertilizer prices. The availability and affordability of imported fertilizers to most of the urban and peri-urban farmers is very low because of lack of government subsidies for urban/peri-urban farmers, unlike those provided for rural farmers. The urban/peri-urban farmers get fertilizers at a higher price from local vendors, and the product is difficult to get at any cost at times of shortage.

This scenario suggests the need to look for alternative sources of phosphate to achieve sustainable agriculture. Recovery of phosphorus from digested sludge water has long been a well-established technology in some of the developed countries. Different technologies are available to recover phosphorus from various wastewater streams. Some have been implemented at an industrial scale with maximum recovery efficiency. So far, Ethiopia has not adopted any phosphorus recovery technologies at any level.

This PEER project was aimed at demonstrating that digested wastewater can be used to reliably produce good quality, safe, and marketable struvite fertilizer using full-scale systems. The focus of the study was on preferred approaches for recovery of phosphorus and nitrogen from digested wastewater with the minimum prevalence of various types of contaminants, such as micropollutants (drugs and metabolites) and biological contaminants (microorganisms and antibiotic resistance genes).

The lab facilities accessible through collaboration with the U.S. partner were anticipated to be useful for the initial survey of these contaminants from the fertilizer product (struvite) and its raw material, with the information generated anticipated to leverage subsequent in-house monitoring studies.

FINAL SUMMARY OF PROJECT ACTIVITIES

In early 2022 as the project approached its closing date at the end of February, Dr. Desta and her team completed sampling from the pilot-scale FBR, extracted DNA samples from the FBR, and sent them to a sequencing facility. The results will be submitted to the U.S. National Center for Biotechnology

Information for inclusion in their publicly accessible databases. Additionally, the researchers have partnered with an institute for HPLC analysis, and the samples were being validated for analysis at the time of the final report. The team also organized five focus-group discussions with fifteen voluntary farmers to discuss waste-derived fertilizer. They have also analyzed the struvite on selected vegetables in greenhouse scale.

Among the project's outputs and potential impacts, the study included several activities focused on optimizing a struvite production method that is the first of its kind in Ethiopia. Assessment of pollutants (other than nitrogen and phosphorus) that might affect the production process is key task involved in harvesting the product in a safe and optimal way. Additionally, the metagenomic component of the project, although it remained in the primary result stage when the PEER project ended, is ultimately expected to reveal any potential risks in large-scale application of the product. This technology can be scaled up by relevant and interested stakeholders and is expected to cover a portion of the fertilizer demand in the urban and periurban agricultural settings.

On the capacity building and outreach side, the project supported three PhD candidates in pursuing their training in the biological, engineering, and social aspects of the research. Additionally, the team trained four MSC students (three women and one man) on the different objectives of the project throughout the project period. The PI Dr. Desta reports that she also contributed PEER findings to two Ethiopian governmental documents. The ten-year National Biotechnology Research and Development program document was finalized, reviewed, and validated pending implementation by the responsible institutions. The Environmental Biotechnology section was prepared based on research-based evidence, including from the PEER project. The concepts of recovery of nutrients from waste and wastewater as well as valorization of waste were strongly emphasized and action plans put forth for program implementation. Second, the recently started government genomic surveillance document also emphasized the need to pay attention to environmental health in order to address human health and stressed the importance of making wastewater surveillance one of the key focus areas for addressing public health emergencies such as SARS-CoV-2 and polio.

Dr. Desta and her team have also contacted key stakeholders to suggest ways of incorporating their findings and recommendations into policy and practice. They discussed with the Addis Ababa Water and Sewerage Authority the possibilities of establishing the FBR technology in the vicinities of some of their wastewater treatment plants. They also introduced and discussed with officials of the former Job Creation Commission (currently Ministry of Youth and Job Creation) possibilities of training youth on the available waste-to-fertilizer technologies. Regarding collaboration with farmers, the team learned the importance of working on the mindset of what waste and wastewater mean before demonstrating waste-derived products. The team also learned that talking about waste and wastewater is a taboo and using products derived from them is completely unimaginable in some parts of Ethiopia. Working to build acceptance and planning efforts to change community attitudes towards waste are essential.

The project has also had broader educational impacts beyond the benefits to the students who participated. Beginning in January 2022, the team initiated a curriculum review of the MSC and PhD programs in the Department of Microbial, Cellular, and Molecular Biology at Addis Ababa University. One of the streams, Applied Microbiology, focuses on nonclinical aspects of microorganisms and includes courses on soil microbiology, rhizobiology, food microbiology, plant pathogens, and industrial microbiology. Surprisingly, there are very few courses on wastewater microbiology, environmental microbiology, and nutrient recovery. Given the applied nature of the latter areas, the PI and her colleagues have improved the curriculum by adding extra courses on wastewater microbiology and nutrient recovery.

Although the PEER project has ended, Dr. Desta intends to continue collaborating with her U.S. partner Dr. Nancy Love on preparing manuscripts for publication. She is also seeking local funding to continue and expand her research.

PUBLICATIONS

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ETHIOPIA - PROJECT 5-610: IMPROVED ACCESS AND UPTAKE OF MATERNAL AND CHILD HEALTH SERVICES IN RURAL ETHIOPIA THROUGH COLLABORATIVE COMMUNITY AND HEALTH SYSTEMS PARTNERSHIP

PI: Getahun Asres Alemie, University of Gondar
U.S. Partner: Judd Walson, University of Washington (Funding by the National Institutes of Health)
Dates: December 2016 – March 2020

PROJECT OVERVIEW

In 2015, the average Ethiopian woman had a 1 in 64 lifetime risk of death due to complications of childbirth, and 87,414 newborns died before their 28th day of life. Reducing maternal and neonatal deaths has been at the top of the global health agenda for more than a decade and was recently included in Goal 3 of the Sustainable Development Goals (SDGs). Demand for maternal, newborn, and child health (MNCH) services, however, still remains low in Ethiopia's rural communities most at risk. Complex challenges, including transportation, health literacy, imbalanced decision-making authority, and harmful traditional practices, create barriers to increasing health coverage.

This implementation science study utilized an integrated delivery approach to increase demand for MNCH services in the Gondar region of Ethiopia. The research design aimed to address primary drivers of maternal and neonatal death, including access to antenatal care, prevention of mother-to-child transmission of HIV (PMTCT), facility-based delivery, and postpartum visits through a culturally driven lens. The goal of the project was to improve MNCH outcomes in rural Ethiopia by increasing demand for services through the linkage of local health workers and community influencers. The study team collected and analyzed qualitative data to establish a baseline for women's engagement with their health facilities, identify barriers to accessing MNCH services, and parse out traditional practices and beliefs around childbirth and infant health, including religious rituals. From the baseline information, a behavior change intervention was implemented in which community leaders from the Ethiopian Orthodox Church were paired with members of the Health Development Army (HDA) and trained to conduct maternal and child health outreach and education. Strategies for transporting laboring and postpartum women to health facilities were devised and implemented by the local communities. The study team developed a clear monitoring and evaluation plan at the outset of the study, including tracking time to seeking care, frequency of seeking care, removal of barriers to care, and measures of morbidity and mortality. The study hypothesis was that there would be an increase in demand for MNCH services following the intervention, with targeted increases in the uptake of antenatal care, PMTCT, facility-based delivery, and postnatal care and referral. The impact of increased engagement with health facilities was expected to decrease maternal and neonatal deaths in the study population compared to the control group.

FINAL SUMMARY OF PROJECT ACTIVITIES

At the project onset, team members met with the U.S. partners to discuss key aspects of the project including the design of the project, management of activities, and development of study tools. In addition, as part of the preparation for the project, the project team in Gondar was given training on development and use of electronic data collection tools by the University of Washington (UW) through the Strengthening Care Opportunities through Partnership in Ethiopia (SCOPE) collaboration.

Following approval of the project by the University of Gondar (UoG) Institutional Review Board (IRB), The team conducted two of the initial preliminary studies: (1) a health facility assessment that focused on delivery and emergency obstetric and neonatal care activities of the health facilities in the project area; and (2) a formative qualitative study involving focus group discussions and key informant interviews with pregnant women and their partners, health workers, and religious leaders to generate information on Maternal and Child Health (MCH).

Early in 2018, analysis of the formative qualitative study was completed and a report of the results was shared with regional and national authorities. Subsequently, results of the formative studies and summaries of the project progress were shared at international fora by the study team and UW student fellows. These included: 1) A scientific presentation in Seattle that won the Global Healthies Award; 2) A presentation at a scientific workshop and exhibition hosted by the UoG; 3) A presentation at a scientific forum in Accra, Ghana; and 4) Presentations in Seattle for the US collaborators and undergraduate and graduate students at UW.

In preparation for the intervention phase, the project team developed Standard Operating Procedures (SOPs) for all the major activities of the project, and a training manual was prepared to guide the training of outreach workers (faith leaders and members of the Health Development Army (HAD)). A one-week training was given to 121 priests and members of HAD recruited from the catchment areas of the six health centers selected as project intervention areas. The trained outreach workers were then dispatched to their respective communities to start the intervention activities. Monitoring and evaluation of the outreach activities were done through regular follow-up group discussions with outreach workers in the 6 intervention areas conducted by the project team. These were coupled with regular health facility data extraction visits to all the 18 project areas (6 intervention sites and 12 control sites).

The main activities in the first two quarters of the third year of the project (2019) were continuation of the intervention activities, monitoring and evaluation of the intervention activities, and health facility data extraction. Problems encountered during the implementation of these activities were regularly discussed with the field workers, the project team in Gondar and the collaborators in Seattle, and solutions were set forth and implemented. The planned one-year intervention activities ended at the end of May 2019 marked by an official closing/handover ceremony with the involvement of local officials and stakeholder organizations, whereas the data extraction activities continued for some time beyond to complete missing data from some health facilities due to in country security-related problems and public unrest.

The participation of the UW student fellows in the project continued in the third year. During the year, one of the student fellows did her doctoral presentation back in the United States on the work she had done with the team in Gondar. A team of people including SCOPE Board members from Seattle travelled to the project site in Gondar during which they visited one of the health facilities involved in the project, and had a meeting with the UoG study team to discuss project progress. In 2020, the project team was able to complete the initial data analysis and produce dissemination materials (reports to the Regional Health Bureau and the Ministry of Health, policy brief for policy-makers, summaries and presentation materials for local officials, partners and stakeholder organizations). While the team was able to conduct the local dissemination activities, and further dissemination activities were put on hold because of the COVID-19 pandemic and the continued political situation of the country.

ETHIOPIA - PROJECT 5-194: BRINGING SEASONAL FORECASTS TO THE FARMER: PARTICIPATORY CLIMATE SMART VILLAGES FOR GREEN GROWTH IN ETHIOPIA

PI: Belay Simane, Addis Ababa University
U.S. Partner: Benjamin Zaitchik, Johns Hopkins University
Dates: December 2016 – May 2021

PROJECT OVERVIEW

Climate change adaptation is a high priority for Ethiopia and other climate-vulnerable countries. At the farm and village level, however, long-term planning for climate change means very little. Subsistence agriculture communities survive on a year-to-year basis, and the productivity of the coming season's crops is typically too important and is often too uncertain to allow for adaptation planning on the decades-long time horizon of climate change projections. In this context, improved use of seasonal forecasts offers a climate resilience building strategy that pays dividends under current conditions and is likely to become even more essential as patterns of climate variability shift in coming years. The use of seasonal forecasts is also flexible and adaptable to context in a way that few adaptation strategies are. A specific cropping technology or seed variety may not work across agroecosystems, but improved approaches to interpreting and acting on seasonal climate forecasts can contribute to resilience in a wide range of settings.

The guiding principle for this project was that seasonal forecasts generated at the agroecosystem level, developed collaboratively with farmers, will advance understanding of the adaptation process and contribute to climate resilience in subsistence-based communities. The project was intended to leverage and expand a climate smart village (CSV) network that has proven to be an effective mechanism to engage farmers in generating climate resilience solutions. The CSVs were intended to inform application of forecasts through participatory forecast interpretation and communication. The project focus on best-available seasonal forecasts was intended to add a dimension of capabilities to CSVs that was at the time absent.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project team implemented a sustainable institutional infrastructure that will be used to study resilience over longer time periods. Many CSA practices incur establishment and maintenance costs that are not affordable by subsistence farmers. It also requires a considerable time before farmers benefit from them. Therefore, a long-term support and subsidy system is essential for sustainable future.

Establishing climate smart villages and implementing climate smart agriculture (CSA) are both knowledge and capital intensive and require long-term support. Subsistence farmers found it hard to innovate and invest in better land management and climate smart agriculture. Therefore, the skill and capacity building effort should be location-specific and provided by very senior and senior experts and researchers. Further scaling up of best sustainable green technologies and approaches will be only materialized at the local level by establishing business model enterprises will be a viable option to expand CSA practices.

The team plans to continue and reinforce the following activities for a sustainable future at CSV levels:

(1) Establish clear decision-making processes and transparency among the lead offices and institutions (DMU, Agriculture, environment, cooperative, NGO,) to manage and coordinate the climate-smart agriculture at community levels.

(2) Establish and facilitate a platforms for stakeholder engagement and consultation, including the private sector and ensuring the inclusion of small holder farmers.

(3) Provide adequate and accessible climate information services to farmers and other agricultural decision makers.

(4) Produce agreed-upon vision and goals that balance food security, adaptation and mitigation at village level and regional levels.

(5) Expedite additional financial resources including rural credit to individual farmers.

(6) Give more focus to renewable energy and backyard fruit and vegetable development that enhances nutrition and food security at local levels.

(7) Scale up best sustainable green technologies and approaches by establishing business model enterprises outside CSVs as a viable option to expand CSA practices.

Based on the PEER project, local governments have adopted the conceptual and analytical framework to plan and implement a Climate Compatible Development (CCD) which is a new concept that bridges climate change adaptation, mitigation, and community-based development ('Triple wins'). Universities have also adopted the research approach to establish and promote Climate Smart Villages in other areas.

PUBLICATIONS

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ETHIOPIA - PROJECT 4-315: ENHANCING FOOD SECURITY THROUGH IMPROVED PRODUCTIVITY, NUTRITION, AND MARKETING OF CHICKPEAS IN CENTRAL AND WESTERN ETHIOPIA

PI: Kassahun Tesfaye Geletu, Institute of Biotechnology, Addis Ababa University
U.S. Partner: Douglas Cook, University of California, Davis (Funded by the National Science Foundation)
Dates: October 2015 – March 2021

PROJECT OVERVIEW

Agriculture in Ethiopia forms the basis of the economy, with 80% smallholder farmers. These farming systems are characterized by low yields, widespread use of unimproved landraces, outdated production technologies, and biotic and abiotic stresses. In western and northwestern Ethiopia, soil acidity and consequent aluminum toxicity are a primary limitation to crop productivity, especially for chickpea (*Cicer arietinum*). Chickpea is the world's second most widely grown pulse crop and a major source of human protein nutrition, with 40% of Africa's chickpea crop being grown in Ethiopia. However, Ethiopia's chickpea yields remain low, well below yield potential.

Among the constraints to chickpea production is its sensitivity to aluminum toxicity (Sahu et al., 2010), which is a defining feature of low pH soils that are widely distributed in Ethiopia. It is critical to identify tolerant germplasm and understand the molecular genetic basis of aluminum tolerance. Moreover, because chickpea yields depend on beneficial soil microorganisms, especially nitrogen-fixing symbiotic bacteria and phosphate solubilizing micro-organisms (PSMs), a parallel need is to identify acid/Al-tolerant chickpea microbes.

This project combined expertise in plant breeding and genomics, soil microbiology, and socioeconomics to develop chickpea technology to improve crop productivity and marketing in central and western regions of Ethiopia. The project leveraged the resources and expertise of the U.S. partner by testing wild-cultivated introgression lines, landraces, and elite cultivars for tolerance to acid. In parallel, the project researchers identified tolerance to acid soils in endemic symbiotic *Mesorhizobium* and co-occurring PSM populations. Products will be pipelined to national chickpea breeding programs with Ethiopia for variety development and release.

FINAL SUMMARY OF PROJECT ACTIVITIES

In Ethiopia, the low productivity of various crops including chickpea is attributed to the use of traditional management practices and various stress factors including soil acidity. Chickpea is widely grown in Ethiopia and serves as a major source of protein. However, its productivity remains low, 1.8 t/ha, well below global average. Hence, this project was amid at identifying tolerant germplasm and microbial inoculants for smallholder farmers in western Ethiopia. Moreover, through value chain, seed system and marketing analysis, we aimed at generating policy recommendations. Overall, significant achievements have been recorded during this project and key findings are presented below.

CORE ACTIVITY 1: Screening genotypes against Al toxicity

The general objective was to screen for Al toxicity under hydroponic condition; multi-locations, characterize F2 and map QTL for genomic region conferring Al tolerance. After several studies and experiments, 20 advanced lines with promising tolerance were handed over to Ethiopian Biotechnology Institute (EBTI) for final evaluation before applying for variety registration at the Ministry of Agriculture (MoA).

CORE ACTIVITY 2: Screening chickpea *Mesorhizobium* strains for acid soils

The aim was to collect chickpea rhizobia from acidic soils of Ethiopia and determine their genomic diversity, and further screen for low pH tolerance and phosphate solubilization under laboratory, greenhouse and field conditions. The genomic diversity with a whole-genome sequence approach showed that 81 *Mesorhizobium* strains were obtained and estimated with average genome sizes 7Mbp, average depth of 143 X coverage. The pattern of genomic diversity observed indicates the existence of multiple, broadly distributed phylotypes, with no relationship between geographic and genetic distance The result also indicated that 62 strains grew well at low pH 5; and 47 of them were phosphate solubilizers. The strains showed wide diversity in their substrate utilization and tolerance to acidity, high temperatures, toxicity and heavy metals. Under field conditions, the inoculants showed significant improvement in biological nitrogen fixation, growth, yield, nitrogen and phosphorus uptakes of chickpea compared to the commercially available reference strain Cp41. The Natoli variety better performed in many parameters followed by DZ-ck-2011-s-2-0042 variety with the applications of inoculant in the field. Therefore, these inoculants have potential to improve chickpea production in acidic soils in Ethiopia. These 3 inoculants have been handed over to EBTI team for further test for final approval by the Regulatory Authority at MoA. Furthermore, Dr. Atsede Muleta successfully completed her PhD studies in Inoculant Biology through this project and currently she is serving as academic staff at University of Gondar, Ethiopia.

CORE ACTIVITY (3) Seed system study, marketing and value chain analyses

This core activity had two sub-component studies viz. chickpea value chain analysis; and chickpea seed system and marketing study. The study identified two types of chickpea varieties produced in the study area, namely Desi (smaller, reddish brown colored) and Kabuli (larger, cream-colored seeds). In general, Desi varieties are grown for home consumption whereas the Kabuli varieties are for markets beyond the production area and export. Like most legumes, the formal seed system for chickpea is poorly developed and most farmers rely on their own farm saved seed, neighboring farmers or the local grain markets. The major problems in the chickpea seed chain are price fluctuation, need assessment gap, disease and pest, limited shelf life of the seed, seed quality, lack of awareness, high seed price, in availability of inputs, seed shortage and lack of supporting institutions. Supply chains of chickpea are also poorly organized and products move less quickly at high transaction and transport costs between the different trade levels. To improve the value chain, sufficient supply of Kabuli type seeds, introduction of low-cost technologies for processing, strong support from cooperatives and access to information and finance are highly recommended. The project team met with district agricultural officials and experts to share the outcome of the project in smaller groups. Accordingly, they have shared several potential interventions needed in the chickpea seed system, value chain, and marketing: Furthermore, discussions were made with research institutes and universities to make soil acidity and related issue part of their research agenda for future joint intervention.

ETHIOPIA - PROJECT 3-94: DEVELOPMENT OF A MICROGRID RESEARCH CENTER IN ETHIOPIA TO SUPPORT USAID'S POWER AFRICA PROGRAM

PI: Belachew Gessesse With Co-PI Nigus Gabbiye Habtu, Bahir Dar University
U.S. Partner: Suman Banerjee, University of Wisconsin-Madison (Funded by the National Science Foundation)
Dates: September 2014 – February 2019

PROJECT OVERVIEW

The rate of electrification for rural Ethiopia is less than 1%, while 85% of the rural population is distributed in villages. Providing electricity access to such dispersed populations using the traditional electrification models based on centralized power systems is impractical from both the economic and engineering perspectives. The bottom-up electrification model using the technology of microgrids offers a competitive and practical alternative. This technology is just emerging, however, so there is a need for research, development, education, technology transfer, and business development before it can reach the technical maturity of the well-established centralized electrification model. This research project aimed to bridge the gap by developing a microgrid research cluster in Ethiopia, centered at Bahir Dar University (BDU). Project activities included development of analytical and technical research capabilities, a laboratory-scale microgrid testbed, a field-site proving ground, education, technology transfer, and outreach activities.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main objective of this project was to develop a microgrid research center at Bahir Dar University by establishing a laboratory scale microgrid testbed and a field-site proving ground in the village nearby Bahir Dar city. The laboratory scale microgrid at Bahir Dar University and the prototype microgrid in Woramit village near Bahir Dar has made a significant impact as a rural electrification model. The newly constructed and commissioned prototype microgrid is being used to promote the concept of microgrids and bring electricity access to rural populations. With this electricity access higher quality lighting has been made possible which has led to an increase in literacy and education levels, primarily among women and children as it enables them to study in the evening. This also practically provides access to technology tools that include TVs, computer, internet, mobile charging, etc. Moreover, both the development of the research lab and prototype microgrid has assisted in the development of a university-level research program in the field of microgrids. Previously, students' research on the topic of microgrids was based solely on simulation software with no practical implementation.

ETHIOPIA - PROJECT 2-333: DEVELOPMENT AND FIELD TESTING OF HIGH-PERFORMANCE ALUMINIUM OXIDE-BASED TECHNOLOGIES FOR FLUORIDE REMOVAL IN THE ETHIOPIAN RIFT VALLEY

PI: Feleke Zewge Beshah, Addis Ababa University

U.S. Partner: David Sabatini, University of Oklahoma (Funded by the National Science Foundation)

Dates: August 2013 – June 2017

PROJECT OVERVIEW

The available technologies used for removing fluoride from water such as reverse osmosis, activated alumina, and synthetic resins are difficult to implement in Ethiopia due to their high cost, the need for skilled manpower for system operation and maintenance, and the challenges of ensuring a continuous supply chain for the required chemicals and materials. Relatively simple and low-cost technologies such as the Nalgonda technique and bone char have been tried in Ethiopia, but they have proven inefficient under the prevailing water quality conditions. The objective of this study was to develop, characterize, and evaluate the effectiveness and sustainability of innovative high-capacity aluminum oxide-based materials, composite oxides, and impregnated high surface area adsorbent based technologies for fluoride removal in rural villages of Ethiopia. The project looked at socioeconomic and entrepreneurial aspects to find ways to make the technologies sustainable in the Ethiopian context. Besides laboratory-based synthesis and characterization of adsorbents, the project included preliminary field testing of the new materials, as well as assessment of socioeconomic and social entrepreneurship factors and presentation of findings in workshops and training sessions.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Beshah's original grant was awarded to develop, characterize and evaluate the effectiveness and sustainability of innovative high-capacity aluminum oxide-based materials and composite oxides for fluoride removal in rural Ethiopia. The project aimed at socioeconomic and entrepreneur aspects to find ways to make the technologies sustainable in the Ethiopian context. The project also received a supplement to explore scaling up fluoride treatment technologies in rural Ethiopia. The defluoridation technologies implemented and tried by various organizations in Ethiopia have yet to be proved sustainable due to inadequate capacity of the organizations dealing with the technologies, lack of understanding of the limitations associated with the technologies, affordability and lack of awareness by the users, and absence of proper material supply chain either through the government channel or by private sectors or in partnership.

During the project, the team conducted a concise stakeholder analysis outlining both a categorical and individualized map of institutions and persons relevant in implementation of fluoride removal technologies (drivers for scaling up). The team also visited the water, health and education bureaus in four fluoride affected regional states (Afar, Oromia, Southern Nation, Nationalities and Peoples Region, and Somali), as well as fluoride affected woreda, Kebeles or communities in each regional state.

The main objective of the field visits in the sample areas was to conduct situation or stakeholder analysis, assess the situation of field implemented technologies, and carryout socioeconomic surveys.

Regional water bureaus were involved in selecting the assessment sites and targets for scaling scaling through needs assessments. Document review was also an important source of data to capture the existing gaps for scaling up the fluoride removal technologies in rural villages in Ethiopia. With this in mind, policy/strategy documents, programs, and action plans were reviewed to come up with a proper strategy.

Cognizant of the fact that fluorosis is a serious public health problem affecting the national development, the Ministry of Water, Irrigation and Electricity (MoWIE) has established a National Fluorosis Mitigation program which is aiming at the implementation intervention measures including implementation of Water Defluoridation Technologies. Recently, the NFMPO and other NGOs, particularly the Oromo Self Help Organization (OSHO) and the Catholic Relief Service (CRS) Ethiopia, are making efforts to implement water defluoridation technologies in rural areas both at household and community scales. The key issue related to the ongoing technological interventions is ensuring the overall sustainability and building local capacity.

In addition, USAID supports the Government of Ethiopia's efforts by incorporating water, sanitation and hygiene activities into its health, education, humanitarian assistance and democracy and governance programs, and water resources management into its agriculture and food security activities. Among many other large scale programs and projects, USAID provided a grant of USD $500,000 to OSHO which has been used for the installation of 12 community scale fluoride removal units based on a bone char and production system of hydroxyappatite material in Modjo over a period of 2 to 3 years starting from early 2014. The output of this project will have strong impact on the USAID's support to Ethiopia to enhance access to safe drinking water in the Ethiopian Rift Valley where at least 14 million people are at risk of dental, skeletal and systemic fluorosis. The strategy for scale up can be used all implementing partners.

The output of this project will also have an impact on water science and technology education and research in Ethiopia. The problem of fluoride in particular and water quality in general will be included in graduate curriculum which in the process of development with financial support from the World Bank through soft loan mechanism for the Government of Ethiopia. The Ministry of Science and Technology of Ethiopia also developed an interest to support further field testing and dissemination of fluoride treatment technologies.

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ETHIOPIA - PROJECT 1-289: REDUCING SOIL LOSS THROUGH EFFECTIVE SOIL AND WATER CONSERVATION PRACTICES USING HYDROLOGIC CONSIDERATIONS AND FARMERS' PARTICIPATION IN BLUE NILE BASIN

PI: Seifu Tilahun, Bahir Dar University

U.S. Partner: Christopher Barrett, Cornell University (Funded by the National Science Foundation)

Dates: May 2012 – November 2014

PROJECT OVERVIEW

Soil erosion decreases food production and hampers poverty reduction in the highlands of eastern Africa. Despite intensive efforts since the 1980s to reduce sediment production and halt land degradation, erosion continues unabated, decreasing already low crop yields further. Shallow soils are becoming shallower, often abandoned, and gullies are swallowing productive cropland. Lost soil fills reservoirs and silts downstream irrigation canals. Current measures to reduce soil loss are ineffective, necessitating new approaches that consider the whole landscape's hydrology and utilize traditional farmer knowledge for erosion control.

This project aimed to develop appropriate watershed and farmer-based erosion control practices for the Ethiopian highlands, replacing inappropriate foreign technologies. Researchers installed instruments in the Debre Mawi (5.27 km²) and Bir (64 km²) watersheds in the Blue Nile headwaters and continued monitoring the Mizewa watershed (27 km²), previously instrumented by the International Water Management Institute (IWMI). They identified erosion hotspots by measuring spatially distributed runoff and soil loss and using participatory watershed methods and sediment tracers. By locating hotspot areas, they proposed effective conservation practices. A simple physically-based hydrology model was applied to locate practices in vulnerable areas, comparing predictions with farmers' knowledge and traditional practices.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project showed that current massive soil conservation practices on the highlands of Blue Nile Basin Ethiopia have an immediate impact on reducing erosion and soil loss. However, responsible organizations including government and NGOs should also focus on best management practices at bottomlands where gullies are expanding and not just to the current massive practices on the steep hill slopes. Moreover, the team showed that gullies as deep as 15 m deliver the majority of the sediment to the rivers and swallow valuable grass and cultivated lands. Despite the obvious and enormous effect of gullies on sediment transport, large-scale government-led conservation mobilization works do not target them as hotspots that need fixing. One of the reasons might be that these gullies are difficult and expensive to rehabilitate and are seen by the communities as a punishment from God for being against his will and, as such, any efforts to rehabilitate them will be in vain. In one of the experimental watersheds, this project team was able to rehabilitate five gullies with the aid of the community and thereby change the perception of farmers on their ability to stop gully formation.

The research work in Bir watershed had an impact on the communities of the areas and beyond as communities were not expecting any benefit from the rehabilitation of gullies. The benefit from the gully was fodder for livestock for fattening and milking and these benefits to farmers were the major mechanism to mobilize the community to work on gully rehabilitation activities. To pass the message of our successes beyond the local communities, a workshop was conducted in October 2014 and 22 research papers were presented. Presentations included land use change, hydrological processes, erosion rates, flow restricting pan formations, gully erosion, evaluation of conservations practices, and conservation of gullies. All 11 PhD students and MSc students associated with PEER Science project presented their findings. During the workshop three briefing notes and one book of abstracts were distributed to the participants.

Moreover, one documentary film was produced. The video will be useful as a means to translate research results to policy makers and awareness creation amongst those dedicated to planning, implementing and maintaining soil and water conservation practices. The video can also be use at an internationally to create awareness of the soil and conservation problems and challenges in Ethiopia and might even prevent misdirected efforts of future donors.

This project received supplemental PEER funding to conduct research dissemination workshops and field visits to showcase to farmers, low and high level SWC practitioners and policy makers that:

- To reduce storm runoff and soil loss from a catchment, SWC measures should be tailored to specific field conditions by considering the hydrology (such as ground water table pattern), topography and soil types. Infiltration ditches were found effective on the hillsides whereas on the saturated bottomlands, such structures concentrate runoff, initiated gullies and caused more erosion.

- Including gully treatment and stabilization as an important component of the large soil and water conservation measures can help to reduce sediment loads in major Ethiopian rivers such as the Blue Nile basin.

- Treatment of shallow gullies is necessary. Findings indicated different priorities and issues between gullies having a depth greater than 3m and less than 3m. In the deeper gullies, a huge amount of labor and cost was required for treatment as compared with shallow gullies. The shallow gully treatment was completely effective unlike the collapse of structures in the deeper gully.

- The cost comparison was done to determine how much it costs for the head treatment regarding adding stone rip rap at the head with the currently used loose stone and gabion check dams. The head treatment is low cost ($9/m2) and technically can be implemented by the local farmers. Whereas loose stone and gabion check dams costs $69 and $120 respectively.

In collaboration with Bahir Dar University, the Bureau of Agriculture of Amhara Region took an initiative to implement these research outputs at the farmers' fields. Because of this, farmers, development agents, district level, zonal, and regional natural resource management officials participated in an upscaling workshop in Finote-Selam. After the completion of the workshop, four regions in the Amhara Region implemented the recommended measures from project research findings in their watersheds and invited guests to observe their efforts. The Bureau of Agriculture is now using lessons learned from the pilot districts as part of the regional natural resource management plans.

ETHIOPIA - PROJECT SG1-003: UNLOCK THE POTENTIAL OF BEGAIT CATTLE: GENOME WIDE ASSESSMENT OF GENETIC DIVERSITY, POPULATION STRUCTURE AND ASSOCIATION STUDY USING HIGH DENSITY SINGLE NUCLEOTIDE POLYMORPHISM (SNP) MARKER

PI: Selam Meseret, Ethiopian Biotechnology Institute

Dates: October 2019 -July 2021

PROJECT OVERVIEW

Ethiopia has the highest cattle population in Africa, with an estimated 70 million total cattle in the country, and cattle farming plays a pivotal role in the livelihood of smallholder farmers. The majority of the animals are indigenous breeds, well adapted to the local environment and distributed in diverse topographic and climatic conditions in the country. One of the best known breeds for dairy production in Ethiopia is Begait. This project sought to identify baseline data for genetic conservation to unlock the genetic potential of Begait cattle. The results from this research will help to identify appropriate animals for selection programs to increase milk production and improve its composition to produce quality cheese. The PI mentored female student researchers as part of this project, offering hands-on training on data collection and analysis, molecular laboratory work, and paper writing. The project also supported graduate thesis work, and the research results generated rarely-available data on from indigenous cattle and formed the baseline for future work and grant proposals.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers began their work targeting a Begait cattle breed kept in the nucleus breeding herd in Humera, Tigray Region, seeking to genotype the breed to perform a genome-wide association study (GWAS). They captured pedigree information, milk yield and quality (such as composition of fat, protein, and lactose), and reproduction-related data points using a customized open data kit digital tool. Unfortunately, this work could not be completed because of unrest and political instability in the study area. Pure Begait cattle are not found in other parts of the country in large enough numbers to conduct GWAS, so the researchers turned to identifying genetic diversity and possible k-casein (CSN3) and beta-lactoglobulin (LGB) gene polymorphism among various Ethiopian breeds.

They extracted genomic DNA from blood samples collected from a breeding dairy farm in central Ethiopia, including Begin, Borena, Fogera, and crossbreeds. The team observed genetic diversity both among and within breeds and proved polymorphism in the study population. The team noted that this suggests that selection of animals can improve the genetics of the cattle population, as LGB and CSNs genes both have an effect on milk production.

The milk yield and composition data generated from the Begait cattle under free grazing were on the higher side compared to data from other research on Ethiopian indigenous and exotic breeds, indicating a higher potential of the breed and need for future research. The researchers presented their results at the Ethiopian Biotechnology Institute, Addis Ababa University, and other partner organizations.

GHANA

GHANA - PROJECT 9-518: COMMUNITY AND HOSPITAL-BASED OBSTETRICS WHATSAPP TRIAGE, REFERRAL, AND TRANSFER (WAT-RT) SYSTEM

PI: Veronica Millicent Dzomeku, Kwame Nkrumah University of Science and Technology, Kumasi

U.S. Partner: Jody Lori, University of Michigan (Funded by the National Institutes of Health)

Dates: May 2021 – July 2023

PROJECT OVERVIEW

The overarching project goal was to increase continuity and access to quality maternal care, reducing preventable obstetric-related deaths through (1) a WhatsApp Triage, Referral and Transfer (WAT-RT) System connecting community health workers (CHWs), midwives at rural health facilities, and healthcare personnel at referral hospitals; and (2) an obstetric (OB) triage system implemented at referral hospitals to decrease facility delays. The WAT-RT system allows two-way communication to assist in early problem identification and prompt referral to the next level of care. It will allow the facility to prepare for incoming increased workload, thus preventing delays upon arrival. Phase I of the project employed a participatory action research design to identify health system challenges from the perspective of patients, providers, community leaders, and government. The team conducted a learning needs assessment of the familiarity of CHWs and healthcare providers with the WhatsApp platform and a review of the risk factors for OB emergencies warranting referral from the community to the facility. Next, with stakeholders, the team designed the protocol for the WAT-RT system. Using a train-the-trainer model to implement the system at 40 rural clinics and two referral hospitals, the team trained clinic staff who will then become facilitators, training CHWs from their respective catchment communities. Phase II training took place at the referral hospitals. Following an assessment of current OB triage protocols, including observations of admission and labor ward activities, structured intake assessments, waiting times, and focus group discussions, the project team used an iterative approach to design and deliver an interactive triage training course for all emergency department and labor and delivery hospital personnel.

FINAL SUMMARY OF PROJECT ACTIVITIES

After baseline data collection and protocol design were complete, the project applied a carefully coordinated train-the-trainers model for introducing their WhatsApp based system to healthcare providers. In November 2021, the project team trained Ghanaian midwives and community health workers on triaging, referral, and transfer of obstetric emergencies using the WAT-RT system. Specifically, 29 rural health workers from 16 rural health facilities and 3 midwives from the Kwame Danso hospital were trained on identifying risk factors for OB emergencies warranting referral from the rural health facility to the referral hospital. As part of their training, all 32 participants representing the total of 17 health facilities from the Sene West and Sene East Districts, were split into groups of 6 to develop and present on a birth preparedness plan they will develop with each pregnant woman they encounter. Again, they all received a step-by-step training on using WhatsApp for communicating as part of the WAT-RT System. During the same period, the project team in Liberia also held a train-the-trainers workshop for 20 rural health facility midwives in Bong County to guide the on the establishment and operation of the WhatsApp platform on smart phones/tablets and recognition of danger signs during pregnancy. The objective of the training was to ensure that the midwives in turn, will train community health assistants in their catchment community use the WhatsApp platform for referral and for feedback communication loop.

As the system rolled out in both countries, the project teams remained in regular contact with the implementers, including making site visits to the facilities where they were based, to make sure the system was working well and make any necessary adjustments or provide retraining. As the project culminated, the researchers convened a dissemination meeting on May 24, 2023, at the KD District Hospital in Ghana to share their findings with stakeholders and agree on next steps with regards to sustainability. The district directors, midwives, and the in-charges of the participating health facilities participated in the meeting, along with Ghana Health Service Deputy Director Dr. Anthony Ofosu, U.S. partner Dr. Jody Lori, and a maternal and child health specialist from USAID. The project team recommended that extending the intervention to other rural communities and districts within Ghana would ensure that obstetric emergencies are handled appropriately.

A strong collaboration has been developed with the Ghana Health Service from national, regional and district levels for the implementation of the project. Dr. Anthony Ofosu has served as an advisor to the project, and the team has also been regular contact with relevant Liberian healthcare authorities. Regular meetings were held with the Bong County Health team that supervises the implementation level of the project. KNUST has also formed a stronger collaboration with the University of Liberia through sharing of experiences and learning on the project.

The main output from the project is the user-friendly, online-based triage and referral system that was developed and piloted at 16 rural health facilities. After they experienced the effectiveness of the system with regards to improving communication between health facilities at different levels of care and preparing the receiving facility for incoming referrals to avoid delays in emergencies, the health facilities have adopted the system, as well as the associated triage form that was also developed under the project. Another key result was that midwives received training on OB emergencies, triaging, and effective communication with clients and colleagues. During the two years that the project was implemented with PEER support, a total of 306 referrals were made using the system. Midwives and patients attested that the system was effective and contributed to improving health outcomes. Going forward now that the PEER project has ended, the PI and her team will create a network of all midwives who received training in the use of the referral system to ensure frequent communication and sustained implementation of the system. The district health directors and directors of the implementing facilities will also be engaged to ensure that resources are available to support the system. Researchers from the project team will continue to provide technical support to the implementing facilities, and Dr. Ofosu will lead the team for national engagement and dissemination of the developed system. Other funding support will be explored to extend the project beyond the district to the regional level.

PUBLICATION

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GHANA - PROJECT 9-117: AGRIVOLTAIC TECHNOLOGY IN DRYLANDS OF WEST AFRICA: STRENGTHENING NATIONAL INNOVATION SYSTEMS FOR DIFFUSION AND MARKET DEVELOPMENT AT THE WATER-ENERGY-FOOD NEXUS

PI: Francis Kemausuor, The Brew-Hammond Energy Centre, Kwame Nkrumah University of Science and Technology, with Co-PI Patricia Amankwaa-Yeboah, CSIR-Crops Research Institute

U.S. Partner: Efthymios Nikolopoulos, Florida Institute of Technology (Funded by the National Science Foundation)

Dates: May 2021 – April 2024

PROJECT OVERVIEW

Ghana's Renewable Energy Masterplan has targeted the installation of 448 MW of utility-scale solar photovoltaic (PV) capacity by 2030. Achieving this target requires approximately 1,120 acres of land. As of 2019, less than 50 MW of the target had been achieved, leaving close to 400 MW still to be developed. The land requirement to install the remaining systems is high and has potential to erode the environmental benefits of renewable energy. In land-scarce areas, using agricultural lands for solar PV installation may also generate conflicts with existing land users.

The introduction of agrivoltaic systems in dryland regions is a step towards renewable energy and food production security in deprived rural areas where farming is the dominant occupation. The microclimatic conditions found beneath solar PV panels are expected to have positive impacts on crop production, irrigation water management, and renewable energy production. In warmer temperatures, the solar PV panels are expected to maximize crop yield by introducing a shading effect to the crop, thereby reducing heat and light stress and preventing depression in photosynthesis, thus allowing for greater carbon uptake for growth and reproduction. The system is also expected to ensure the efficient delivery of water to plants by decreasing evapotranspiration from soil and crop canopies.

This PEER project sought to inform solar installation companies and funding agencies, particularly in northern Ghana, about outcomes from agrivoltaic systems and how to maximize land use by incorporating crop cultivation under large-scale solar PV installations. The team sought to inform policies to improve agricultural sector growth while increasing renewable energy contribution into the national grid, thereby expanding the access rate of electricity to deprived farming communities in northern Ghana.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers set up two tropical agrivoltaic research fields in Ghana, one on the research fields of Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Fumesua, and one on the New Energy compound, under Hikma Agro Services Limited, Tamale. This experiment collected data on radiation and understory panel temperature, photosynthetically active radiations and air temperature within the plant canopies in the open field agriculture and agrivoltaic systems, as well as soil temperature and volumetric moisture content. The team also installed weather stations at both sites to understand the impact of the technology across climatic gradients. This PEER project also included training for staff on data collection protocols for a variety of parameters, including plant height, stem elongation, number of primary branches, crop penology, number of flowers per cluster, and plant physiological data. Team members collected field data weekly.

Prior to setting up the experimental fields, a socioeconomic baseline survey was conducted in the northern parts of the country to assess farmers' willingness to support agrivoltaic projects. The results showed that farmers are more likely to adopt or agree to an agrivoltaic technology if they believe the project will benefit local communities, farmers, and the state. After setting up the experimental fields, the PEER team also held farmer field activities to introduce farmers to the concept of agrivoltaics and how it could help optimize land use for energy and food production.

The researchers found that agrivoltaics would have a higher initial cost than traditional PV installations, so the government would have to intentionally drive change using the policy, much like an energy efficiency program. As a result, the project team has engaged with the government team that prepared the Ghana Energy Transition Framework, suggesting that a mandatory 5% of all utility scale projects be agrivoltaic. The team also engaged with several PV installers through meetings and project workshops, including a potential agrivoltaic trial collaboration with the country's largest solar installer.

The project PI received a grant from the Center for Global Equality to advance activities within the Climate Compatible Growth (CCG) program, in which he will receive £55,000 annually for two years to organize CCG activities in Ghana. The project co-PI is also a member of a team that received a €140,000 grant from the Revenue Diversification Pathways in Africa through Bio-based and Circular Agricultural Innovations (DIVAGRI) program, funded by the European Union. In August 2021, the PI and partners from Denmark and Tanzania received a grant for a project entitled "Energy Struggles: renewable energy in Africa." Francis Kemausuor is the PI on the Ghana side of the project, with his university receiving approximately $395,000. The university's College of Engineering has also received a grant of one million Canadian dollars (CAD $1 Million) to establish a multidisciplinary Responsible Artificial Intelligence Lab (RAIL) under the AI4D Africa Multidisciplinary Labs project initiated by International Development Research Centre (IDRC). Francis Kemausuor is a member of the team.

The PEER team presented their findings at a variety of events, including a student workshop, the International Conference on Irrigation and Agricultural Development, a stakeholder workshop, and a field visit at the Council for Scientific and Industrial Research. A manuscript on their findings is forthcoming.

GHANA - PROJECT 4-040: DEVELOPMENT OF HIGH-YIELDING AFLATOXIN-RESISTANT MAIZE HYBRIDS FOR IMPROVED NUTRITION AND HEALTH IN GHANA

PI: Allen Oppong, CSIR, Crops Research Institute
U.S. Partner: Marilyn Warburton, USDA/ARS Corn Host Plant Resistance Research Unit
Dates: October 2015 – September 2018

PROJECT OVERVIEW

Dr. Oppong and his team applied Simple Sequence Repeat (SSR) and Single Nucleotide Polymorphic (SNP) aflatoxin-resistant markers to help speed up the development of aflatoxin-resistant maize for Ghana. The incorporation of aflatoxin resistant genes into local elite inbred lines for the production of high yielding hybrids will not only improve maize availability in Ghana but will also improve the nutrition and health of Ghanaians. The process of developing aflatoxin-resistant maize will enhance the skills of Ghanaian scientists in using marker-assisted selection/breeding to hasten maize breeding activities in Ghana, and these modern techniques can also be utilized in other breeding activities for improved biotic stress resistance in Ghana and beyond. Currently, the use of marker-assisted breeding is at the initial stages in Ghana, and using aflatoxin-resistant markers will reduce considerably the time needed to breed for high yielding aflatoxin-resistant maize in Ghana. In addition, the acquisition of equipment to support marker-assisted selection was intended to improve the technical infrastructure at the Crops Research Institute.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main objective of this project was to apply SSR and SNP aflatoxin-resistant markers to help speed up the development of aflatoxin-resistant maize for Ghana and also equip human resources with the skill needed for marker assisted selection especially, breeding for aflatoxin resistant varieties in Ghana. The project has identified 10 potential high yielding hybrid varieties, which are being tested in multi-locational environments to assess their stability and the best performing lines for eventual registration and release as varieties for use and cultivation in Ghana. These promising hybrids were obtained following a strict selection regime involving field phenotyping and genotyping using SSRs and SNP markers with the support of laboratory analysis and quantification of aflatoxin levels.

The PI reports that the laboratories of CSIR-CRI have been equipped with basic equipment needed for aflatoxin detection and quantification that never existed prior to the implementation of the project. The VICAM aflatoxin set up provided thanks to PEER funds is currently being used to detect and quantify aflatoxins in maize. Similarly, the acquisition of the microplate reader as well as KASP reagents for SNP analysis has enabled the Institute to carry out marker assisted selection using SNPs.

The human resource capacity of the of CSIR-CRI has improved considerably following training received by project staff and students especially, the skills for marker assisted selection with SNPs and SSRs for breeding for high yielding aflatoxin resistant maize varieties. The project organized a training course, which attracted over 40 participants from various stakeholder institutions in the country, namely;

CSIR-Crops Research Institute, Kumasi, Kwame Nkrumah University of Science and Technology, Kumasi, West Africa Centre for Crop Improvement (WACCI), University of Ghana Legon and CSIR-College of Science and Technology, Kumasi. The participants were trained on how to use SNP and SSR Marker for breeding as well as how to detect and quantify aflatoxins in maize using the VICAM aflatoxin detection and quantification set up. Until the training CSIR-CRI had no capacity to detect aflatoxins in maize.

Currently, CSIR-CRI is advertising its capacity to detect and quantify aflatoxins in maize to interested stakeholders. The PI hopes that these services when used by farmers will inform farmers the aflatoxin status of their maize before they are consumed. With close to realization of developing high yielding stable aflatoxin resistant varieties in Ghana, it is believed that these varieties when they are available can highly contribute to the nutrition and health of Ghanaian maize consumers thereby improving their health.

The next phase of this work after identifying two or three high yielding aflatoxin resistant hybrids is the registration and release of these genotypes as varieties for use and cultivation in Ghana. This is a crucial step to make all the work done so far complete for utilization and consumption by the general public. It is estimated that in the next two years this can be become a reality.

GHANA - PROJECT 3-186: PRESSA: PHOTOVOLTAIC RELIABILITY EVALUATION IN SUB-SAHARA AFRICA

PI: Gabriel Takyi, Kwame Nkrumah University of Science & Technology
U.S. Partner: Christiana Honsberg and Mani G. Tamizmani, Arizona State University
(Funded by the National Science Foundation)
Dates: September 2014 – February 2019

PROJECT OVERVIEW

Many countries are procuring and installing large numbers of photovoltaic (PV) modules for various grid-tied and stand-alone applications. These modules need to be evaluated to ensure that they will meet the safety requirements (both electrical and mechanical), meet the nameplate rating requirements (rating tolerance shall be minimum), and be reliable and durable for at least 20 years. Because consumers decide to purchase modules based on their "$/watt" ratio as per the nameplate rating, it is critical to ensure that the rating is accurate. In this PEER project, the nameplate rating will be verified by the principal investigator's laboratory in Ghana before procurement decisions are made by investors and the government of Ghana.

The lifetime of PV modules is dictated by failure modes and degradation rates. PV module manufacturers typically provide 20-year warranties, but there are two problems. First, due to the dynamic nature of the investors' decisions, many manufacturing companies do not last longer than a few years, rendering the 20-year warranty useless. Second, most manufacturers provide a 20-year warranty due to heavy competition in the industry but do not have substantiated evidence to justify these long warranty periods. Based on the experience gained in the U.S. partners' laboratory at ASU, it has been demonstrated that the majority of modules do not meet warranty requirements, and most manufacturers are no longer in business to make good on warranty claims when they are made. Three of the major failure/degradation modes in the climatic conditions prevalent in Ghana are solder-joint degradations/failure; encapsulate browning; and high relative humidity/rain-related degradation. In this PEER project, samples of PV modules will be evaluated for the above failure and degradation modes both in the field and the laboratory.

Two major impacts are expected with regard to purchasing decisions by various stakeholders, including the government of Ghana and Ghanaian investors and consumers. The first impact is related to nameplate rating verification. The stakeholders can purchase the modules based on their independently measured power provided by the Ghanaian researchers rather than their manufacturer rated power. The second impact is related to the lifetime of the modules in the field. An extensive evaluation of PV modules is required to predict module lifetime under various climate conditions. Given the limited budget and time available for this PEER project, the entire lifetime-related research could not be performed, but the team carried out a few key reliability studies in the laboratory and in the field to identify the major failure modes using less expensive, non-destructive tests.

FINAL SUMMARY OF PROJECT ACTIVITIES

The data collected so far under PRESSA provides compelling evidence that some of the PV modules that are imported do not perform as expected based on the manufacturers' nameplate ratings. The

Ghanaian consumer (including individuals, government agencies etc.) and other stakeholders must be aware of this through the demonstration of their research findings. For instance, research on risk priority number (RPN) of a 2.5 MW solar power plant in Northern Ghana indicates that after only five years of operation, the rate of degradation has exceeded the rate that is expected in 25 years. These results will be presented to the Volta River authority, the operators of the plant. They have been able to show the performance in terms of prevalent degradation and rate of degradation of different PV technologies installed at different climatic zones (Tropical Savannah and Semi-Arid Zones) in Ghana.

The project's potential development impacts include:

1. Prediction of life of PV modules installed in SSA using accumulated strain energy density from the modelling of solar PV interconnections.
2. The prevalent defects of PV modules installed in the tropical savanna and semi arid climatic zones in Ghana have been identified. This could be of great benefit in product development
3. The use of climatic condition (temperatures of KNUST) has helped generate a temperature profile representative of sub-Sahara Africa. This Information will be useful for manufacturers in the design of robust crystalline silicon PV modules.

The PI and his team will continue to collaborate with the U.S. partner on both current and new research. KNUST is currently partnering with ASU on MasterCard Accelerated Master's Degree Programs (3+1+1) in mechanical engineering, biomedical engineering and business programs. Under this program, ASU will be training up to 150 KNUST students for five years. The U.S. partner has agreed to take some of the students to do their projects in his laboratory at ASU Polytechnic.

PUBLICATIONS

Nyarko F., Takyi G., Amalu E., Adaramola M. 2019. Generating temperature cycle profile from in-situ climatic condition for accurate prediction of thermo-mechanical degradation of c-Si photovoltaic module, Engineering Science and Technology, an International Journal 22(2): 502-514. https://doi.org/10.1016/j.jestch.2018.12.007.

Takyi G. 2017. Correlation of Infrared Thermal Imaging Results with Visual Inspection and Current-Voltage Data of PV Modules Installed in Kumasi, a Hot, Humid Region of Sub-Saharan Africa. Technologies 5(4):67. https://doi.org/10.3390/technologies5040067

GHANA - PROJECT 2-251: DEVELOPMENT OF EDIBLE AND MEDICINAL MUSHROOMS AS FUNCTIONAL FOODS IN GHANA

PI: Mary Obodai, Council for Scientific and Industrial Research, Food Research Institute

U.S. Partner: Steven J. Schwartz, The Ohio State University (Funded by the National Science Foundation)

Dates: August 2013 – October 2016

PROJECT OVERVIEW

Across the world, including Ghana, edible wild mushrooms are commonly collected when in season. Mushrooms are low in fat and sugars, a good source of protein, vitamins and minerals and most importantly, are the only vegetable that contains all nine essential amino acids. Edible mushrooms have attracted much interest as functional foods due to their antimutagenic, anti-tumor and anti-viral properties. Food product development must address these changing consumer demands; the development of a convenient mushroom-based functional food is one example. Thus, the goals of this project were to (1) develop methods to cultivate different mushrooms in Ghana and assess nutritional quality, (2) develop a mushroom-based infant functional food, and (3) assess the consumer acceptability of the new mushroom product. Four species of mushrooms--two oyster mushrooms, monkey seat, and termite mushrooms—were cultivated as part of the project, using agricultural residues and tissue culture methods to transform organic waste into food. Product development initially focused on infant food, guided by the needs of consumers and considering both technical feasibility and profitability.

The U.S. partner provided technical training to Dr. Obodai and a member of her group, and unemployed women and rural groups were targeted as the workforce for production of the food products to be developed. The anticipated outcomes of the project include four mushroom species available for use and further product development, a new market-tested mushroom-based product ready for commercialization, and a trained workforce to grow and produce the initial mushroom product. Ultimately, the project researchers hoped that expanding children’s diets to include mushroom products would reduce the burden of malnutrition and improve food security in Ghana and throughout Africa.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over the course of the project, three mushroom-based products were developed for children ages 2 to 5, including mushroom orange-fleshed sweet potato (OFSP) mash, mushroom soup mix, and mushroom-based cereal mix. These were developed from mushroom varieties including *Pleurotus ostreatus* strain EM1, *P. sajor-caju* strain PSCW, *P. tuber-regium* strain PTR, *Ganoderma lucidum* strain GLA, *Auricularia auricula* strain AU, and *Termitomyces* species. The team also carried out sensory evaluation and consumer acceptability tests for 60 caregivers of children ages 2 to 5. The caregivers selected mushroom-based cereal mix made from *Pleurotus ostreatus* strain EM1 and *P. sajor-caju* strain PSCW for use. These caregivers were consequently trained in the cultivation and use of mushrooms for the production of mushroom-based cereal mix. Three mushroom demonstration sites were set up in Kukrantumi in the Eastern Region, Hohoe in the Volta Region, and Accra in the Greater Accra Region.

Dr. Obodai and her team also analyzed 57 mushroom samples from two selected forests (Ayum and Atiwa) for bioactive compounds such as beta-glucan, ergothioene, and vitamin D. Most of the selected species contained varying amounts of these compounds, and these results form the basis for further biotechnological applications. The project published one paper, and the PI hopes to continue her collaboration with her U.S. partner in writing future manuscripts, as the project has generated a great amount of data.

In summary, Dr. Obodai's institution, the Council for Scientific and Industrial Research- Food Research Institute (CSIR-FRI), has incorporated the new mushroom products into the mushroom cultivation training that they conduct twice per year. The developed mushroom-based foods will also be promoted at workshops organized by CSIR-FRI. Their enhanced nutritional properties, which have been documented, will be published in leaflets and handouts and distributed at workshops organized by the Institute.

PUBLICATION

Obodai, M.; Narh Mensah, D.L.; Fernandes, Â.; Kortei, N.K.; Dzomeku, M.; Teegarden, M.; Schwartz, S.J.; Barros, L.; Prempeh, J.; Takli, R.K.; et al. 2017. Chemical Characterization and Antioxidant Potential of Wild Ganoderma Species from Ghana. Molecules 22: 196.
https://doi.org/10.3390/molecules22020196

GHANA - PROJECT 1-142: POSSIBLE CAUSES OF THE CONTRACTION OF WEST AFRICA'S RAINFALL SEASON UNDER GLOBAL WARMING: IMPLICATIONS FOR AGRICULTURE

PI: David Cudjoe Adukpo, University of Cape Coast

U.S. Partner: William Gutowski, Jr., Iowa State University (Funded by the National Science Foundation)

Dates: July 2012 – November 2014

PROJECT OVERVIEW

Observations and research results have shown changes in the onset of the main rainfall season in West Africa, which in turn have an impact on agricultural practices. In many parts of West Africa, rain-fed agriculture is a prominent instrument for economic growth, food security, and poverty reduction, so future changes in climate may cause significant disturbances. This project studied the possible causes of the reduction in West Africa's rainfall season and explored the relationship between onset and retreat of rainfall dates in West Africa and climate index interactions using response surface analysis. The project also studied how the variability in rainfall is affecting the present and future maize yield in Ghana, as well as other potential impacts such as hydroelectric power generation and fisheries.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Adukpo and his colleagues published their most recent joint paper in the June 2014 issue of the *International Journal of Geosciences*. The paper uses the International Centre for Theoretical Physics (ICTP) Regional Climate Model, Version 3 (RegCM3), and rain gauge data selected from the Ghana Meteorological Agency (GMet) from 1990 to 2008 to investigate the extent and nature of variability in the annual rainfall and pattern of the rainy seasons in Ghana. Several of Dr. Adukpo's students gave seminar presentations at the Department of Physics as part of their continuous assessments towards the M.Phil degree. In September, another of the team's jointly published papers, "Farmer's observation on climate change impacts on Maize (*Zea mays*) production in a selected Agro-Ecological zone in Ghana," was presented at the Fifth International Conference of the Organization for Women in Science for the Developing World, in Cuernavaca, Mexico.To disseminate their findings and recommendations broadly, the research team visited farmlands and discussed changes with the farmers impacted by the rainfall season, as well as organized a workshop on climate change and food security in Ghana.

PUBLICATIONS

F. Nkrumah; N.A.B. Klutse, D.C. Adukpo, K. Quagraine, K. Owusu, A. Owusu, W. Gutowski Jr. 2014. Rainfall variability over Ghana: model versus rain gauge observation. International Journal of Geosciences 5(7): 673-683. http://dx.doi.org/10.4236/ijg.2014.57060

N.A.B. Klutse, K. Owusu, D.C. Adukpo, F. Nkrumah, K. Quagraine, A. Owusu, W.J. Gutowski. 2013. Farmer's observation on climate change impacts on Maize (*Zea mays*) production in a selected agro-ecological zone in Ghana. Research Journal of Agricultural and Environmental Management 2(12): 394-402, December 2013. https://core.ac.uk/download/pdf/38939991.pdf

GHANA – PROJECT SG1-002: THE GUT MICROBIOME COMPOSITION AND ITS IMPLICATION FOR HYPERTENSION

PI: Adjoa A. Boakye, University of Health and Allied Sciences

Dates: February 2020 – May 2021

PROJECT OVERVIEW

In many sub-Saharan countries, research has been tailored mainly towards infectious diseases and food security, while research into noncommunicable diseases (NCD) has been neglected. Studies of NCDs across Africa showing an increasing burden of NCDs related to cardiovascular disease. This PEER project sought to understand the extent of hypertension as a public health concern in the Volta region of Ghana. The team's findings, as well as a community engagement exercise, indicate the need for community-based education on this topic. This is particularly important because in a country like Ghana, which already has a struggling healthcare system, risk factor identification and prevention is the easiest way to prevent the collapse of the system. The project also supported the PI in becoming a mentor to several undergraduate researchers who are beginning their scientific careers.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers gathered data from adults across several Volta region communities, including demographic and lifestyle information, various measures of obesity and blood pressure, and anthropometric and bioelectrical impedance measurements. The overall prevalence of hypertension in the study population was 28.56%, but more than 50% of those with hypertension did not know their status. Some of those who knew their status did not comply with the treatment regime that had been prescribed due to misconceptions about the side effects of antihypertensive drugs. The researchers found significant associations between hypertension and age, as well as measures of central obesity such as visceral fat. Measures of general obesity such as percentage of body fat and body mass index did not show good predictive value and had weak positive associations with hypertension. No associations were seen with regard to physical activity level and hypertension, since most of the study participants had a rather sedentary lifestyle.

Parts of this research were submitted as theses by two of the PI's mentees, and the PI presented the results at a technical meeting at the University of Health and Allied Sciences. The PI received a new grant within the project period from the Royal Society of Tropical Medicine and Hygiene and published several manuscripts, including one on the results of this project. She mentored and supervised three undergraduate students who successfully defended their theses and graduated.

PUBLICATION

Adjoa Agyemang Boakye, David Adedia, Gaston Kofi Hunkpe, Rosina Afua Ampomah Carr, Veronica Fafali Ami AdanusahAll, Bless Seyram Agbenyo, and Kwabena Obeng Duedu. 2022. Comparative assessment of the utility of anthropometric and bioelectrical impedance indices as potential predictors of hypertension within a Ghanaian adult population: a cross-sectional study. International Journal of Hypertension 2022: 2242901. https://doi.org/10.1155/2022/2242901

KENYA

KENYA - PROJECT 9-69: ENHANCING CAPACITY OF LOCAL COMMUNITIES IN LAIKIPIA COUNTY, KENYA: INCREASING PREPAREDNESS AND RESPONSE TO EMERGING INFECTIOUS DISEASES IN PARALLEL WITH PRESERVATION OF BIODIVERSITY

PI: Joseph Kamau, University of Nairobi
U.S. Partner: Dawn Zimmerman, Smithsonian Institution (Funded by the Smithsonian Institution)
Dates: April 2021 – June 2023

PROJECT OVERVIEW

The burden of zoonotic diseases has been increasing globally over the last few decades, raising concern among governments. Zoonotic disease has led to increased household health-care costs, loss of income from livestock trade, and loss of endangered and rare wildlife biodiversity, among many other negative impacts. These diseases impair progress towards attainment of Sustainable Development Goals, the African Union Agenda 2063, and Kenya's Vision 2030. The factors contributing to the increasing burden of these diseases include the expanding population, degrading wildlife habitats, international travel and trade, changing farming systems, urbanization, cultural practices, poverty, and climate change, among others. The One Health approach that brings the interconnection between biosafety, biosecurity, and biodiversity, involving multisectoral and multidisciplinary collaboration between human health, animal health, and environment sectors among other stakeholders, is only one approach that presents a viable solution to this challenge.

A key finding of the USAID-funded PREDICT-2 program in Laikipia County, Kenya, was a general lack of awareness in all communities that contact with animals can cause disease in people. Laikipia has closely interacting human, wildlife, and livestock elements in an environment under multiple pressures, such as land use changes and increasing livestock, wildlife, and human populations. Unpublished USAID PREDICT-Kenya data identified the following gaps: (1) the role of biological diversity and its ecological role in relation to transmission of emerging infectious diseases (EIDs); (2) potential behavioral and cultural practices that potentially expose the community to EIDs; and (3) lack of EID risk awareness in terms of sources, identification, and interventions. It is on this basis that future risk mitigation strategies should emphasize education tailored to specific sites to be socially and culturally acceptable. Targeted training of community-based health workers, community leaders, rangers, and wardens who are chosen by the community would provide a communication channel for dissemination of national and tailored local public health initiatives to vulnerable people living at high-risk human-animal interfaces. This study sought to increase preparedness and response to EIDs by enhancing the local communities' understanding, through a more integrated One Health approach, of the importance of ecological correlates to global EIDs.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over the course of the project, which involved organization of 29 public events attracting 790 participants, the team was able to increase preparedness and response to diseases among the community members, resulting in a more alert community that is conscious of their interaction with animals and the environment. They also increased the communities' awareness on the role of biodiversity on disease dynamics, including emergence, transmission, and spillover, and stakeholders now appreciate the role of biodiversity and its conservation in emerging diseases. The community members were also able to relate their traditional and current knowledge of biodiversity to disease dynamics.

The project also enhanced capacities of various cadres of health workers on disease epidemiology and occurrence using the One Health approach. Health workers are now applying the acquired knowledge in diagnosis and management of diseases. This has led, for example, to the quick identification of the potential origin of disease symptoms. In one case, a health worker linked patients to ingestion of meat from a dead camel.

Lastly, the project worked on the incorporation of emerging diseases and pandemics as a threat in the Laikipia County Community Strategy 2021-2025. The County Health Department incorporated disease emergence and pandemics as one of the threats that required concerted effort in preparedness and response. To support this, the county has allocated resources to address disease emergence and pandemics. Despite the progress made on the project, the PI Dr. Kamau and his team note that there remains much work to be done to address the disconnect between the One Health approach to disease surveillance and clinical diagnostics. There is a need for further education to raise awareness at the county level (particularly county disease surveillance officers and health managers). In particular, the project team recommend two key areas for improvement. First, a training module should be developed that incorporates the project findings regarding tick-borne disease, disease epidemiology, and disease ecology. Second, the training module should be accredited to count towards continuing medical education requirements for healthcare workers and other health professionals. Although the PEER project has ended, Dr. Kamau and his colleagues will continue working to build on their stakeholder linkages and research partnerships to further their efforts in this regard.

KENYA - PROJECT 8-105: DISTRIBUTION AND SPECIES DIVERSITY OF BATS (MAMMALIA: CHIROPTERA) IN KENYA

PI: Paul Webala, Maasai Mara University
U.S. Partner: Dawn Zimmerman, Smithsonian Institution
Dates: January 2020 – June 2022

PROJECT OVERVIEW

In the face of unprecedented population declines in many wildlife species, monitoring changes in ecological communities is critically important for conservation planning and decision making. Bats (Mammalia: Chiroptera), with approximately 1,400 species, are the second-largest mammalian group on earth. They are also ideal biodiversity and environmental health indicators, as they have a wide range of ecological traits and tolerances to environmental variables, playing key roles in ecosystems. Since many bat species use sound to detect, localize, and classify objects, they can be monitored remotely and non-invasively by acoustic sensors. Acoustic monitoring is therefore a useful conservation tool to monitor anthropogenic effects on biodiversity. However, the paucity of local call reference libraries presents a major challenge to monitoring bats in tropical, megadiverse regions.

Kenya is home to more than 100 bat species, but despite the high diversity, they have not been systematically surveyed. In addition, more than 20% of the species are endangered and severely threatened due to anthropogenic drivers (e.g., habitat loss, climate change). The PI and his colleagues surveyed select Kenyan preserves and remote unsampled areas to collect biological samples and record vocalizations to speciate the bats.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team used a diversity of techniques in field collections, using mist nets, hand nets, and harp traps in different situations. Both mist nets and harp traps are useful in identifying areas used by bats in foraging or commuting. The researchers also used hand nets in caves, mines, tunnels, and dwellings to capture bats at roosts. The latter method was particularly informative, as it shed light on the bats' social groupings, as well as their roosting preferences.

They routinely recorded echolocation calls from insectivorous bats. Calls were collected by releasing newly captured bats into a portable flight chamber and recording their ultrasonic calls as they flew around the chamber, looking for an exit. Echolocation calls were also recorded as bats were released into the wild and flew around. Other species families (e.g., Rhinolophidae) were recorded using hand-held bats because the "resting frequency" of these stationary individuals varies very little within a sequence, making hand-held calls best suited for frequency comparisons between individuals or populations.

Over the course of the project, they recorded more than 2,400 bats of 62 species. All ten echolocating bat families of Kenya are represented in the records, which will form the foundation of a national call library. The researchers also collected thousands of samples for disease surveillance, including blood, oral swabs, rectal swabs (or feces), urine, and external parasites. They also documented the myriad mites, ticks, fleas, bat flies, and bat bugs on the bats—in all, nearly 3,000 sets of parasites were collected and distributed to specialists. The team extracted prey DNA from fecal samples from 91 different species, and despite the lack of funding for immediate analysis, these samples currently constitute a sampled study of trophic habits.

The team also collected duplicate tissue samples, typically muscle but also wing biopsies, either flash frozen in liquid nitrogen or preserved in ethanol to aid genetic studies. Skulls were later extracted from the carcasses and cleaned to allow osteology and dentition analyses; it should be noted that this preparation preserved for study the highly variable soft-part anatomy of bats' nose-leaves, ears, lips, and chins, which vary due to their use in echolocation and intraspecific communication.

The PEER team presented their findings at several conferences, including the 2022 American Society of Mammalogists and the 2023 African Small Mammal Symposium. Many early-career students and assistants gained invaluable training and experience working with bats during the project cycle, some of them for the first time in their lives.

The team received nearly $250,000 in additional grants from two projects of the National Geography Society for continuing this work. A new species of Horseshoe Bat, Webala's Horseshoe Bat (*Rhinolophus webalai*) from Kenya, has been named after the PI in recognition of his important contributions as a field biologist, prolific author, conservation leader, and mentor to the next generation of African bat biologists. Going forward, the PEER team is working with Kate Jones at the University College London to develop algorithms that will form the basis of an automated acoustic call library for Kenya's diverse bat species.

PUBLICATION

J. Kamau, K. Ergunay, P.W. Webala, S.A. Justi, B.P. Bourke, M.W. Kamau, J. Hassell, M.N. Chege, D.K. Mwaura, C. Simiyu, S. Kibiwot, S. Onyuok, L. Caicedo-Quiroga, T. Li, D.M. Zimmerman, and Y.-M. Linton. 2022. A Novel Coronavirus and a Broad Range of Viruses in Kenyan Cave Bats. Viruses 14(12): 2820. https://doi.org/10.3390/v14122820

KENYA - PROJECT 8-66: DEPLOYING *STRIGA* SMART SORGHUM: THE LAST MILE

PI: Steven Runo, Kenyatta University
U.S. Partner: Emily Bellis, Arkansas State University (Funded by the National Science Foundation)
Dates: January 2020 – March 2022

PROJECT OVERVIEW

Crop losses caused by parasitic plants of the genus *Striga* pose a great danger to the livelihoods of millions of smallholder farmers in Africa. The parasite attaches to host crops and siphons nutrients, leading to severe growth retardation and death of infected plants. One efficient and cost-effective way to control infestations would be to develop crops that are resistant to *Striga.* Extensive searches have led to the identification of cultivars and wild relatives of crops that are resistant to *Striga* parasitism, and subsequently resistant varieties have been introduced in some breeding programs in sub-Saharan Africa. However, the resistance often is weak and tends to break down.

This PEER project sought to develop a platform to deploy sorghum varieties with durable resistance to *Striga*. Dr. Steven Runo and his team aimed to improve the sustainability of food crop production systems and contribute to the alleviation of hunger and poverty of smallholder farmers by reducing the risk of crop failure, increasing profit margins, protecting yield, and extending the life of varieties that farmers have adopted. The PEER team also linked farmers to the extended sorghum value chain. Because sorghum is considered a "women's" crop in most Kenyan communities, this economic advancement will directly impact women.

The PI and his team worked with local farmers and extension officers to select, from a set of *Striga* resistant varieties already tested under laboratory and field conditions, sorghum varieties with preferable traits. The researchers also leveraged *Striga* genetic diversity data generated by U.S. partner Dr. Emily Bellis to determine how *Striga* adapts to various environments and determines host compatibility, including seeking eco-geographic regions with the most aggressive *Striga* and compatibility or incompatibility between *Striga* ecotypes and selected sorghum varieties.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team worked with farmers to grow sorghum varieties in their farms before making their preferred selection. The researchers carried out field evaluations of *Striga*-resistant sorghum in four field sites for one season (April–August 2021) and two sites for two seasons (September–December 2021), collecting data on farmer selection and *Striga* resistance. The farmers preferred grains that are bird resistant (high in tannin), *Striga* resistant, early maturing, and that have large heads, a dual purpose for feed. Some *Striga*-resistant sorghum identified in the team's study had traits desirable to farmers. Other sorghum varieties were more desirable for industrial uses, including one for brewing.

To develop varieties of sorghum that have more desirable traits in addition to *Striga* resistance, the PEER team developed a breeding platform for sorghum to introgress more traits into *Striga* resistance. Research assistant Cecilia Shinda made several crosses, including *Striga*-resistant sorghum with brewing quality, *Striga*-resistant and bird resistant, and crosses of sorghum with more than one mechanism of resistance. To identify early maturing sorghum with *Striga* resistance, PhD student

Sylvia Mutinda screened the sorghum accession panel (SAP) and identified 12 new *Striga*-resistant early maturity sorghum varieties. The PEER team therefore created a solid foundation for carrying out the screening of these varieties under field conditions.

The researchers used genomic sequence data from the U.S. partner Dr. Bellis to determine the distribution of *Striga* pathotypes (variants) in various regions in western Kenya. They identified genetic variants of *Striga* that may cause differences in virulence (aggressiveness of infection). The data have been used to develop virulence maps. The team also analyzed samples from *Striga* growing on various *Striga*-resistant sorghum lines in different locations and carried out a transcriptome analysis of sorghum varieties having distinct mechanisms of *Striga* resistance.

Genomic analysis of *Striga* and sorghum data showed specific adaptation of the parasite to some hosts. Further work revealed the evolution of the parasite to overcome host resistance. This will inform specific guidelines for the deployment of the resistant varieties. Genomic data and transcriptome analysis revealed distinct mechanisms of resistance in sorghum. This work led to the identification of more *Striga*-resistant sorghum varieties and inspired further work to impart *Striga* resistance in sorghum using genome editing. In the short term, varieties will be registered and deployed to improve livelihoods in Kenya.

The PEER team received three additional grants to continue this work, including from the King Abdullah University of Science and Technology and the Mawazo Foundation. The team and U.S. partner also delivered a virtual workshop on genomics and R tools in spatial data analysis. More than 100 people from Africa, Asia, the United States, and Europe participated.

PUBLICATIONS

Gilles Irafasha, Sylvia Mutinda, Fredrick Mobegi, Brett Hale, George Omwenga, Asela J. Wijeratne, Susann Wicke, Emily S. Bellis, and Steven Runo. 2023. Transcriptome atlas of *Striga* germination: Implications for managing an intractable parasitic plant. Plants People Planet 2023;1–15. https://doi.org/10.1002/ppp3.10395

Sylvia Mutinda, Fredrick M. Mobegi, Brett Hale, Olivier Dayou, Elijah Ateka, Asela Wijeratne, Susann Wicke, Emily S. Bellis, and Steven Runo. 2023. Resolving intergenotypic *Striga* resistance in sorghum. Journal of Experimental Botany 74(17): 5294–5306. https://doi.org/10.1093/jxb/erad210

Gilles Irafasha, Sylvia Mutinda, Fredrick Mobegi, Brett Hale, George Omwenga, Asela J. Wijeratne, Susann Wicke, Emily S. Bellis, and Steven Runo. 2022. A transcriptome atlas of *Striga hermonthica* germination. BioRxiv preprint. https://doi.org/10.1101/2022.12.14.520245

Joel Masanga, Richard Oduor, Amos Alakonya, Mathew Ngugi, Patroba Ojola, Emily S. Bellis, and Steven Runo. 2022. Comparative phylogeographic analysis of *Cuscuta campestris* and *Cuscuta reflexa* in Kenya: Implications for management of highly invasive vines. Plants People Planet 4(2): 182–193. https://doi.org/10.1002/ppp3.10236

Emily S. Bellis, Clara S. von Münchow, Alan Kronberger, Calvins O. Odero, Elizabeth A. Kelly, Tian Xia, Xiuzhen Huang, Susann Wicke, Steven M. Runo, Claude W. dePamphilis, and Jesse R. Lasky. 2022. Genomic signatures of host-specific selection in a parasitic plant. BioRxiv preprint. https://doi.org/10.1101/2022.02.01.478712

Tesfamichael S. Mallu, Gilles Irafasha, Sylvia Mutinda, Erick Owuor, Stephen M. Githiri, Damaris A. Odeny, and Steven Runo. 2022. Mechanisms of pre- attachment *Striga* resistance in sorghum through genome-wide association studies. Molecular Genetics and Genomics 297:751–762. https://doi.org/10.1007/s00438-022-01882-6

Leena Tripathi, Kanwarpal S. Dhugga, Valentine O. Ntui, Steven Runo, Easter D. Syombua, Samwel Muiruri, Zhengyu Wen, and Jaindra N. Tripathi. 2022. Genome editing for sustainable agriculture in Africa. Frontiers in Genome Editing 4: 876697. https://doi.org/10.3389/fgeed.2022.876697

Joel Masanga, Beatrice Njoki Mwangi, Willy Kibet, Philip Sagero, Mark Wamalwa, Richard Oduor, Mathew Ngugi, Amos Alakonya, Patroba Ojola, Emily S. Bellis, and Steven Runo. 2021. Physiological and ecological warnings that dodders pose an exigent threat to farmlands in Eastern Africa. Plant Physiology 185: 1457-1467. https://doi.org/10.1093/plphys/kiab034

KENYA - PROJECT 8-056: APPLICATION OF PARTITIONED WOODY AND HERBACEOUS FORAGE ESTIMATES IN INDEX-BASED LIVESTOCK INSURANCE, A BETTER ALTERNATIVE TO NDVI AS A PROXY FOR FORAGE INDEX

PI: Milkah Kahiu, International Livestock Research Institute, in Partnership with Jomo Kenyatta University of Agriculture and Technology

U.S. Partner: Niall Hanan, New Mexico State University (Funded by the National Aeronautics and Space Administration)

Dates: January 2020 – July 2023

PROJECT OVERVIEW

Pastoralists inhabiting African rangelands primarily depend on livestock for their livelihoods but remain extremely vulnerable to droughts, the single largest cause of livestock mortality in the region. To mitigate the devastating impacts of drought, the International Livestock Research Institute initiated Index-Based Livestock Insurance (IBLI) to cushion pastoralists. In 2015, the Kenyan government adopted IBLI through the Kenya Livestock Insurance Programme (KLIP), as part of a larger national social protection program. As of 2019, it provided coverage to nearly 20,000 households, with expansion plans to include not only Kenyan households but also those in Ethiopia, Niger, Uganda, and Somalia.

Current IBLI contracts are based on an independent index derived from the Normalized Difference Vegetation Index (NDVI) as a proxy for forage scarcity, thus making it immune to manipulations by insurance clients or companies. NDVI is an indicator of vegetation vigor or greenness for all vegetation in a landscape. However, livestock in pastoral systems largely feed on herbaceous foliage, limiting the precision of NDVI for estimating forage availability, especially in areas with significant tree and tall shrub cover. This also poses a challenge for planned expansion into agrosilvopastoral systems.

This PEER project explored alternative data sources for IBLI, including the use of new satellite products for estimating forage index, contract design, and feasibility analysis in Kenya. Dr. Kahiu and her colleagues focused on expanding the analysis to include both leaf area index (LAI) and NDVI data from the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) to ensure continuity in data flows.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team derived an updated estimate for woody cover in the Horn of Africa, an important component of their leaf area index (LAI) partitioning approach, using Sentinel radar and optical data for 2018 through 2021. They used several different models and approaches developed by their U.S. partner and others to ensure that changes in woody cover over time were captured in the estimates.

As the MODIS satellite approaches decommissioning, the PEER team actively explored alternative data sources to ensure the continuity of the work, including the Visible Infrared Imaging Radiometer Suite (VIIRS). They compared estimates derived from the two satellites, which showed a 93% correlation between the aggregate LAI values obtained from both MODIS and VIIRS. They plan to continue with this analysis in other regions in Africa and potentially globally to understand the differences and potential time lags between the two products, especially during the early stages of vegetation growth.

Finally, the researchers studied the suitability of partitioned LAI estimates in IBLI forage models. They used historical livestock mortality data from northern Kenya to test two competing forage type models using a random forest regression approach. The team showed partitioned forage models, including woody and herbaceous forage.

The PEER group hosted a workshop to share their approach and results, published several academic papers, and presented their work at the 2022 annual meeting of the American Geophysical Union. They also hosted a training with the Regional Centre for Mapping of Resources for Development focused on forage estimates derived from partitioned LAI, which was aimed at engaging a diverse range of stakeholders from pastoral regions in Kenya. Through the U.S. collaborator, the partitioned LAI products were also shared through a web portal for forage monitoring.

PUBLICATIONS

Njoki Kahiu, Julius Anchang, Lara Prihodko, Qiuyan Yu, and Niall Hanan. 2024. Satellite-based woody canopy cover for Africa: uncovering bias and recovering best estimates across years. Science of Remote Sensing 9: 100124. https://doi.org/10.1016/j.srs.2024.100124

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Yihenew Zewdie, Rupsha R. Banerjee, Njoki Kahiu, and Wako Gobu. 2020. Pre-feasibility study for an index-based livestock insurance product in Meyumuluke woreda, East Hararghe, Ethiopia. ILRI Research Report. https://hdl.handle.net/10568/109698

S.S. Kumar, L. Prihodko, B.M. Lind, J. Anchang, W. Ji, C.W. Ross, M.N. Kahiu, N.M. Velpuri, and N.P. Hanan. 2020. Remotely sensed thermal decay rate: an index for vegetation monitoring. Scientific Reports 10(1): 9812. https://doi.org/10.1038/s41598-020-66193-5

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KENYA - PROJECT 5-093: REMOTE SENSING AND GIS MAPPING FOR LAND USE CHANGES IN LAIKIPIA ECOSYSTEM, KENYA: A TOOL TO EXPLORE PATTERNS OF BIODIVERSITY AND EMERGENCE OF VECTOR-BORNE ZOONOSES AND ENHANCE ENVIRONMENTAL MANAGEMENT AND COMMUNITY HEALTH

PI: Nancy Moinde, Institute of Primate Research-National Museums of Kenya
U.S. Partner: Peter Leimbruger, Smithsonian Institution
Dates: December 2016 – October 2021

PROJECT OVERVIEW

Laikipia County in central Kenya supports one of the highest levels of mammalian diversity in East Africa. The semi-arid environment is changing rapidly due to land use changes, and climatic changes are projected to alter ecosystem resilience. These anthropogenic changes can alter the dynamics of zoonotic infectious diseases in wooded and bushland fringes of semi-arid ecosystems. Vector-borne diseases carried by vectors such as mosquitoes, ticks, and sand flies are known for their rapid response to environmental modifications and climate change.

In this PEER project, the team focused on the interrelationships between climate change, land use patterns and their impacts on large mammal distribution, and disease vector diversity. They studied how these, in turn, influence human adaptation and ecosystem resilience to ecological change. Using the Advanced Very High-Resolution Radiometer (AVHRR)-derived Normalized Difference Vegetation Index (NDVI), the researchers examined the relationship between inter-annual NDVI parameters and species richness of large mammals and ticks and sand flies as disease vectors. They also studied primary productivity of current land use systems within current climate patterns and its relationship to mammals and vegetation cover and variation in host feeding preferences of zoophilic mosquitoes, sand flies, and ticks from different land use systems and climatic zones of Laikipia. Dr. Moinde and her team used remotely-sensed data to represent environmental factors influencing species richness in different ecosystems, as well as disease vector sampling and molecular analysis of vector feeding preferences.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted and analyzed a community questionnaire on perceptions of climate change in Laikipia County and its effect on their livelihoods, after which they correlated the survey findings with climate data analysis. The rainfall dataset indicated a shift towards a late start and early stop of seasonal rainfall, coupled with erratic distribution of the rains within the rain seasons and increased occurrence of heavy episodic rainfall events. Laikipia land users (i.e., farmers, agro-pastoralists, pastoralists, and commercial ranchers), expressed that the erratic nature of rainfall patterns in Laikipia have reduced livelihood production within the pastoralist, commercial rancher, agro-farmer, and farmer communities. The questionnaire dataset indicated the prevalence of various strategies like diversifying to two or more livelihood practices, which is becoming a mode of survival to mitigate vulnerabilities and increase resilience.

The researchers also held 10 community and stakeholder workshops, in which participants clearly articulated the link between extreme onset of episodic rainfall events and the relatively higher incidences of tick loads, which was also linked to corresponding increase of malaise symptoms similar to malaria and typhoid. The team collected blood samples from 570 individual mammals during the two-year data collection period, and their zoonosis data analysis indicated that the pathogens *Rickettsia felis* and *Anaplasma p.*, found in small wild mammals, have symptoms that overlap widely with those of malaria and typhoid. Stakeholders also indicated that people within Laikipia County have access to clinics but are primarily only tested for the latter diseases. The key argument that came out of these workshops was that the public health authorities at the county level need to expand their clinical laboratory protocol to include other prevalent diseases identified in this study. These discussions also highlighted local mitigation strategies, such as applying marigold plants and hot chili peppers during the higher occurrences of tick load where goats are kept within certain sections of the rural Maasai households.

Research findings on small mammals also suggested that certain land use practices appear to impact mammal diversity and prevalence of zoonotic infection. The various datasets collected by the PEER team were integrated into an ecological model using binomial GLMM analysis to examine the interrelationship between climate and land use effects on small mammals and zoonotic disease. They found climate and land use can affect the prevalence of zoonotic diseases by conducting a conducive environment for pathogens, their vectors, and their reservoir's host. Land use can in addition increase or decrease the interface for pathogen transmissions between different species. The team's overall ecological model findings suggest that aridification and global warming due to climate change will increase zoonosis incidences as well as reduce species diversity and specifically evenness which can also increase incidences of zoonosis.

PUBLICATION

B.M.H. Wells, R.D. Crego, P. Chiyo, M. Otiende, I. Lekolool, G. Ouma, W. Gitau, S. Kivai, M. Jeneby, J. Stabach, P. Leimgruber, and N. Moinde. 2018. Management Regime Mediates the Precipitation-Vegetation Relationship in Rangelands: Implications for "Climate-Smart" Ecological Restoration Planning. 11th SER Europe 2018 Conference in Reykjavik, Iceland: Restoration in the Era of Climate Change, September 9-13, 2018.

KENYA - PROJECT 4-494: ENHANCING CONSERVATION OF AFRICAN BUFFALO AND RANGELAND HABITAT THROUGH MOLECULAR INVESTIGATIONS OF FOOT-AND-MOUTH DISEASE AT THE WILDLIFE-LIVESTOCK INTERFACE

PI: Francis Gakuya, Kenya Wildlife Service
U.S. Partner: Andres Perez, University of Minnesota (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: October 2015 -May 2018

PROJECT OVERVIEW

Disease transmission at the wildlife-livestock interface is among the foremost challenges in wildlife conservation in landscapes shared by livestock and wildlife. Foot-and-mouth disease (FMD) is one of the most important animal diseases globally, and the virus has major impacts on a country's ability to engage with the global livestock industry. One of the greatest challenges for FMD control in Africa is transmission of the virus between cattle and the primary wildlife reservoir, African buffalo (*Syncerus caffer*).

Nearly 70% of buffalo in east Africa are infected with FMD. Measures taken to separate cattle from wildlife to prevent transmission, such as the use of fences, have negative impacts on wildlife populations via habitat fragmentation and restriction of movement. This project utilized molecular genetic techniques to address critical knowledge gaps about FMD transmission at the wildlife-livestock interface in Kenya, including quantifying transmission dynamics across multiple land-use scenarios and genetic characterization of circulating strains in each host to inform vaccine development. Specifically, the project objectives were to (1) characterize the frequency and directionality of transmission between buffalo and cattle, (2) determine the geographic sub-structuring of FMD virus across three localities of central Kenya, and (3) assess the effect of management strategies separating buffalo and cattle on FMD transmission dynamics.

FINAL SUMMARY OF PROJECT ACTIVITIES

African buffalo are reservoirs for foot-and-mouth disease virus (FMDV), one of the most important pathogens affecting livestock globally. The role of buffalo in the epidemiology of FMDV is poorly understood in eastern Africa, a region where cattle and wildlife populations regularly intermix. In this PEER project, Dr. Gakuya used molecular genetic methods to evaluate the frequency of buffalo-cattle FMDV transmission in central Kenya and assess the phylogenetic relationship between FMDV outbreaks in cattle populations and viruses found in buffalo. They collected samples from 92 buffalo and 98 cattle from in and around Ol Pejeta Conservancy (OPC) in Laikipia County. Blood samples were analyzed for detection of antibodies to FMDV non-structural proteins, and oropharyngeal (probang) samples were used for virus isolation and genetic sequencing of the VP1 region (Sanger sequencing / Next-generation sequencing-NGS). In addition, 21 samples from cattle outbreaks were analyzed.

They recovered 75 sequences from buffalo, all of which were FMDV serotypes SAT1 or SAT2. NGS revealed dual infection by both serotypes in six buffalo, which is among the first demonstrations using sequencing of dual infection by multiple serotypes of a naturally infected host. Despite extensive contact with infected buffalo populations, no SAT1 or SAT2 viruses were found in cattle in OPC, suggesting that cross-species transmission is rare.

In addition, viruses found in buffalo and in some cattle outbreaks were genetically distinct from current vaccine strains, suggesting that the vaccine utilized in Kenya may need to be reformulated to better protect cattle from circulating FMDV strains. These results will potentially change the current policy discussions in four main areas; enforcement of quarantine and movement restrictions in view of pastoralists lifestyle, veterinary vaccine development and assessing efficacy, integration of wildlife-livestock as a means to increase per acreage earning from the rangelands, and disease monitoring and management at the wildlife livestock interface.

It was also revealed that the FMD viruses found in buffalo and cattle do appear to be intermixed, which provides the clearest evidence of linkages between FMDV in cattle and buffalo in Eastern Africa to-date. Furthermore, results also suggest that there is a significant long-distance movement of FMDV across central Kenya, most likely related to livestock movements. This is shown by the close relation between viruses found in OPC cattle and viruses found in Isiolo and Nakuru, both of which are regions from which OPC purchases cattle.

Based on this results and the fact that fencing does appear to prevent disease transmission to buffalo, the project partners intend to engage in a broader policy discussion with the Director of Veterinary Services - Kenya, Foot-and-Mouth Disease Laboratory, Kenya Veterinary Vaccine Production Institute, and the Kenya Wildlife Service. This is already underway through sharing the results with the Foot and- Mouth Disease Laboratory and incorporation into the Directors brief. This will be followed up through a workshop discussion to generate policy recommendations. This is focused on four key areas of enforcement of quarantine and movement restrictions in view of pastoralists lifestyle, veterinary vaccine development and assessing efficacy, integration of wildlife-livestock as a means to increase per acreage earning from the rangelands, and disease monitoring and management at the wildlife-livestock interface.

The project partners have planned a follow-up study to be conducted in Masai Mara National Reserve and surrounding community conservancies (an area that has variable livestock-wildlife interaction and concomitant disease outbreaks). This sampling will partly be based on research grants submitted and through doctoral dissertation work by a PhD student in this grant (Dr. George O Paul). This will focus on Foot and- Mouth disease, Lumpy Skin Disease, Peste De Petits Ruminants (PPR) and Bovine tuberculosis.

The work will also cover other wild ungulates, including small herbivores such as antelopes, with a view to expanding the understanding of the epidemiological role of other species besides buffalo, and animal movement in the region. Future work will address other knowledge gaps about wildlife-livestock disease transmission in Kenya, including the roles of other species (antelopes, goats, and sheep) and the ecology of animal movement and cross species interactions.

KENYA - PROJECT 4-457: USING AN INTEGRATED MODELING FRAMEWORK TO EVALUATE THE IMPACT OF HUMAN-INDUCED LAND USE/LAND COVER CHANGE ON CARBON DYNAMICS IN THE UPPER EWASO NGIRO RIVER BASIN, KENYA

PI: Stephen Kiama, Kenya Forestry Research Institute

U.S. Partner: Scott Goetz, Woods Hole Research Center (Funded by the National Aeronautics and Space Agency)

Dates: October 2015 – March 2019

PROJECT OVERVIEW

The goal of the project was to strengthen monitoring and prediction of the dynamics of ecosystem services, primarily carbon and water balance in wooded and open grasslands. This research team's contribution lies in advancing a scientifically and operationally robust methodological framework that will be able to quantitatively evaluate terrestrial carbon and water fluxes. Specifically, they integrated complementary approaches, including ground-based observations, remotely sensed measurements, and modeling, combining their strengths with an aim of circumventing shortcomings of stand-alone approaches, as well as enhancing the predictive power of the integrated modeling framework. The project involved testing the use of modern tools such as hyperspectral images or images captured by drones to improve spatial resolution of characterizing patterns of vegetation composition and functional traits. The researchers studied the use of such tools to support plot-level inventory needed to drive a Landsat-based geometrical-optical model for characterizing the vegetation structure.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team collected massive amounts of data on biophysical variables in both Mpala and Ilmotiok study sites, which they continue to organize and analyze. As the data is progressively being analyzed, there is a better understanding of the land surface, including the biophysical properties and processes. Moreover, the existing operational Terrestrial Carbon and Water Observatory is yielding more data to generate more insights. Using real data, they are progressively generating comparable statistics along the gradient of anthropogenic pressures, i.e., showing the disparity between Ilmotiok and Mpala sites on factual basis. The ongoing analysis of the collected biophysical data and efforts to fit empirical models and calibrating process-based models, is itself rewarding in terms of enriching critical modeling skills which has been lacking among Kenyan scientists. Since they are doing this as a group (including the students who have been participating in the project, they are thus building long-term capacity. The fitted/calibrated models, on preliminary basis, are simulating those targeted biophysical phenomena fairly well, and already demonstrated their potential as operational tools.

During the course of this project, the PI and his team developed a good working relationship with key offices of the County Government of Laikipia. The visit by a team from the County Government of Laikipia to the Terrestrial Carbon and Water Observatory, provided a good basis to advise the County Government on impact-based targeting of their investments. During the 2018/2019 financial year, the County Government allocated funds for re-seeding some of the degraded rangelands. This was the first time the County Government allocated money meant to contribute towards rangelands rehabilitation. Although the funds were just a start, it demonstrated the value of the evidence-based advice to the County Government.

The team also developed collaborations with other organizations implementing programs in the same locality such as the IMARA Program being implemented by the World Vision (Kenya) and Stockholm Environment Institute (SEI Africa). The program will use data generated by the PEER Project to generate baseline research to then evaluate improvements after interventions.

The research is now entering a new phase which is aimed at rehabilitating the degraded pastures and securing the livelihood of the pastoralist. The primary focus of the research will be to test potential (social and physical) technologies that would be practically feasible to be adopted at a large scale, yet being simple in terms of cost and implementation. The second focus of the research will be maintaining the existing Terrestrial Carbon and Water Observatory, together with the network of sensors, for purpose of using the data that continue to be generated and used to monitor the success of restoration interventions. The third focus of the research would be to discuss with the County Government, and test or pilot new policy and/or legislative tools that would serve as opportunity for the government to stimulate the pastoralists to adopt the restoration strategies, as well as mobilizing the support of the commercial ranchers.

KENYA - PROJECT 4-428: ENHANCING ELEPHANT CONSERVATION AND PROTECTION IN EAST AFRICA WITH MOLECULAR GENETIC TOOLS

PI: Moses Otiende, Kenya Wildlife Service

U.S. Partner: Samuel Wasser And David Schindel, Smithsonian Institution

Dates: October 2015 – December 2020

PROJECT OVERVIEW

DNA tools are becoming increasingly useful for investigating and prosecuting wildlife crimes, including matching carcasses to smuggled biological products and determining the location of poaching hotspots. Elephant-specific microsatellite DNA markers have been accurately used to map elephant populations over the entire African continent using DNA extracted from their feces. The map is currently being used to trace illegal ivory shipments back to their origin using DNA extracted from seized ivory.

Elephant poaching within East Africa has progressively increased since 2006, with the greatest concentration of large ivory seizures coming from East Africa and especially southern Tanzania. Identification of the origins of these seizures is vital, not only for timely prosecutions but also to provide intelligence on major shifts in poaching activities across East Africa. This project aimed to build a collaborative forensic network between Kenya, Tanzania, and Uganda by enhancing the forensic capabilities of newly formed wildlife DNA labs in both Kenya and Tanzania, where the largest elephant populations reside in East Africa and considerable cross-border movements of elephants occur.

A major part of this effort also involved enhancing coverage of the existing continent-wide elephant DNA database by sampling and genotyping elephant dung in all important elephant areas within the region where samples are still lacking. Enhancing this comprehensive elephant DNA database for East Africa will greatly increase the capacities of authorities to monitor changes in areas of concentrated poaching as well as bring cases to successful prosecution on a timely basis.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI, co-PI, and their teams collected and genotyped dung and tissue samples from key elephant populations in savannahs across Kenya and Tanzania. Tissue samples were opportunistically obtained during veterinary clinical interventions, such as treatment for diseases and injuries. The researchers tested and optimized several mitochondrial markers developed in previous elephant studies. Through this work, they began constructing an elephant genetic database for mitochondrial DNA in selected elephant populations in Kenya and Tanzania. They also piloted non-invasive methods for enumerating forest elephants and molecular tools for forest elephant population surveys using DNA. Analyses and genotyping of the samples were done at the forensics and genetics laboratories at Kenya Wildlife Service and Sokoine University of Agriculture in Tanzania. In the long term, these labs will be among the reference labs for the East African and Central African region.

The PEER team organized a training for rangers and wildlife officers actively involved in wildlife crime management in Tanzania, the first such high-level forensic training involving field-based personnel. The training equipped rangers, often the first responders to wildlife crime scenes, with tamper-proof evidence bags and crime scene investigation kits, which will ensure integrity and traceability of evidence collected in the field as well as supporting good chain-of-custody procedures. The PEER researchers developed the curriculum and related manual for this training, which will be used as a guidebook for trainees and is now part of the key reference documents in the Kenyan National Elephant Action Plan.

During the project period, the Kenya Wildlife Service procured a new 3500XL genetic sequencer and trained staff to use this unit for forensic analysis of elephant and other wildlife genomic material. This new equipment will help to generate court-admissible forensic reports to prosecute wildlife offenders. They also installed relevant equipment required for extraction of DNA from ivory, allowing the forensic and genetics laboratory to undertake analyses that in the past were done only at the University of Washington.

Six scientists from the PEER team visited the U.S. Fish and Wildlife Service forensic laboratory in Oregon for training on morphological identification of ivory, crime scene management, and DNA laboratory operations. The researchers also visited the Uganda Wildlife Authority to present their work and conduct reconnaissance of key elephant areas in the country and to discuss plans for sampling of elephant fecal samples for genetic analysis. To enhance adoption and use of DNA evidence in wildlife crime litigation, team members held workshops with prosecutors and magistrates. During the PEER project period, team members received three additional grants for a total of $150,000 to continue their work.

PUBLICATION

Daniel O. Ouso, Moses Y. Otiende, Maamun M. Jeneby, Joseph W. Oundo, Joel L. Bargul, Scott E. Miller, Lillian Wambua, and Jandouwe Villinger. 2020. Three-gene PCR and high-resolution melting analysis for differentiating vertebrate species mitochondrial DNA for biodiversity research and complementing forensic surveillance. Scientific Reports 10: 4741. https://doi.org/10.1038/s41598-020-61600-3

KENYA - PROJECT 4-365: DNA BARCODING TO COMBAT WILDLIFE CRIME

PI: Henry Ndithia, National Museums of Kenya
U.S. Partner: David Schindel, Smithsonian Institution
Dates: October 2015 – December 2019

PROJECT OVERVIEW

Wildlife criminals, poachers, and traffickers of endangered species protected under CITES and national laws are developing new ways to avoid detection and prosecution. In the case of protected animals, traffickers are shipping them as butchered and processed meat, eggs or juvenile stages, dried powders, and other forms that have proven difficult to identify. In these forms, even taxonomic experts cannot provide species identifications based on morphology because diagnostic characteristics (commonly provided by bones and hides) are absent from confiscated material. As a result, border inspectors, police, and park rangers may not suspect that intercepted objects come from protected species. Even in cases where suspicions are aroused and the materials are confiscated, crime investigators can't identify them with confidence. The same may prove true even for the expert zoologists who receive the objects for identification. In those rare cases when an expert provides an identification using the few morphological features preserved, it is difficult to overcome the objections of defense attorneys who raise doubts in the minds of magistrates.

This project used DNA barcode sequence data to identify confiscated materials by their species of origin. DNA barcoding has become an accepted and commonly used method for species identification practiced by taxonomists, ecologists and other academic researchers.

The two main objectives of the project were to expand training and technical assistance to new participants in Tanzania, as well as strengthen Kenya's systemic response to poaching in two ways. First, DNA-based research on endangered species through the National Museums of Kenya will create new tools for prosecuting wildlife criminals. Second, collaboration with the Kenya Wildlife Service will put these tools to work in Kenyan courtrooms. The result should be a rapid near-term rise in the rate of convictions for poaching and trafficking, followed by long-term growth in the population sizes of endangered species and measures of ecosystem health.

FINAL SUMMARY OF PROJECT ACTIVITIES

Building on the predecessor project, the PEER project team identified gaps in wildlife species that are poached, illegally-traded or are trafficked, from the initial 200 species identified by the Barcode of Wildlife Project Kenya (BWPK). The team visited different parts of Kenya and collected tissue samples (either voucher or e-voucher depending on whether an animal species is allowed to be collected in the wild) from five individuals of each species where possible. A total of 225 samples were worked on (Mammals 49 (17), Birds 76 (26), Fish and Marine Samples 59 (17), Herpetofauna 40 (14) (individuals and species in brackets)). This information was entered in a database called the Field Information Management System (FIMS). Voucher specimens were later catalogued and stored in the collection for reference. In the laboratory, the tissues were entered into the Laboratory Information Management System (LIMS) database. Thereafter, tissues samples were analyzed in the lab by going through the process of DNA extraction, DNA amplification, DNA sequencing and purification and eventual publication in GenBank. In total, 161 barcodes were uploaded in GenBank. 290 tissues that had been collected were sub-sampled into barcoded tubes for archival storage. DNA was then extracted and sub-sampled into barcoded tubes as well for archival storage. 260 genomic DNA samples were amplified targeting the Cytochrome c oxidase subunit 1 gene. 201 amplicons have been purified and submitted for sequencing. The data was transferred from the Amazon servers to the National Museums of Kenya (NMK) servers. The team now accesses the database locally and is validating the field metadata on the Biscicol website (http://www.biscicol.org/).

Additionally, the capacity of the molecular genetics lab was improved through renovation that provided the lab with a facelift from the deteriorating state it was in, replacing obsolete equipment with state of the art equipment. This center will not only serve Kenya but the region. In addition, the project built the capacity in Tanzania by initiating the DNA barcode process there through the training of 12 new participants on DNA barcoding. The project also trained one PhD student in Kenya, who is studying interspecific hybridization in lovebirds.

Dr. Ndithia's future plans include raising funds that can finalize the process of initiating DNA barcode in Tanzania and establish a DNA library in Tanzania. The process in Tanzania faced numerous challenges that made it difficult to have the trained participant to sit for the proficiency test that qualifies one to be a DNA analyst. Additionally, besides the need to develop a DNA library in Tanzania, there is need to establish a museums collection for voucher specimen in Tanzania, and to conduct training on standard operating procedures (SOPs) a step that is important in the DNA library construction process.

KENYA - PROJECT 4-342: USE OF DNA TECHNOLOGY IN COMBATING ILLEGAL TRADE AND PROMOTING CONSERVATION AND SUSTAINABLE USE OF PLANTS IN KENYA AND TANZANIA

PI: Beatrice Khayota, National Museums of Kenya
U.S. Partner: David Schindel, Smithsonian Institution
Dates: October 2015 – April 2020

PROJECT OVERVIEW

This project created and utilized two knowledge sources to inform policies, programs, and activities. The first was a new knowledge base on the legal and illegal markets for plants in Kenya and Tanzania. By compiling official records, new market surveys, and genetic analyses of plants sold domestically and trafficked across borders, the project sought to provide a clearer picture of plant use and overuse. This knowledge base aimed to help enforcement agencies improve efforts to stop poaching and illegal trafficking, identify areas of illegal harvesting, pinpoint potential markets for legally cultivated plants, and create sustainable community-based strategies to restore and protect ecosystem services.

The second knowledge source was a public reference library of DNA barcodes—short DNA sequences that help enforcement officials identify plants difficult to classify by traditional methods. This component built on the Barcode of Wildlife Project, led by the Smithsonian and funded by Google, with Kenya as a partner country.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project demonstrated the effective use of DNA technology in combating wildlife crime, enhancing regional capacity, both in Kenya and Tanzania, in its application. It improved understanding of DNA barcoding processes crucial for enforcement, including formulation, data generation, and interpretation, and is now being used to prosecute traffickers in courts. DNA barcoding technology also facilitated improved labeling, traceability, and legal trade of authentic wildlife products, alongside enhanced MEAS reporting. Data generated from the project will be uploaded to GenBank for use in wildlife prosecution efforts.

The project also advanced understanding in formulating legislation and policies for effective wildlife trade enforcement. It developed a comprehensive training curriculum, serving as a crucial resource for ongoing capacity building initiatives in the region for stakeholders, including wildlife senior managers, legal officers, and prosecutors on the importance of DNA technology in wildlife crime prevention. A ten-day DNA barcoding training was conducted in Eastern and Southern Africa for ten middle-level officers from government institutions in Kenya, Uganda, and Madagascar. In Tanzania, efforts are underway to amend wildlife legislation to incorporate processes related to non-human DNA.

PUBLICATION

Hilonga, S., Otieno, J. N., Ghorbani, A., Pereus, D., Kocyan, A., & de Boer, H. 2019. Trade of wild-harvested medicinal plant species in local markets of Tanzania and its implications for conservation. South African Journal of Botany, 122, 214–224. https://doi.org/10.1016/j.sajb.2018.08.012

KENYA - PROJECT 4-192: END OF THE ROAD FOR ILLEGAL BUSHMEAT TRADE IN EAST AFRICA: ESTABLISHING TRANSBOUNDARY SURVEILLANCE BY HIGH RESOLUTION MELTING ANALYSIS OF VERTEBRATE MOLECULAR BARCODES

PI: Jandouwe Villinger (Original PI: Lilian Wambua), International Center for Insect Physiology and Ecology
U.S. Partner: Scott Miller, Smithsonian Institution
Dates: October 2015 – March 2022

PROJECT OVERVIEW

Illegal bushmeat trade is a global impediment to biodiversity conservation and public health. In Kenya and Tanzania, bushmeat trade has escalated to unsustainable levels, presenting a major threat to East African wildlife populations. Bushmeat trade and consumption expose humans and livestock to diseases such as Ebola and retroviruses, and bushmeat hunters risk contracting diseases from ticks and tsetse flies. Prosecution of bushmeat trade perpetrators in East Africa requires forensic evidence based on cytochrome oxidase I (COI) DNA-barcode sequencing, which is costly and time-consuming. There is a need for rapid, cost-effective forensic tools to screen for wildlife DNA in meat samples to support surveillance of bushmeat trade and improve law enforcement against perpetrators.

Effective prosecution against illegal bushmeat trade in Kenya and Tanzania is hampered by lack of cheap scientific methods and trained personnel to undertake high-throughput screening of suspect samples. This project developed cost-effective high resolution melting analysis (HRMA)-based bushmeat identification and built the capacity for its implementation by wildlife agencies in Kenya and Tanzania. The protocols were anticipated to enhance transboundary surveillance systems by accelerating identification of wildlife barcodes in samples, which can then be sequenced to provide forensic proof for prosecution. Adoption of this method by the wildlife agencies were expected to generate crucial data on the extent of illegal bushmeat trade in the region, thereby providing a basis for review and harmonization of national and cross-border policies, laws and penalties against illegal bushmeat trade.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ran for 6.5 years thanks to supplemental PEER funding, resulted in the development of a cost-effective tool based on PCR-HRM analysis for surveillance and preliminary identification of bushmeat in eastern Africa. This tool holds promise as a companion diagnostic assay if integrated into forensic pipelines, as an initial screening test for bushmeat to eliminate samples of domestic origin, and for the identification of wildlife, which can then be fully barcoded to generate prosecution evidence. This approach was already tested in identifying illegal bushmeat samples from covert surveillance exercises, and in Kenya, the PI and his team were able to demonstrate a 91% cost reduction by using PCR-HRM analysis in a test in which out of >90 suspect specimens, only one meat sample was identified as giraffe (Ouso et al., 2020).

As a result of the PEER project, the team at icipe are expanding the use of HRMA to identify livestock meat-species substitution in the meat-value chain and using HRMA to differentiate meat-species sources from a wide range of processed meat samples (Njaramba et al., 2021). These additional studies have further conservation and consumer protection applications. The project has validated this novel approach as a useful tool to reduce the cost and speed up identification of illegally traded wildlife products. The PEER-funded transfer of the technology to Tanzania, coupled with technical capacity building provided by the PI and his team, has created a platform for Kenya and Tanzania to engage in and intensify transboundary initiatives to curb illegal wildlife trafficking in the region. Dr. Villinger anticipates that continued use of PCR-HRM analysis in Kenya and Tanzania and its further adoption in Uganda, where counterparts also received training and technology transfer, will facilitate close cooperation among wildlife forensics laboratories in East Africa and will enhance regional forensics capabilities and sustainability of the outputs beyond the project lifecycle. This will potentially generate crucial data on the extent of illegal bushmeat trade in East Africa, leading to identification of hotspots to target anti-poaching and anti-trafficking measures. Additionally the techniques developed in the project are leading to better understanding of arthropod disease vector blood feeding habits and highlighting the possibility of vector-borne disease transmission between wildlife, livestock, and humans (Musa et al., 2020; Oundo et al. 2020; Makhulu et al., 2021).

The PCR-HRMA technology and protocols that have been developed through this research have been adopted by government partners in Kenya and Tanzania for surveillance of bushmeat and screening of suspect specimen and as of July 2022 will reportedly soon also be adopted in Uganda. The users have reported cost reduction and speed as advantages of this technology, although formal adoption of PCR-HRM analysis in the forensic pipeline will require further validation and accreditation. In Tanzania, HRMA has also been used to contrast reported bushmeat sales with species-identifications (Ibrahim et al. in prep). The Bushmeat Surveillance in East Africa workshop (May 29-31, 2019), which was funded through this PEER award, has resulted in the beginning of a new network of African scientists involved in wildlife forensics research, which the participants hope, beginning with forensic scientists in Kenya, Tanzania, Uganda, and Zambia, will improve intra-continental cooperation and communication in wildlife forensics.

In terms of capacity building among the project team, eight postgraduate students (Daniel Obado Ouso, Ali Musa, Joseph Oundo, Edward Makhulu, Philip King'a, and Jane Njaramba in Kenya, and Shadia Ibrahim Kilwanila and Rehema M. Makoy in Tanzania) were attached to the project for their MSc studies. They have been involved in field sampling as well as application of PCR and HRMA in their individual projects. Additionally, the PEER project offered placements and short-term training to 13 undergraduate students, of which four were hosted in icipe, Kenya, and nine at Sokoine University of Agriculture Tanzania.

Although the PEER project has been successfully completed, the PI reports that research is ongoing using the techniques for arthropod bloodmeal-host identification at icipe, supported by a new EU Horizons 2020 grant, which will run from September 2021 through August 2025. His institute will receive approximately 559,000 euros out of the entire 6 million euros supporting the consortium of researchers involved. In addition, research on the bushmeat trade is ongoing at the partner organizations involved in the project (Kenya Wildlife Service, Tanzania Wildlife Research Institute, and Uganda Wildlife Authority) based on national priorities.

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KENYA, ETHIOPIA, AND TANZANIA - PROJECT 3-233: GEOPOWER AFRICA

PI: Nicholas Mariita, Dedan Kimathi University of Technology, Kenya, With Co-PIs Jacques Varet, Dedan Kimathi University of Technology (Dekut); Tesfaye Kidane Birke, Addis Ababa University; and Gabriel Mbogoni, Geological Survey of Tanzania

U.S. Partner: Cynthia Ebinger, University of Rochester (Funded by the National Science Foundation)

Dates: September 2014 – November 2017

PROJECT OVERVIEW

Satellite and ground-based studies of the East African Rift (EAR) in Kenya reveal active magmatic and fluid movement beneath 40% of the volcanoes. Similar results are emerging from studies in Ethiopia and Tanzania. This project had two aims: mapping small geothermal areas and identifying new forms of geothermal exploitation along the EAR. These sites, using medium to low enthalpy resources (70-150°C), combined power and heat applications, including powering groundwater pumps. The project's results will also inform volcanic and earthquake hazard mitigation programs in Ethiopia, Kenya, and Tanzania.

The project required an interdisciplinary approach, including geology, hydrogeology, fluid geochemistry, shallow crustal geophysics, and power engineering. It surveyed geothermal fields along the EAR (Afar through Kenya to Rungwe Province, Tanzania) using existing and newly emerging data from past geothermal exploration and two active NSF projects—CRAFTI and SEGMENTS. The team sought to build a strong regional framework for scientific and technological exchange while empowering and educating local communities, especially in pastoralist regions. Their training and research exchange program engaged researchers from Africa, the United States, and Europe, aiming to determine the necessary conditions and training for deploying these applications in test sites in Ethiopia, Kenya, and Tanzania.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over the course of the project, the GeoPower Africa team investigated and mapped the geothermal sites as planned and identified new forms of applicable economic activities that could be introduced to utilize the geothermal resources along the Rift Valley. The project employed an interdisciplinary approach, including using data from geology, volcanology, hydrogeology, fluid geochemistry, and geophysics to carry out the research. A sizable number of sites were visited by the team in the three countries, employing a systematic socioeconomic approach through community interviews, as well as observing the environment and economic activities of the communities around the geothermal sites. Results from the GeoPower Africa efforts indicate that numerous geothermal sites visited can support small units combining power generation and heat applications. Direct heat applications include greenhousing, food drying, food preservation, thermal bathing, and green tourism. These activities are expected to eventually contribute to improving socioeconomic life for the communities around the sites.

The GeoPower Africa project also demonstrated that similar initiatives can be successfully replicated on a large scale along the East African Rift Valley system and that there are numerous suitable sites that have the required conditions for immediate development. The socioeconomic conditions of the areas visited and feedback on needs of the local communities surrounding these sites indicate a lack of adequate modern energy and clean water supplies, a situation that can, at least partially, be remedied by geothermal exploitation. The outreach programs carried out by the team also enabled the formation of linkages between the local communities around the geothermal sites, the GeoPower Africa team, and local institutions. The government and non-governmental agencies contacted were very supportive of the project and regarded the efforts as being supplementary to government energy programs. The concerned communities are now aware of the potential use of their geothermal resources and how they can collaborate with investors.

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KENYA - PROJECT 3-210: DEVELOPMENT AND IMPLEMENTATION OF A SOLAR PV OUTREACH TRAINING MODULE FOR CAPACITY BUILDING IN EAST AFRICA

PI: Izael Da Silva, Strathmore University
U.S. Partner: Benjamin L. Ruddell, Arizona State University (Funded by the National Science Foundation)
Dates: September 2014 – December 2016

PROJECT OVERVIEW

Although the Kenyan solar photovoltaic (PV) market is often seen as successful, poor quality service has hindered its growth. Studies have shown many poorly designed and installed solar PV systems. In December 2012, the Energy Regulatory Commission (ERC) published the "Energy Solar Photovoltaic System Regulation 2012." These regulations are crucial due to the market size ($6-8 million annually, growing at about 10%). There are about 800-1,000 solar PV technicians in Kenya, most without formal training or certification. The regulations aim to improve service delivery by requiring only licensed technicians to design and install solar PV systems, and to be licensed, technicians must complete a solar training course. A 2012 JICA-funded survey revealed that only 50% of 41 higher education institutions offered solar PV courses, and only 16% of 368 teaching staff had prior training in solar PV technology. Additionally, 52% of the institutes lacked adequate training materials, 60% lacked appropriate hands-on training equipment, and 20% had none. This PEER project aimed to develop and implement a solar PV training and outreach program, including training, testing, and certification services across the country. The goal was to train 100 trainers and 1,000 technicians to certification level T2 within 36 months, with mobile labs fitted with hands-on training equipment and materials.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Da Silva's Power Africa-funded project ended on December 31, 2016. Its goal was to develop and implement a solar photovoltaic (PV) outreach training module for capacity building in East Africa. With PEER funds, the Strathmore Energy Research Center (SERC) at Strathmore University (SU) aimed to support the energy sector by strengthening solar PV training in Kenya. This involved providing training equipment, materials, and capacity building for solar PV trainers to enable practical and high-quality instruction at technical training institutions (TTIs). The project successfully achieved its main objectives, including supporting the Government of Kenya's programs to increase access to renewable energy, particularly in rural and marginalized areas.

The project activities began with a launch at SU to raise public awareness. Dr. Da Silva and his team initiated collaboration with the German Development Cooperation (GIZ EnDev) and signed Memoranda of Understanding with various TTIs to ensure commitment. SU designed a Mobile Training Toolkit for hands-on training at the TTIs, which was locally made to ensure sustainability. The SU-developed toolkit, along with the Vocational Training and Education for Clean Energy (VOCTEC) toolkit from Arizona State University (ASU), proved to be effective and cost-efficient for training purposes. Additional training kits were provided to each TTI with support from GIZ EnDev.

Train-the-trainers sessions were conducted at the SU training laboratory, with 50 technicians from 25 institutions being trained, and 20 of them subsequently receiving their licenses. Follow-up workshops and field visits helped TTIs understand accreditation requirements. The feedback from these sessions was used to review and improve the training curriculum.

Special solar PV training courses were organized to build the capacity of female technicians, empowering them to educate others, develop entrepreneurship skills, and become ambassadors for the solar PV program. A total of 60 women were trained in three sessions led by female trainers. This led to the formation of Women in Sustainable Energy and Entrepreneurship (WISEE), which has since conducted additional training, completed consultancy assignments, and secured contracts for solar installations.

To avoid duplication and identify synergies, Dr. Da Silva and his team engaged relevant public and private sector stakeholders in the training activities. The PEER project attracted the attention of decision-makers, policy makers, and other key stakeholders, including the Energy Regulatory Commission, National Industrial Training Authority, Ministry of Energy, Ministry of Education, GIZ EnDev, and others. Activities promoting inclusion and engagement led to support from GIZ and the Ministry of Energy in Kenya.

In summary, Dr. Da Silva's PEER project contributed significantly to the Power Africa initiative by expanding off-grid solutions and facilitating Kenya’s Vision 2030. The project built the human and training infrastructure capacity of Strathmore University in solar PV, leading to the training and certification of at least 50 trainers and 1120 technicians at level T2. This created a qualified pool of solar PV professionals skilled in design, installation, commissioning, and maintenance. Additionally, the project enhanced the role of women in the solar industry, helping to improve gender balance. Overall, the project increased access to modern and renewable energy in rural and peri-urban areas of Kenya through quality solar home systems.

KENYA - PROJECT 3-154: MWANGAZA PROJECT ON SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS AND COMPUTING EDUCATION FOR STUDENTS IN KENYA WITH VISION LOSS

PI: Marguerite Miheso O'Connor, Kenyatta University

U.S. Partner: Bruce N. Walker, Georgia Institute Of Technology (Funded by the National Science Foundation)

Dates: September 2014 – September 2016

PROJECT OVERVIEW

Every day we are bombarded with numbers and values, often presented via charts and graphs. For people with vision loss, accessing this data can be difficult or impossible, making education and employment in STEM fields particularly challenging. Prof. Bruce Walker's Sonification Lab at Georgia Tech had been working for over ten years to make data more accessible to blind students and workers, focusing on auditory graphs and developing software tools for multimodal data displays in classrooms. Dr. Walker was conducting a field study at the Georgia Academy for the Blind, deploying and studying Sonification Lab software and methods in middle-school math classes.

The Sonification Lab partnered with the U.S./Kenyan non-profit inABLE to equip computer labs at schools for the blind in Kenya and train teachers and students in computer skills. With PEER grant support, Kenyatta University faculty joined as local research partners to conduct focus groups, stakeholder meetings, baseline surveys, fieldwork, and iterative evaluations. This partnership allowed for wide-scale research and a significant impact on education by deploying computers, training, and STEM teaching tools across an entire school system in Kenya. Additional partners include Safaricom, Microsoft, and Uwezo.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ended August 31, 2016, was a shared effort involving the Sonification Lab at the Georgia Institute of Technology (Georgia Tech) in Atlanta, Kenyatta University (KU), and inABLE, a non-profit organization based in Nairobi, Kenya. STEM education for blind and low-vision students worldwide, including in Kenya, has been held hostage to a combination of fear, doubt, and lack of knowledge, teacher training skills, and resources. These views over time have become institutionalized in education systems. This in turn has had significant impacts on the lives and career choices of blind and low-vision persons, as evidenced by their minimal participation in these courses, particularly at the university level. This PEER project aimed to make positive strides towards changing that situation. Dr. O'Connor and her project team report that their results are just the beginning. There remains so much more to do, once they move forward from the solid foundations of research and evidence-based design laid thus far.

The two-phase project completed by the research team included: (1) a nationwide survey of the interests, needs, skills, and opinions of blind students and their teachers regarding information and communications technology; and (2) initial development, deployment, and evaluation of some novel assistive technologies that offer potential new approaches to STEM education for students with vision loss. The visually impaired cohort of learners are spread in 11 schools of the more 9,000 schools in Kenya. However, very little data on this group of learners is available. The team's baseline survey for both teachers and students was the first of its kind. It now provides a database for future research and decision making by other stakeholders.

This project is timely, as Kenya is preparing to roll out digital education in all primary and secondary schools in the country. The information gathered on the status of learners and their affinity to technology was very critical and informed the Ministry of Education of the possibilities students with vision loss can have. It is in these schools where one also finds blind teachers. An extended research component carried out by the team regarding teachers in these schools provided important information on the readiness of teachers to use technology. In addition to the questionnaire, the PEER team also held a focus group discussion with the teachers. The researchers also gathered data at the university that enrolls students with vision loss. These learners provided great feedback on the usability and accessibility of the project initiative.

The project also created an accessible weather app and other accessible websites that provided students with vision loss experiences in analytic cognition that can be used in the STEM discourse. In addition, when the students get used to technology, they are able to make sense of mathematical concepts when taught. Once teachers get sufficient exposure to the experiences in which their students are engaged, they can restructure their lessons to incorporate the results of weather reading in their lessons to compute and make sense of STEM concepts.

The Mwangaza Project represents a blend of education research, technology, training, and accessibility, rolled together with the deployment of both computer labs and training, and with the support of major research universities, corporations, and the government's education department. This effort is intended to be a truly transformative project, on an international scale. The project addressed individual needs for learners with vision loss while at the same time increasing learning opportunities in STEM education. The large data set they collected is instructive in and of itself, in relation to the needs and preferences of this educational cohort in Kenya. There are many additional analyses that could be conducted, and research questions addressed, using the current data set. More importantly, the data serves as a baseline against which to evaluate any future programs, in terms of program goals and effectiveness. The project team is already seeing evidence that computer skills training (i.e., at Thika) is having an important impact not only on skills and computer confidence but also in terms of the psychosocial well-being of the students who have received training. The teachers have made it clear how much they also value computing skills, but additionally expressed their opinions regarding training, support, and careful deployment. Deploying software tools that already exist, and developing (and evaluating) new software tools to supplement, is the next step in leveraging technology. The PI and her team look forward to continuing the process of deploying such tools and working closely with teachers (and education officials in the Kenyan government) to develop teaching modules and strategies to make effective use of the tools in their classes.

KENYA - PROJECT 2-447: CAPACITY BUILDING IN FISH BIODIVERSITY DISCOVERY IN KENYA

PI: Dorothy Wanja Nyingi, National Museums of Kenya
U.S. Partner: Henry Bart Jr., Tulane University (Funded by the National Science Foundation)
Dates: August 2013 – January 2016

PROJECT OVERVIEW

The ichthyology section is the youngest of all the research collection departments at the National Museums of Kenya (NMK). Founded in 1997, the section holds the largest collection of fishes within East and Central Africa. Despite its potential, however, it has suffered from the lack of adequate funding and human capacity. Previous collaboration with Tulane University with funding from the National Science Foundation supported field collections, morphological and genetic analyses, and capacity building of local researchers. However, many gaps remained in field expeditions, specimen curation, data analyses, publication, and dissemination.

The main goal of the PEER project was to support the NMK research team and Kenyan researchers at large in their work on fish species discovery and creation of identification keys. The project involved field excursions to rivers, particularly the mid and lower basins of the Tana and Athi rivers and rivers in northern parts of Kenya. The project also included support for proper curation of fishes at the ichthyology section of NMK, training in phylogenetic analyses, and support for undergraduate and postgraduate student participants.

FINAL SUMMARY OF PROJECT ACTIVITIES

As part of the project, Kenyan scientists and students received additional training in various components of biodiversity research, specifically taxonomic revisions and new species descriptions, and molecular phylogenetic analyses on DNA sequence data. This allowed unfinished fish taxonomic work to be completed, greatly increasing knowledge of the Kenyan freshwater fish fauna. Researchers sought to impart this knowledge to local indigenous people to increase their desire to protect fish species and their riverine habitats.

The team also sought to improve the state of specimen preservation at NMK through the purchase of supplies for the ichthyological collections. They also added Web-based dissemination of data from the collection. Dr. Nyingi and her colleagues published two papers on their findings, as well as one book chapter co-authored by the PI. The team participated in the Pathways Kenya 2016 International Conference: Integrating Human Dimensions into Fisheries and Wildlife. The PI organized a special session at the conference about conflicts between humans and wildlife in water dependent ecosystems of arid and semi-arid areas, where most of the presentations involved work supported by PEER funding.

The team received a new grant of approximately 24000 euros to study the impact of dams on Kenyan wetlands, funded by the Kenya National Commission for Science, Technology and Innovation and the French Embassy in Kenya. The PI was also awarded the Palmes Académiques for exceptional scientific and educational merit by the French ambassador to Kenya.

The project supported two female undergraduate students during internships at the Ichthyology Section under the Kenya Wetlands Biodiversity Research Team, as well as two graduate students for joint projects on freshwater fish diversity work in Lake Turkana.

PUBLICATIONS

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KENYA - PROJECT 2-349: DERAILING WITCHWEED (*STRIGA*) VIRULENCE IN RICE TO ACHIEVE DURABLE AND BROAD-SPECTRUM RESISTANCE

PI: Steven Runo, Kenyatta University
U.S. Partner: Mike P. Timko, University of Virginia (Funded by the National Science Foundation
Dates: August 2013 – July 2016

PROJECT OVERVIEW

Striga spp. are parasitic plants notoriously difficult to control due to the poorly understood biological processes underpinning host-parasite compatibility. Striga affects plant growth quickly after attaching to host roots, stunting crop plants within 2-4 days. Control measures need to act before or very shortly after attachment. Recent findings suggest Striga produces virulence factors (effectors) that help it subdue host defenses. The long-term goal of this project is to identify mechanisms controlling the release of these virulence factors to develop breeding strategies for durable resistance to Striga.

The project's specific aims were to assess mutations or polymorphisms in Striga effectors and their effects on plant cells, identifying various Striga races for effector genes and their role in virulence. This understanding is crucial for developing resistant cultivars through gene pyramiding. The results could significantly impact agricultural productivity in regions affected by Striga, including Africa, where crops like rice, corn, millet, and sorghum are majorly impacted.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project ended in September 2016 before receiving a supplement in 2017 to disseminate the results further. Below are the main highlights of the research.

Novel Sources of *Striga* Resistance from Wild Sorghum Accessions Identified: The team sought to determine to what extent wild sorghum are resistant to *Striga*. The screening strategy involved controlled laboratory assays on rhizotrons – where they artificially infected sorghum with *Striga* – as well as field experiments in three sites where they grew sorghum under natural *Striga* infestation. They tested the resistance response of 7 accessions of wild sorghum of *Aethiopicum, Drummondii* and *Arundinaceum* races against N13, a cultivated *Striga* resistant landrace. From the laboratory experiments, they found three wild sorghum accessions (WSA-1, WSE-1, and WSA-2) that had significantly higher resistance than N13. These accessions had the lowest *Striga* biomass, fewest and smallest *Striga* attached to them. Further microscopic and histological analysis of attached *Striga* haustorium showed that wild sorghum accessions either hindered ingression of *Striga* haustorium into the host cortex or induced intense hypersensitive reaction (HR) at the infection site, a hallmark of systemic acquired resistance (SAR). Field experiments affirmed the laboratory screening experiments where these same accessions were found to have resistance against *Striga*. In the field, the wild sorghum had low Area under *Striga* Number Progressive curve (AUSNPC) – which measures emergence of *Striga* from a host over time. They concluded that wild sorghum accessions are an important reservoir for *Striga* resistance that could be used to expand the genetic basis of cultivated genotypes for resistance to the parasite.

Strigolacton Profile of Wile and Cultivated Sorghum Determined: There is yet another important aspect of *Striga* resistance, germination stimulant (strigolactone) production, which provides a level of resistance on host crops due to decreased strigolactone (signaling molecules produced by plants) production results in lower frequency of *Striga* germination. The study sought to determine SL production in wild sorghum accessions as these have been found to be tolerant to *Striga* infestation. The study further determined the relationship between SL production and tillering in wild sorghum accessions. Experiments involved collection of root exudates from sorghum and using them to induce *Striga* germination. Liquid chromatography-tandem mass spectrometry was used to determine the type and amount of SL in wild sorghum root exudates. Results showed that: i) the most abundant SL in wild sorghum was 5-deoxystrigol, ii) wild sorghum contained low levels of SL compared to their cultivated counterparts, 5-deoxystrigol has been reported earlier as stable strigolactone molecule making plants producing it more susceptible to *Striga* and this could explain why the wild cultivars though producing very low amounts of 5-deoxytrigol were able to induce germination iii) there is an inverse relationship between strigolactone concentration and tillering and a positive relationship between the Strigolactone concentration and *Striga* germination stimulation. All sorghum genotypes were able to induce *Striga* germination even in genotypes that produced least amounts of 5-deoxtrigol. These genotypes could provide more insights in developing sorghum lines that are resistant to *Striga* weed.

***Striga* Sorghum Arms Race as Revealed by Dual RNA Sequencing:** The team then carried out dual RNA sequencing (both host and parasite tissue) of wild and cultivated sorghum and their parasites, using Illumina Hiseq. RNA sequencing data was used to determine genes in wild sorghum that are differentially expressed at early and late S. hermonthica infection and compared their profile to those of cultivated sorghum. In addition, they compared the profile of differentially expressed genes between S. hermonthica infecting wild and cultivated sorghum. Finally, the team also compared the profile of differentially expressed genes between S hermonthica and S. asiatica in cultivated sorghum. They found that more genes were differentially expressed in wild sorghum upon *Striga* infection and that more *Striga* genes were differentially expressed when the infection was on wild sorghum. These findings suggest that wild sorghum has more genetic diversity to cope with *Striga* and that more genes in *Striga* are required to overcome resistance from the host. RNA sequencing data further led them to identify a set of candidate *Striga* resistance genes from wild sorghum as well as a rapporteur of molecules (effectors) that may be aiding *Striga* to overcome the innate immunity of its hosts

Through this PEER project, three students were trained at Master of Science level. Two of these have submitted their thesis for examination. Also, due to the role of women in agricultural value chains and well documented evidence of technology uptake when women are involved, the project specifically trained two women

PUBLICATIONS

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KENYA - PROJECT 2-335: UNLOCKING AGRICULTURAL POTENTIAL IN DRYLANDS: ENHANCING EFFICIENT UTILIZATION OF SOIL MOISTURE FOR IMPROVED SMALLHOLDER FARM PRODUCTIVITY IN ASALS OF KENYA

PI: Mary Baaru, Kenyatta University
U.S. Partner: Ethan Allen, Pacific Resources for Education and Learning (Funded by the National Science Foundation)
Dates: August 2013 – January 2023 (including supplement)

PROJECT OVERVIEW

The amount of land devoted to agriculture has decreased due to rising population and growing demands for land resources, leading to increased exploitation of drylands. In this context, dryland resource utilization can no longer proceed on a "business as usual" basis. This PEER project aimed to address water scarcity, deforestation, insufficient extension services, and lack of appropriate cropping systems in Kenya. Alongside its research components, the project included capacity-building activities for farmers in drylands. Farmers were trained in soil and water conservation measures and provided with kits to implement these measures, first on their own farms and then on non-member farms.

FINAL SUMMARY OF PROJECT ACTIVITIES

Trainings were conducted on farms selected in a participatory manner where extension officers, administration staff, and farmer groups were involved in selecting the most appropriate farm as a demonstration site. Field activities were carried out on these plots, including included land preparation, weeding, soil sampling, crop data collection, and harvesting. This was done for three short and two long rainy seasons. Training of farmers was carried out to highlight the importance of water use efficiency, soil and water conservation and environmental degradation. About 45 farmers were well trained to be able to pass same knowledge to their fellow farmers.

The PI and her team worked with government agencies, mainly the Ministry of Agriculture, who are well versed with the area, and farmers and provided linkages between the research team and farmers. It was important to collaborate with both government agencies and community groups as they could up scale the technology to other farmers. A survey was carried to find out community awareness on causes and impacts of soil erosion and a study to understand erosion hotspots was also carried out. Out of this work a master's thesis was developed and the student graduated in September 2015.

In summary, results from the demonstration plots set up at the start of the project indicate that this technology could be an appropriate alternative to conserve and store water for increased production especially by the poor farmers who may not afford the expensive technologies. It is also possible that the adoption rate of the same practice was an improvement of what they already are doing, meaning the livelihoods of the communities could be enhanced. The results also indicate the need for capacity building in the community on soil erosion management. The survey indicated that most farmers did not understand what it was, the causes and how it can be prevented. This gave the extension agents a niche from where to start. They are using this technology as one of the simple alternatives in water conserving that can be embraced by farmers to increase crop yield. Kenyatta University is now developing a PhD program based on the PEER research achievements.

KENYA - PROJECT 2-219: STRENGTHENING INSTITUTIONAL CAPACITY FOR PARTICIPATORY ACTION RESEARCH IN SUSTAINABLE AQUACULTURE

PI: Joyce Gichiku Maina, University of Nairobi
U.S. Partner: Irene Kimaru, St. John Fisher College (Funded by the National Science Foundation)
Dates: August 2013 – April 2017

PROJECT OVERVIEW

The overall objective of this project was to use the Action Research paradigm to develop, validate and disseminate new technologies to enhance development and sustainability of a vibrant fish farming sector in in Kenya. Four main objectives were involved. The first was to build capacity for Participatory Action Research among the selected graduate students and teaching staff in the Faculty of Agriculture at the University of Nairobi and other participating institutions. Some of the students and staff were subsequently used in carrying out research in fish farming in Kenya. The second objective was to do a baseline survey to establish the main socioeconomic, gender, and technological factors that influence fish farming. This was done using a semi-structured questionnaire targeting the main actors in the farmed fish value chain. The third objective was to develop and validate models for integrating fish farming into crop and livestock farming. In this component of the project, models for efficient use of water for crop irrigation and rice farming and use of livestock manures as fertilizers for fish ponds were evaluated. The fourth objective involved evaluating the environmental effects of fish farming on the water systems. This part of the research was done in collaboration with the U.S. partner, leveraging her expertise in environmental chemistry.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project covered various aspects of the farmed fish value chain during the three years, resulting in interesting findings and ongoing discussions with stakeholders. The study on profitability of fish farming showed that farmed fish had very short value chains and because of this, fish farmers were also engaged in other enterprises. Fish farmers with three or more ponds consistently made profits, with catfish being the most profitable cultured fish and black clay soil sites the best for fish farming. The study recommended that the county promote large scale fish farming at sites with the most potential and fish farming be integrated with other enterprises.

The presence of ecto and endo parasites in farmed fish in Nyeri and the prevalence among different species and production methods was communicated to stakeholders. A group was formed consisting of the University of Nairobi and other stakeholders in Nyeri to continue this discussion and discuss ways of increasing fish productivity to feed into the new Wamagana Fish processing factory in Nyeri. Their evaluation of feed resources in Nyeri led to Othaya feed millers improving fish feeds that are supplied farmers. In their analyses, they found that some of the raw materials they were using were of low nutritional quality, resulting in fish feed with low protein content. After working with the millers to improve their feeds, the last sample they sent to the PI’s lab had doubled the protein levels. The farmers used their data to improve the way they made their feeds and it is in the process of certification by the Kenya Bureau of Standards.

Using molecular techniques, Dr. Maina reports there is very little variation among brood stock in some of the hatcheries that supply fingerlings to farmers, as well as little variation among catfish in Lake Naivasha. The team has planned presentations at the Aquaculture Round Table where they will discuss this with policy makers. Their studies showed that the catfish found in that lake may have all come from one pair, which was communicated to stakeholders, but have since been requested to conduct additional studies and increase the number of sampling sites.

In Kibwezi, the PI and her team conducted a study on the profitability of fish farming when compared to other enterprises in the region. The student who did that work presented his findings and recommendations to the Cabinet Secretary for Agriculture, Livestock and Fisheries and also to the Principal Secretary in charge of State Department of Fisheries and the Blue Economy. He has been nominated as a board member for the State Department of Fisheries and Blue Economy. In addition, he has received grant from another project to train farmers in 7 Counties in Kenya.

In Migori, they found extremely high levels of mercury in fish and sediments collected in gold mining and adjacent areas. The team aims to continue with this work and determine the extent of environmental contamination with mercury and the effects on vulnerable populations.

Through this PEER project; capacity was built among researchers including graduate students and their supervisors on participatory research. This capacity has also been built among researchers at the Kenya marine and Fisheries Research Institute and the Kenya Agriculture and Livestock Research Institution. More researchers are now using participatory methods in their research. The team supported two PhD and four Master's students.

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KENYA - PROJECT 2-135: HARNESSING GENOMICS OF EDIBLE AFRICAN SOLANACEAE PLANTS FOR IMPROVED NUTRITIONAL AND FOOD SECURITY

PI: Willis Owino, Jomo Kenyatta University of Agriculture and Technology, with Co-PI Jane Ambuko, University of Nairobi
U.S. Partner: James Giovannoni, USDA/ARS, Boyce Thompson Institute for Plant Research, Cornell University (Funded by the National Science Foundation)
Dates: August 2013 – January 2016

PROJECT OVERVIEW

Plant genetic diversity is the principal resource for crop improvement efforts. Africa maintains thousands of wild crop relatives to be collected, studied, and documented to facilitate use in improved crop varieties to meet the challenges of food security in the face of rising food demand. Abundant genetic resources in the developed world for *Solanaceae* crops, including the tomato and the potato, has provided a springboard for plant genomics to assist in the exploitation of underutilized crops and enhance productivity, sustainability, and quality. In turn, developing world germplasm and scientific resources have significant potential for impact on developed world agriculture. There is great potential for both developed and developing countries to benefit from enhanced productivity and sustainable resource utilization to promote greater nutritional security.

The primary goal of this project was to use existing *Solanaceae* genome resources and state-of-the-art technologies in the Western world to characterize genetic diversity and nutrient/non-nutrient metabolite compounds in *Solanaceae* crops of importance to smallholder farmers and consumers. The project team aimed to provide a foundation of plant genomics useful for improvement of indigenous African fruits and vegetables. The researchers engaged local breeders to identify *Solanaceae* germplasm representing a spectrum of genetic diversity to be used in agronomic improvement programs targeting sustainability, nutrition, and food security. The resulting resources sought to aid in (1) variety identification, (2) assessment of genetic diversity, (3) development of genetic linkage maps, (4) marker-assisted selection of yield and nutritional traits, and (5) linkage to fruit nutrient and performance quality traits and postharvest loss relevant to local food security. Results obtained through this project were also incorporated into the Solanaceae(SOL) Genomics Network Database, the NSF-funded project of the U.S. partner, which constitutes one of the main meeting, data storage, and data enabling resource for the *Solanaceae* community worldwide.

FINAL SUMMARY OF PROJECT ACTIVITIES

Following are the key accomplishments of the project::

1. Create a stable and accurate African Solanaceae germplasm resource

The team collected tomato and African eggplant accessions from various sources, including the Kenya Gene Bank, farmers in the Eastern and Western provinces, and the World Vegetable Centre. They established a germplasm collection at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) comprising 67 tomato and 74 African eggplants accessions. These were then then characterized to identify desirable morphological and agronomic traits that could be used in tomato crop improvement. Field and greenhouse experiments were laid out in a randomized, complete block design with three replicates at the University of Nairobi's Kabete field station in 2014 and 2015. Characteristics were evaluated based on the International Plant Genetic Resources Institute tomato descriptor list on 14 Agronomic and 10 morphological traits at flowering and fruiting stages.

As for the African eggplants, morphological data collected was subjected to Genstat's univariate analysis, bivariate, multivariate, and Darwin6 software for statistical analysis. The dendogram grouped the accessions into two main clusters with a majority falling in cluster 2, revealing a narrow genetic base in the cluster. The findings of this study reveal significant variation among the selected African eggplant mainly contributed by plant height, leaf blade length, leaf blade width and fruit width. Substantial variation among the 67 accessions was also observed in fruit color, fruit shape, fruit texture, leaf base and leaf lade color. Variation in growth, fruit yield and nutritional quality exist among African eggplant accessions hence enabling the breeders to use the well adapted accessions like RV100200, RV100445 and GBK 050572 in breeding programs.

2. Development of whole genome and transcriptome DNA sequence resources using high throughput Next generation sequencing for better classification and characterization of orphan African *Solanaceae* species.

The mRNA extracted from leaf and fruit samples was sequenced using the Illumina next generation sequencer to evaluate the genetic makeup, Statistical data analysis was done using Genstat and Darwin 6 software. The sequence data analyses were yet to be completed at the time the final report was submitted in early 2016, but the PI indicated he and his team could o generally conclude that African eggplant and tomato have diverse fruit, vegetative traits, and novel genes that can be utilized in plant breeding programs to improve the currently cultivated accessions for better yield and nutrition improvement.

3. Evaluate the metabolite profiles of the collected accessions.

The team established the effect of drought stress on carotenoid profiles of nineteen African eggplant accessions selected based on leaf and fruit morphological traits. Fresh leaves were sampled at different maturity stages; before stress, 2 weeks and 4 weeks after stress for carotenoid analysis. The results of this study indicate that water stress has significant impact on the concentration of some carotenoids and photosynthetic pigments. This knowledge will have significant implications for farmers and could unlock the potential for stress management for improved food security and sustainable livelihoods in Africa.

PUBLICATIONS

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KENYA - PROJECT 1-382: NATURAL RESOURCES INTERACTING WITH HEALTH OUTCOMES: UNDERSTANDING FISHERY RESOURCE USE AND IMPROVING NUTRITION IN WESTERN KENYA

PI: Richard Magerenge, Organic Health Response-Ekialo Kiona Center
U.S. Partner: Justin Brashares, University of California, Berkeley (Funded by the National Science Foundation)
Dates: June 2012 – May 2015

PROJECT OVERVIEW

While ecosystem and human health are closely linked, the mechanisms through which natural systems interact with livelihoods and human health are often poorly understood. The Organic Health Response-Ekialo Kiona Center partnered with National Science Foundation Coupled Natural and Human Systems (NSF-CNH) grant recipients at the University of California-Berkeley to improve understanding of these mechanisms and how resource access mediates health and nutrition outcomes. This collaboration represented the first research program on Mfangano Island, Kenya, aimed at equipping local researchers with training, resources, and mentorship to design, evaluate, and create models of local programs.

The NSF-CNH project aimed to inform a broader understanding of links between ecosystem and human health by focusing on natural resources that provide food, particularly fishery resources, which significantly impact local people. Poor nutritional status is often linked to degraded fisheries and agro-ecosystems. The new PEER project analyzed these relationships, specifically the role of fish use and access in the Lake Victoria fishery of Western Kenya. This study investigated how fishery health shapes human nutrition, livelihoods, and health outcomes, and aimed to predict how human health and household wealth affect reliance on harvested biodiversity. An interdisciplinary approach combined ecological monitoring, nutritional epidemiology, and political ecology, with data collection including fishing activities, fish consumption patterns, diet calendars, and child nutrition measures. The findings have implications for broader poverty and resource management policies to guide community programs.

FINAL SUMMARY OF PROJECT ACTIVITIES

In 2012, Organic Health Response completed a highly successful HIV program for the social network groups who would subsequently participate in the nutrition intervention. These groups were established based on existing social networks, and members recruited their families, friends, church groups, fellow fishermen, soccer teams, etc.

Social network groups participated in six curriculum sessions from May 2014 to August 2014. The curriculum was designed to provide knowledge and empowerment, and it emphasized hands-on activities, including cooking and farm demonstrations, dramas, and creating family plans. Community members also made plans to support each other in case of future challenges like grain shortages or child malnutrition. The program structure was designed to drive sustainable behavior change and allow participants to build relationships with Community Health Worker facilitators for ongoing support.

The team continued to follow up with these groups to maintain group engagement, encouraging them to continue meeting, providing additional curriculum, and continuing Community Health Worker training. They also shared technical resources, addressed acute malnutrition referrals, and provided technical support for fishing and agricultural initiatives to improve food access in tandem with the findings from the research project. In this work the team engaged more than 500 individuals and 50 community health workers in 41 social support groups. In total, 40% of families with young children joined the social support groups. After initial data collection, the PI and his team conducted the 18 and 21 month follow-up surveys within the island community. The U.S.-based partners at UC-Berkeley and Kenyan-based partners at Organic Health Response worked together actively to build a program to support regional households in improved nutrition and food security.

The research team was awarded additional grants, including PATH's NEEP (Nutrition Evaluation Enhancement Program) grant and The Segal Family Foundation's Organic Health Response grant. Staff in Kenya participated in research ethics, computing and other training sessions, and a research certificate program was created. The PEER team also created a connection between students at Sena Primary School on Mfangano Island and Longfellow Middle School in Berkeley, California. A total of 160 students learned about the research program and connected directly with each other through pen pal letters.

PUBLICATIONS

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KENYA - PROJECT 1-207: ADDRESSING DRINKING WATER QUALITY CHALLENGES IN DEVELOPING COUNTRIES: CASE STUDY OF LAKE VICTORIA BASIN

PI: Shem Wandiga, University of Nairobi
U.S. Partner: Benito Mariñas, University of Illinois Urbana-Champaign, Formerly Mark Shannon (Funded by the National Science Foundation)
Dates: May 2012 - August 2014

PROJECT OVERVIEW

The goal of this project was to develop point-of-use water treatment technology to be used to improve the quality of drinking water for the people living around the Kenyan shore of Lake Victoria. The project team from University of Nairobi and Bondo University College collaborated with the Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS), a science and technology center supported by the U.S. National Science Foundation. The expertise from WaterCAMPWS was used to help utilize locally available materials and regional expertise to develop novel and sustainable point of use water purification systems.

Kenya has large deposits of titanium dioxide (TiO_2) that are now being mined for export. Small particle semiconducting TiO_2 photocatalysts have been extensively studied due to their relatively high reactivity and stability, and this study built upon the photocatalytic advances made by WaterCAMPWS to extend the use of TiO_2 to address regionally specific waterborne chemical and microbial contaminants. Expected outcomes of the project were: 1) improved regional access to safe water; 2) new materials and markets for point of use water purification systems that leverage regionally abundant and underutilized deposits of TiO_2 ore in Kenya; 3) improved research capacity in water disinfection and purification; and 5) increased coordination in addressing drinking water problems at scientific, policy and local communities.

FINAL SUMMARY OF PROJECT ACTIVITIES:

In the first phase, the PEER grantees undertook a survey in three socioeconomic and biophysical settings—rural, peripheral-urban, and urban sites in Bondo District in the Lake Victoria region in order to develop an integrated health knowledge base. The survey included questions on demographics, socioeconomic status, access to water sources, and attitudes and practices around water-borne diseases. Health challenges were found to be linked to water use and quality. Among their findings: almost 70% of the surveyed households had no access to treated water and children as a cohort shared a high burden of waterborne diseases.

In the second phase, the research team developed ceramic filters and several prototype water purification platforms, including the use of titanium oxide and *Moringa oleifera* powder and seeds and tested them with the intent of bringing the successful platform to market scale.

M. Oleifera seeds were found to be effective in removing microbial contaminants with *E.Coli* removal efficiency of up to around 89%, while that of other Coliforms was around 78%. However, the powder was not effective in the removal of ions such as nitrates, nitrites, and phosphates and alkalinity. With the ceramic filters, the efficiency of the *E. Coli* reduction was around 99%, while that of other coliforms was around 89%. In addition, the filters were effective in reducing heavy metals from water. As observed with the *M. Oleifera* powder, the filters did not have the ability to remove dissolved ions from the water.

Throughout the project, the PI and team were able to educate the community and policy makers about water quality and health and on how improved water quality can generate income opportunities and reduce poverty. The researchers organized several workshops to discuss the project with stakeholders, including one presenting the results and to plan future projects.

The research team was awarded several new grants to continue the work, including a SEK 500,000 (about $70,000 USD) International Science Program (ISP) collaborative grant from the University of Uppsala, Sweden. They presented their scientific findings to government agencies, and the Kenyan government expressed interest in implementation once the final product is developed. Researchers were also approached by Proctor and Gamble to work with them on the supply of water in the Kibra slums.

The project also built capacity for advanced students, including two female researchers. The ongoing effort to improve knowledge about water quality has been expanded to Egerton University and schools in Kenya.

PUBLICATIONS

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KENYA - PROJECT 1-198: NATURAL PEST AND WEED SUPPRESSION FUNCTIONS BY BIRDS AS INCENTIVES TO CONSERVE A GLOBALLY THREATENED BIRD SPECIES AND ENHANCE LIVELIHOODS IN AN AGRICULTURAL LANDSCAPE

PI: Peter Njoroge, National Museums of Kenya
U.S. Partner: Matthew Johnson, Humboldt State University (Funded by the National Science Foundation)
Dates: June 2012 – May 2015

PROJECT OVERVIEW

Biodiversity in agricultural landscapes can be part of the solution to problems in the food production sector, as most biodiversity hotspots lie outside nature reserves. New technical research that promotes the mutual relationship between agriculture and conservation is therefore needed. This project aimed to investigate the interactions between agricultural systems and functional bird groups in the Mukurweini district of Kenya. Located in the central Kenya highlands, Mukurweini District is a globally recognized Important Bird Area (IBA) within an intensively cultivated landscape. The research team used birds to understand the influence of landscape composition in Mukurweini on occurrence of natural pest enemies and post-dispersal weed predators.

This study identified and promoted the best landscape composition features in Mukurweini to increase the occurrence of functionally important birds (e.g., pest- and weed seed-eating). Dr. Matthew Johnson, the U.S. collaborator on the project, served as the lead scientific coordinator for the exclosure experiments. He has extensive experience with bird exclosure experiments, including their design, deployment, data collection, analysis, and interpretation. The research sought to benefit the conservation of globally threatened bird species like the Hinde's Babbler, improve food security and livelihoods in rural settings, and help boost the growth of bird watching tourism in Kenya.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers investigated the interactions between agricultural systems and functional bird groups based on their feeding guilds and recorded 116 species across six months of data collection. Among other findings, the data indicated significantly more species recorded during the wet seasons as compared to the dry season.

The PEER team developed close working relationships between local schools, local government, and the Kinyoho women's group throughout the project. They also brought on board Nature Kenya as the local birdlife partner, which will continue supporting the groups and their initiatives, including an Indigenous tree planting program in schools and the beginning of a tree nursery at Wajee Nature Camp. During the grant period, a Master's degree candidate on the team finished his coursework, using work done for the research project as part of his thesis.

The researchers presented their results to local farmers at a workshop held at Wajee Nature Camp, as well as in a presentation to members of the Mukurweini Environmental Youth Group and Wildlife Clubs of Kenya. The presentations included information on integrated land-use systems for both profitable food production and protection of critical ecosystems, as well as enhancing landscape-driven natural pest and weed suppression. During the workshops participants proposed several activities that could be undertaken to help promote and disseminate the project results, such as a commercial tree program, school outreach program, bee-keeping program, conservation awareness tournaments, and Mukurweini biodiversity and culture marketing.

PUBLICATIONS

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KENYA - PROJECT H1-175: IMPACT OF PRONTO TRAINING IN EMERGENCY OBSTETRIC AND NEWBORN CARE ON 24-HOUR NEONATAL MORTALITY

PI: Onesmus Gachuno, University of Nairobi

U.S. Partner: James Kiarie, University of Nairobi (Funded by the National Institutes of Health)

Dates: October 2013 – April 2017

PROJECT OVERVIEW

In Kenya, neonatal mortality accounts for 60% of infant mortality. One-third of these deaths are due to intra-partum complications resulting in birth asphyxia, which can be prevented by effective interventions. The Government of Kenya has identified inadequate provider competencies in Emergency Obstetric and Neonatal Care (EmONC) as a major challenge to implementation of quality Maternal and Newborn Health (MNH) services and has prioritized improving skilled care and enhancing the capacity of health facilities to provide these services. In high-resource countries, simulation training has had the greatest success in changing practice and behavior in EmONC, particularly in emergency situations; however, the models used are expensive, complicated, and not conducive for limited-resource settings.

Developed by a team of U.S. and Mexican researchers and clinicians in 2012, PRONTO is a low-tech, highly realistic simulation and team-based training protocol specifically for limited-resource settings, which has been shown to improve health worker competencies in EmONC and decrease perinatal mortality. This training addresses skill and system barriers to the provision of sustainable quality EmONC thus reducing neonatal and maternal morbidity and mortality. The overall goal of this PEER project was to evaluate the effectiveness of PRONTO simulation and team training in emergency obstetric and neonatal care in a rural Kenyan setting. The PEER team studied the use of the training in Kisii health facilities, for workers caring for women during labor and delivery at these health facilities, and their newborns. Using a cluster randomized trial design, the researchers sought to determine the impact of PRONTO training on 24-hour neonatal mortality in health facilities, as well as on maternal and neonatal morbidity, health care worker knowledge, skills, and practice.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Gachuno and his colleagues conducted trainings for eight intervention health facilities and Kisii Teaching and Referral Hospital, training a total of 92 health workers. They conducted pre- and post-training tests and evaluations on knowledge, skills, and attitudes. At the end of each training, each facility developed strategic development goals in obstetric and neonatal care for implementation in the health facility. The PEER researchers later held a training of trainers of 18 health providers and reproductive health coordinators from Kisii County on PRONTO simulation and facilitation techniques so that they could continue to conduct simulations with the PRONTO packs in the health facilities. The project included a total of eight quarterly supervisory visits during the course of study, during which the researchers monitored the roll out of a “near-miss” tool, reinforced the neonatal resuscitation skills, and held meetings with facility in-charges and their staff to emphasize the importance of filling the tools and conduct on-job training where there were gaps.

By the end of the study, the team found that their intervention group saw a significant decline in neonatal and perinatal mortality (2.4% control vs. 1.6% intervention, $p = .009$), showing the impact of the PRONTO protocol. With the help of the Kenyan Ministry of Health, the researchers developed a national training package to scale up implementation. At the time the project ended in late 2018, there was a high level of adopter commitment, although more funding is needed to implement these trainings as common practice nationwide.

The PI and team held several stakeholder meetings to present findings, including in-progress data collection and final findings to the County Health Management Team, In-Charges of the Health Facilities, and Local Ministry of Health Personnel. The researchers presented their findings across several national and international academic conferences, including the 10th Annual World Congress on Pediatrics, and they received a PEER Evidence to Action Supplement in July 2017 to disseminate their findings more broadly to stakeholders and policy makers at the national and country levels and develop an operational framework for the integration and implementation of PRONTO training.

PUBLICATIONS

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KENYA - PROJECT H1-120: FEASIBILITY AND EFFECTIVENESS OF THE BABY FRIENDLY COMMUNITY INITIATIVE (BFCI) IN KENYA: A PILOT COMMUNITY TRIAL IN A RURAL SETTING

PI: Judith Kimiywe, Kenyatta University

U.S. Partner: Stephen McGarvey, Brown University (Funded by the National Institutes of Health)

Dates: October 2013 – June 2017

PROJECT OVERVIEW:

Nutrition in the first 1000 days of life is critical for child growth, wellbeing, and survival. There is evidence that undernutrition is associated with more than one-half of child deaths due to its influence on morbidity. Interventions promoting optimal maternal infant and young child nutrition (MIYCN) could prevent a fifth of under five deaths. Poor MIYCN practices are widely documented in Kenya, like in other developing countries, with potential detrimental effects on child growth, health and survival. The Division of Nutrition (DON), Kenya, developed a national strategy to promote optimal MIYCN practices in 2007, actualized mainly through the baby-friendly hospital initiative (BFHI) in maternity wards. However, since only two in five women deliver in health facilities, the majority of women lack this support, and MIYCN practices are greatly influenced by traditional beliefs and practices. Hence the impact of BFHI is minimal. Recognizing the need to reach women at the community level, the DON is therefore considering implementing the Baby Friendly Community Initiative (BFCI), which employs the principles of BFHI at the community level. Hard evidence on the effectiveness of BFCI and how it works best in the Kenyan context is needed to create the political buy in, budgetary allocation and effective implementation at the national level.

This study aimed to pilot implementation of BFCI to determine its feasibility and effectiveness with regards to maternal and child nutrition and health status in a rural setting in Kenya. The study was conducted in East Pokot, a semi-arid rural district with poor health access in North Rift region of Kenya. The study combined both qualitative and quantitative methods to answer the research questions. A formative study using participatory action research was conducted. Then, a quasi experimental study with both qualitative and quantitative data collection would be conducted. Data on MIYCN practices, nutritional status, and health of the children was then intended to be collected on cohorts of mother-child pairs in both intervention and control arms through baseline and end-line cross-sectional surveys.

FINAL SUMMARY OF PROJECT ACTIVITIES

The government and development partners have adapted its methods for up scaling to other regions in Kenya and the program has attracted other regional countries who are planning to come and learn from its experiences. The team has received international interest and has been asked for information and expertise in a number of new projects that focus on MIYCN in developing countries.

Initially, the project site was designated as the East Pokot sub-county of Baringo, but due to insecurity challenges around cattle rustling coupled with other hindrances, the project team, in consultation with the Division of Nutrition and Dietetics of Ministry of Health, decided to change the study site to Koibatek within the same county. A reconnaissance and community mobilization visit was conducted in

July 2014 where the team held inception meetings with the Baringo County Health Management Team (CHMT) and Koibatek sub-County Health Management Team (ScHMT). The Ministry of Health was a key stakeholder in the implementation of the intervention and the study and fully involved in every aspect of it including the training of the CHVs, orientation of health care workers in the sub-county on the BFCI package, and supervision of the project.

Community mobilization for the project was conducted in July 2014 with the Baringo County Koibatek health management teams. The officers were briefed on the purpose of the BFCI project and planned activities including the orientation of the sCHMT team, training of the CHVs, CHEWs and health facilities workers. The sub-county health management team briefed the project team on the structure of the community health strategy and how many community health units were in existence and their status. The project team was also briefed on other activities undertaken or were ongoing on nutrition and health within the sub-County.

A formative study was conducted in August 2014 to establish the knowledge, attitudes and practices regarding maternal nutrition, breastfeeding and complementary feeding; establish contextual and cultural factors which contribute towards maternal, infant and young child (MIYCN) practices; and inform customization of BFCI including the role of key persons involved in reproductive health such as traditional birth attendants (TBAs). Focus group discussions were conducted with women of reproductive age (15-49 years) who were either pregnant, breastfeeding or had ever breastfed and with CHVs and village elders. Key informant interviews were conducted with healthcare professionals, sub-County health management team, TBAs, the chiefs, assistant chiefs, village elders and religious leaders. This information was used to guide the structure of the implementation of the intervention and the finalization of the quantitative tools for assessing the study outcomes.

Thirteen qualitative data collectors were recruited in early August, and trained for one week. Community mobilization for the formative study took place immediately after the training and piloting of the data collection tools. The project team reached 145 community members; 8 chiefs, 18 assistant chiefs, 57 village elders, 35 religious leaders and 27 women leaders drawn from across the 13 community health units in Koibatek. The research team conducted a total of 52 interviews involving 160 respondents. These included 16 FGDs, 14 IDIs and 22 KIIs.

A stakeholder's workshop with all relevant partners and other stakeholders including the Unit of Nutrition and Dietetics in the Ministry of Health, nutrition specialists from academic institutions, UNICEF, FAO, Save the Children, World Vision was held on October 2014 and preliminary results of the formative study disseminated, discussions were held on how to use the findings to tailor the intervention and the prospective data collection and a revised work plan for the study was developed. Dissemination, consultation, and planning meetings in Koibatek sub-County were held with the county and sub-county health management teams, stakeholders and community members in December, 2014. Formative study findings were used to inform project intervention activities, formation of community mother support groups, Income Generating Activities for CHVs.

Training/orientation of CHVs on the BFCI was done from 23 – 27 February 2015. 145 CHVs out of a possible 161 were sensitized, in addition to 13 CHEWs who supervise CHVs' activities in the community units. Topics covered included maternal infant and young child nutrition and breastfeeding practices, keys to successful breastfeeding. Other topics were mother to child transmission, infant feeding and HIV, infant and young child nutrition practices, formation of mother support groups. A midline qualitative evaluation was conducted about halfway through the intervention with the aim of documenting experiences by the study community with the ongoing intervention. The midline study explored enablers, barriers and successes recorded thus far and recommendations for change or future practice. This was collected through in-depth interviews and focus group discussions with mothers, and focus group discussions with CHVs and village elders, and key informant interviews with chiefs, religious leaders, health care professionals, TBAs and the sub-county Health Management Team members.

Midline qualitative evaluation was conducted in early February 2016. The team trained conducted 68 interviews involving 163 participants. These included 19 FGDs, 29 IDIs and 20 KIIs. Key informants included the sub-County Medical Officer of Health (sCMOH), sub-County Nutrition Officer (sCNO), and sub-County Community Strategy Coordinator (sCCSC), Health Care Workers (HCWs) from the intervention units and all the Community Health Extension Workers (CHEWs) from all the 13 units. IDIs were conducted with pregnant women below 25 years and above 25 years, lactating women below 25 years and above 25 years, and a Community Health Committee representative. The FGDs comprised of Community Health Volunteers from all the units and spouses and grandmothers in the intervention units.

Endline qualitative assessment was conducted in February 2017 to document experiences by the study community and other stakeholders regarding the BFCI including challenges and opportunities encountered. Evaluation sought information on recommendations for change/future practice for similar interventions.

Interviews with mothers covered their experience with the intervention, lessons learned, challenges, benefits, opportunities and recommendations for change. FGDs with CHVs covered experiences in delivering the intervention, facilitating, limiting factors and recommendations for change. KIIs with CHC representatives, health care workers and the sCHMT covered experiences with delivering the intervention, perceived and observed benefits accruing to the community, lessons learned, challenges, opportunities and recommendations for change. A total of 42 interviews were conducted on 84 participants.

The project team participated in its own and other government initiated workshops between January and March 2015, convened to finalize on the review of tools for monitoring and evaluation of the BFCI intervention. The monitoring tools administered to healthcare workers and CHVs to assess the compliance of the health facilities in the intervention units to BFCI. A workshop to finalize on the tools was held in April 2015.

Recruitment of study participants was completed in May 2016 with a total of 901 participants enrolled into the study while household data collection on mother and child pairs was completed in December 2016. 78 of the recruited mother-child pairs had been lost to follow up for reasons that included death of either the mother or child, outmigration from study area, cross migration from intervention unit to control unit and vice versa and termination of pregnancy among others.

The project team conducted dissemination meetings of the study findings and outcomes at the community, sub-county and county levels in April, 2017 and at the national level in May 2017.

PUBLICATION

Kimani-Murage, E.W., Kimiywe, J., Kabue, M. et al. 2015. Feasibility and effectiveness of the baby friendly community initiative in rural Kenya: study protocol for a randomized controlled trial. Trials 16: 431. https://doi.org/10.1186/s13063-015-0935-3

KENYA – PROJECT SG1-001: EVALUATION OF NUTRITIONAL AND PHARMACOLOGICAL POTENTIAL OF KENYAN DOUM PALM: TOWARDS IMPROVED LIVELIHOODS

PI: Cecilia Mbithe Mweu, Jomo Kenyatta University
Dates: October 2019 – December 2020

PROJECT OVERVIEW

Agriculture is the mainstay and currently accounts for about 70% of the rural incomes in Kenya. Palms, particularly doum palm, are an important component of terrestrial ecosystems and play numerous roles in the arid and semiarid regions of Africa, Madagascar, the Arabian Peninsula, and India. It is an important wild fruit plant with diverse commercial and domestic uses. In Kenya, it is represented by the genus Hyphaene, which has two species the *Hyphaene compressa* and *H. coriacea*, and in Africa by approximately 26 species of the *Hyphaene* genus. The regions where the doum palm grows experience famine, water and forage shortage for livestock, leading to high dependence on doum palm, as it can withstand harsh climatic conditions. Doum palm dominates forests and woodlands, serves as sources of dry season grazing during drought and also protects the riverbanks. In the northern and eastern regions of Kenya, doum palm contributes significantly to the livelihood and welfare of the local communities, who are mainly nomadic pastoralists and agro-pastoralists.

Despite the ubiquitous importance of doum palm, it have been overlooked in nature conservation and are not included in any international biodiversity agreements. This is due to the fact that doum palm is considered a less important species, hence, there is only rudimentary knowledge of its biology, diversity, nutrition, and medicinal properties. The decline in the availability of doum palm due to overharvesting and destruction of their natural habitat are preeminent causes of doum palm genetic erosion. Lack of information on the scope of nutritional and medicinal properties of Kenyan doum palm is one of the greatest limiting factors to prospects of scaling it up for food and pharmaceutical industries.

The PI therefore designed this small pilot project with three main objectives: (1) to determine the nutritional properties of Kenyan doum palm varieties; (2) to establish the bioactive medicinal compounds present in doum palm varieties; and (3) to determine the antimicrobial efficacy of doum palm varieties.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Cecilia Mweu and a graduate student, Esther Seroney Jebichii, researched medicinal bioactive compounds found in doum palm fruit. They sought to improve doum palm utilization as a food commodity and as complementary medicine in arid and semi-arid regions of Kenya facing food insecurity, lower income, and limited access to medical facilities. The team collected samples in Tharaka and Kwale counties of Kenya and then tested them back in the labs at their university. They generated data on nutritional and bioactive compounds and developed a research article on antimicrobial activity of bioactive compounds of doum palm extracts. They also shared their findings in a seminar presentation.

The PI additionally mentored postgraduate students at her institution, including on topics such as research proposal writing, manuscript writing, thesis writing, and sourcing for research funds. The PI also received a $24,000 grant from the International Center for Genetic Engineering and Biotechnology to carry out research on cassava improvement.

KENYA – PROJECT SG1-004: TOWARDS IMPROVING NUTRITIONAL OUTCOMES THROUGH ADOPTION OF BIOFORTIFIED ORANGE FLESHED SWEET POTATO CLIMATE SMART TECHNOLOGIES IN ISIOLO COUNTY, KENYA

PI: Agnes Kavoo, Jomo Kenyatta University

Dates: October 2019 – March 2021

PROJECT OVERVIEW

This project researched and documented the potential of orange fleshed sweet potato (OFSP) in Isiolo County, Kenya. The researchers sought to identify farmers' knowledge, practices, preferences, methods of utilizing sweet potato products and their willingness to grow the OFSP varieties. The effort was designed to provide a baseline to design interventions and inform decision making both for the individual farmers and for farmers' groups and institutions. For example, the improved yields and income from OFSP help other farmers more readily adopt the improved variety based on the firsthand results achieved by fellow farmers.

The team sought to empower the first adopters in order to expand the project, and preliminary findings showed promise in improving the productivity and profit for the farmers, households, and farmers' groups, potentially improving their economic status. Equipping farmers with knowledge, skills, and seed inputs in turn made these farmers champions of learning and adoption of these improved practices.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project team established demonstration centers for OFSP in collaboration with farmers. Five farmers' groups were sensitized on OFSP production and utilization. These groups also served as primary OFSP seed distribution and on-farm demonstration centers. In the subsequent cropping cycle, these groups supplied the OFSP seed to an additional 100 households and two institutions, including a children's comprehensive care center and a hospital that serves women and children.

The researchers also provided demonstration sessions on selected climate smart agronomic practices, such as innovative planting methods (e.g. planting on mounds, ridges, at flat beds) and application of inorganic and organic fertilizers, among others. The adoption of these practices by farmers enhanced OFSP yield and household incomes. For example, a farmer in Burat planted OFSP on a quarter of an acre and harvested 200kg of OFSP after 3.5 months, which he sold at KES 50,000 ($500). This represented an 122% increase in yield compared to the previous season.

At the time they submitted their final PEER report, the PI and her team were finalizing a detailed end-of-project assessment for submission to the county government. The team developed three articles for publication (two of which were still under review) and presented their findings at the 15th JKUAT Scientific, Technological, and Industrialization Conference. The PEER project supported and trained two graduate students and two postdoctoral fellows, including three women. The postdocs were trained on how to write research proposals, gained skills in managing research projects, and were engaged in the day-to-day research activities.

PUBLICATION

Agnes Mumo Kavoo, R.M. Mwajita, Lilian Wambui Kariuki, and Leonard Muriithi Kiirika. 2022. Appraisal of determinants of orange-fleshed sweet potato production and utilization in Isiolo County, Kenya. African Journal of Food, Agriculture, Nutrition and Development 22(3): 19886-19909. https://doi.org/10.18697/ajfand.108.19887

KENYA – PROJECT SG1-005: DEVELOPMENT OF A VISUAL DETECTION MICROARRAY BASED METHOD FOR THE DETECTION OF MULTIPLE AFLATOXIN PRODUCING ASPERGILLUS SPECIES

PI: Lilian W. Kamau-Gatogo, Kenyatta University
Dates: October 2019 – November 2021

PROJECT OVERVIEW

Aflatoxins are produced by certain fungi, including *Aspergillus* species, and are found on a variety of crops, including maize. These toxins can lead to acute poisoning and liver damage, and they increase the risk of cancer for those who harvest and consume such crops.

This PEER project sought to determine the safety of maize (corn) consumed by Kenyans and their livestock through studying the amount and type of fungal contaminants in maize not processed by commercial millers. The study found that most of the maize sampled in this study was contaminated with aflatoxin-producing fungi and other fungi. This and other findings on contamination are needed for policymakers and agricultural extension officers to advise farmers on best post-harvest practices to ensure safe nutrition and reduce maize grain losses due to contamination, thus improving food security.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and her team took samples of surface-sterilized maize seeds from Embu, Kitui, Murang'a, and Nakuru counties in Kenya and plated them in potato dextrose agar to determine fungal contamination. They observed that 223 of the 288 kernels showed fungal growth. The percentage of fungal contamination in the maize seeds was highest in Embu, showing 86% contamination, and lowest in the Nakuru samples at 73%.

The PEER team grouped the fungal isolates into *Aspergillus* and non-*Aspergillus* species. Non-*Aspergillus* isolates largely consisted of *Fusarium, Trichoderma, Talaromyces, Trimorphomyces*, and *Schizophyllum,* among others. The *Aspergillus* isolates groups included *Aspergillus niger, Aspergillus flavus, Aspergillus tubingensis*, and *Aspergillus tamari*.

The highest number of *Aspergillus* species (11) was detected in maize seeds from Nakuru County, while the lowest number was detected in maize from Embu County. *Aspergillus flavus* and *Aspergillus niger* formed the bulk of *Aspergillus* species recovered from the maize seeds. The results indicate a high diversity of potentially harmful microorganisms in maize seed food products in Kenya, but the level of aflatoxins produced differed among the species studied.

In addition to pursuing the research objectives of the project, the PI mentored several young scientists, including supporting the research projects of four graduate students. In addition, she was accepted into Women Researchers of Kenya (WERK) and served as a Kenya Bureau of Standards technical committee member and as a conference abstract reviewer.

MADAGASCAR

MADAGASCAR - COV-164: RESILIENT FOOD SYSTEMS AND BIODIVERSITY UNDER FUTURE CRISES IN MADAGASCAR

PI: O. Sarobidy Rakotonarivo, University of Antananarivo
U.S. Partners: Randall Kramer, Andrew Bell, and James Herrera, Duke University
(Funded by the National Institutes of Health)
Dates: October 2022 – March 2024

PROJECT OVERVIEW

The COVID-19 crisis led to severe increases in global food insecurity. In Madagascar, one of the poorest countries in the world, the pandemic aggravated food insecurity by causing lost revenue from exports and tourism, disruption in agricultural markets, volatility in crop prices due to travel restrictions, and increases in the prices of basic commodities. In addition, COVID-19 reportedly undermined Madagascar's unique biodiversity, as people increasingly turned to wildlife trafficking, charcoal production, logging, and forest clearing for agriculture to make up for lost income. The increased urban out-migration caused by the pandemic also put extra pressure on natural resources and increased local demand for food and other needs.

This PEER project aimed to inform the prevention and resolution of future crises by providing better understanding of the impacts of COVID-19 on rural livelihoods and food security and its knock-on impacts on biodiversity in northeastern Madagascar. The project carried out key informant interviews, choice experiment surveys, experimental games, and focus groups to identify the various mechanisms by which COVID-19 altered food security and livelihoods and explore farmer livelihood coping strategies during COVID-19.

The researchers sought to provide key policy recommendations to decision makers and a wider audience, alongside co-production of recommendations with decision makers and affected communities. Beyond the lifetime of the project, the Duke University Lemur Center and the project PI have ongoing related commitments in the Sava region of Madagascar and will be in a position to continue to engage with communities and various stakeholders on these issues.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers undertook this study to investigate the individual and compounding impacts of the COVID-19 pandemic, the Enawo cyclone, and the vanilla price collapse on vanilla farmers in rural Madagascar. Using 60 semi-structured and scenario-based interviews, they examined the various mechanisms through which the pandemic and these cascading crises influenced livelihoods, food security, and natural resource use across two villages in northeastern Madagascar. They found that the impact of the pandemic, combined with the cyclone event and the vanilla price collapse, disrupted livelihoods, resulting in significant income losses and food security challenges that exacerbated farmer vulnerabilities. Importantly, the declining vanilla prices had important spillover impacts, affecting both farmers and residents reliant on alternative income sources. Local communities reported using the forest resources more frequently as a safety net during crises in the village with more lenient regulations.

The field team also implemented a choice experiment survey and experimental games with 200 farmers in the villages of Mandena and Andrapengy to examine farmers' preferences for regenerative agriculture as an alternative to practices that are reliant on input markets (such as monoculture forest-derived vanilla crops) or the need to engage in forest clearing in the event of crises such as COVID19. The experimental games aimed to examine the impact of policy interventions (price shocks and individual payments) on farmer willingness to diversify crops, (and hence increase resilience) and to support forest conservation. They were developed on Netlogo and played on tablet computers in a group of six farmers. Participants in the game could choose to farm vanilla, plant other crops, or leave the forest or fallow land as-is.

Preliminary results indicated farmers highly valued vanilla monocrops and had lower preferences for diversified vanilla agroforestry. Respondents who owned larger vanilla lands were more likely to place greater value on earnings from diversified agroforestry vanilla.

In the games, the presence of shocks such as a drop in vanilla price significantly led farmers to diversify their crops (less monocrop vanilla and more non-vanilla crops). Shocks also incentivized more diversified land uses (defined as a mix of vanilla crops, forests, and other crops) at the landscape level. Favorable perceptions of diversified vanilla agroforestry and total landholdings were also positively associated with more forest / fallow lands in the game landscape. Payments resulted in improved environmental outcomes through increased vegetation on private lands but decreased land use diversity within households. This study also demonstrates how games can provide a low-risk, low-cost tool to predict the impacts of policy interventions, and study how these impacts might differ between various groups of households.

As part of the PEER project, research assistant Rakoto Harison Henintsoa traveled to Boston University to analyze the datasets with the U.S. partner, Dr Andrew Bell, and discuss the preliminary results with his lab group. She also used the opportunity to learn more about various methods of data analysis applicable across various fields through a few one-to-one meetings with members of Dr Bell's lab.

The PEER team also convened community meetings in the last week of March 2024 to share results with their participants in Mandena and Andrapengy villages. A total of 150 participants attended these events, where researchers presented their findings and asked the community their thoughts about the extent to which the results reflect their views and decisions. They also used the opportunity to ask participants about the effect of the ongoing vanilla price decline on their livelihoods. The PI and team have also presented their findings at IASC2023 and the International Food Policy Research Institute. The team has received two additional grants totaling $510,000 for related work from the Swiss National Foundation and the Belmont Forum.

PUBLICATIONS

Rakotonarivo, O. S., & Andriamihaja, O. R. 2023. Global North–Global South research partnerships are still inequitable. Nature Human Behaviour 7(12): 2042–2043. https://doi.org/10.1038/s41562-023-01728-0

Rakotonarivo, O. S., Rakotoarisoa, M., Rajaonarivelo, H. M., Raharijaona, S., Jones, J. P. G., & Hockley, N. 2023. Resolving land tenure security is essential to deliver forest restoration. Communications Earth & Environment 4(1). https://doi.org/10.1038/s43247-023-00847-w

Bell, A. R., Rakotonarivo, O. S., Bhargava, A., Duthie, A. B., Zhang, W., Sargent, R., Lewis, A. R., & Kipchumba, A. 2023. Financial incentives often fail to reconcile agricultural productivity and pro-conservation behavior. Communications Earth & Environment 4(1). https://doi.org/10.1038/s43247-023-00689-6

MADAGASCAR - PROJECT 9-232: IMPROVING HUMAN LIVELIHOODS THROUGH HOLISTIC CONSERVATION OF MALAGASY ORPHANED PLANTS, THE ICONIC BAOBAB TREES

PI: Seheno Andriantsaralaza, University of Antananarivo
U.S. Partner: Onja Razafindratsima, University of California, Berkeley (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: April 2021 – January 2024

PROJECT OVERVIEW

In the past, many long-lived plant species relied on large-bodied terrestrial animals (megafauna) to disperse their seeds. Unfortunately, many megafaunal communities are now extinct due to anthropogenic activities, leaving these plants "orphaned." Madagascar is facing an alarming extinction crisis, including the loss of large-bodied animal seed dispersers, due partially to poaching and illegal trades. However, almost all targeted conservation efforts in Madagascar rarely consider restoring the missing ecological functions within ecosystems. Understanding such disruptions is essential to reduce the risk of extinction of plant species and resolve biodiversity conservation issues.

This PEER project sought to examine the mechanisms ensuring the persistence and regeneration of Malagasy baobab trees (*Adansonia grandidieri Baillon*), an economically valuable, orphaned, and endangered plant species, to advance solutions to promote its sustainable use to benefit local communities. The researchers aimed to characterize the factors allowing baobab's persistence in the absence of its animal partners, evaluate the role of extant native and non-native animals in compensating for the functional loss of their primary dispersers, and provide conservation-targeted solutions that consider local livelihoods, especially considering threats to the rich biodiversity of Madagascar include widespread poverty, especially among the populations that rely heavily on natural resources.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project's field sites were located in two areas of the Menabe region in western Madagascar: Andranomena village to the north of Morondava and Andranopasy village to the south. Extensive fieldwork was conducted during the baobab fruiting season, where researchers, in collaboration with the Ary Saina association, collected data on the fields. The team's research elucidated the orphaned status of baobab trees and the role of secondary dispersers in baobab seed dispersal. A manuscript on these findings was in process at the time of the final project report in the spring of 2024. The project facilitated capacity building among research team members, fostering skill development and promoting scientific expertise within the local context. The PI visited the U.S. partner's lab to further enhance research skills, and the U.S. partner visited a field site in January 2023, gaining insights into the research activities and providing additional training to the students.

Beyond their research efforts, the PEER team transplanted 21,058 seedlings with the help of local community groups—9,033 in Andranomena and 12,223 in Andranopasy. This joint effort not only helped to restore the Baobab habitats but also instilled a sense of responsibility and ownership among the community groups towards the conservation of the Baobab trees. Additionally, the researchers conducted follow-up assessments every three months on the transplanted seedlings, revealing a survival rate of 63%. The team worked closely with the local community groups, VOI AMI and VOI MITI, to create a fire break in the Andranopasy site as a proactive measure to protect the area against the potential risks of natural and human-caused fires.

A PEER team member also undertook a pilot study on fruit production and trade dynamics, providing valuable insights into the economic aspects of baobab conservation. Ferme Aina, a company located in Andranopasy, has expressed its interest in purchasing baobab fruits from the local communities. The project is acting as a mediator between the two parties, intending to ensure that the fruit is not overexploited. The team proposed a quota system to regulate the harvesting of the fruits, while also ensuring that the local communities benefit from the sale of baobab fruits. Once the quota is formalized by CITES and the scientific authority, they can establish a partnership with the local communities.

The researchers organized a three-day workshop to provide stakeholders with a platform for discussing policy implications based on the findings of the project, as well as a closeout event in January 2024, where they discussed project findings with the USAID mission in Madagascar and participants from the field sites. The PI presented findings in several technical academic presentation, and the team received a $25,000 grant from Daughters for Earth for ongoing work in this area.

MADAGASCAR - PROJECT 8-168: IMPROVING MANGROVE FOREST CARBON AND SOCIOECONOMIC DATA TO IMPROVE MANAGEMENT IN MADAGASCAR

PI: Herintsitohaina Razakamanarivo, University of Antananarivo Laboratory of Radioisotopes
U.S. Partner: Richard Mackenzie, U.S. Forest Service Institute of Pacific Islands Forestry
Dates: November 2019 – October 2021

PROJECT OVERVIEW

Coastal Malagasy populations rely heavily on mangrove forests for food (fish, shrimp, and crabs), building materials, and fuel wood for cooking. Mangroves also protect these human populations from tsunamis and cyclones, as well provide climate change mitigation and adaptation by removing and storing large amounts of carbon (C) from the atmosphere. Despite these many benefits, overharvesting of trees for charcoal has resulted major deforestation rates and 20% loss of the country's mangrove forests. Mangrove deforestation not only results in the loss of goods and services provided by mangrove forests listed above but also negatively impacts their ability to keep up with increased rates of sea level rise. Developing community-based management is key to conserving and/or restoring these tightly coupled human-natural systems, but the first steps are using surveys to identify how communities value mangroves economically, culturally, and ecologically and to examine how these social aspects influence important ecological structure (amount of C stored in mangroves) or functions (rate mangroves are accumulating sediment, burying C in their sediments, or rising in elevation relative to sea level rise).

The main goal of this project was to increase our understanding of how socioeconomic, sociocultural, communication, and decision-making contexts impact the ecological structure and functions of Malagasy mangroves, which can be capitalized for national policies as well as for the different strategies of stakeholders in environmental governance.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project was conducted in the mangrove forest in the western part of Madagascar by three teams from University of Antananarivo with the support of the U.S. Forest Service (USFS) team and other partners for purposes of collecting three types of data: carbon data (ensured by LRI), social data (ensured by CERCOM) and economic data (ensured by C3EDM).

The main challenge of the PEER team was to collect and combine carbon, social, and economic data so it can later be used by the stakeholders for sustainable management of mangrove forest in Menabe Region. The project was conducted in seven villages: Betania, Antanimanimbo, Andikà, Andranolava, Manahy, Menaky, Antsatrabo. Collection of ecological data was conducted in 33 plots of intact forest and 33 plots of degraded forest; collection of economic data was done by doing economic surveys with 256 people to identify perception of economic values of mangrove forest; and collection of social data was done via ethnographic approach, observation, and training conducted in each village.

At the conclusion of the project, the team outlined the need to (1) reinforce environmental education in Menaky , Andikà and Manahy; (2) reinforce reforestation in Manahy, Betania and Andranolava; (3) reinforce the work of stakeholders in Betania (4) continue stakeholders' mangrove management in

Antsatrabo and Antanimanimbo and Andranolava; (5) consider a participative approach; and (6) mentor effective income activities in the villages. For the Menabe region, the project team outlined the need for a real application of existing law for Mangrove Forest, reinforcement of the management of income for local population, and the need to control people's migration.

In terms of future plans, the carbon team and ISSEDD consortium are working with USFS partners on carbon inventories in the Eastern. The PEER team plans to integrate PEER data with this work, which should result in publication of another paper on allometric equation of other Malagasy mangrove species.

The project team shared the results of the project with the Malagasy stakeholders (government, NGOs, students, researchers) during the National Celebration Day of Mangroves (national restitution) and the regional restitution (Menabe Region). According to various exchanges between collaborators, they are planning to use this project's data or research in various ways, such as mangrove management and conservation at various levels (i.e. village or community level, local, or municipal).

MADAGASCAR - PROJECT 7-477: BUILDING A REFERENCE COLLECTION FOR MALAGASY ROSEWOOD, PALISSANDER AND EBONY IDENTIFICATION

PI: Bako Harisoa Ravaomanalina, University of Antananarivo
U.S. Partner: John Hermanson and Michael Wiemann, United States Department of Agriculture, Forest Service, Forest Products Laboratory
Dates: November 2018 – December 2022

PROJECT OVERVIEW

This project aimed to address the ongoing illegal logging of precious timber species in Madagascar, particularly species in the genera Dalbergia and Diospyros, known as rosewood, palissander, and ebony. Despite national trade bans, the demand for these woods has led to increased illegal exploitation. This situation resulted in the listing of Dalbergia and Diospyros logs and sawn wood in Appendix II of CITES to monitor trade legality and protect these species. However, identifying individual species and points of origin is challenging without associated botanical materials. Moreover, gaps in the taxonomic circumscription of these species add to the difficulty, as Malagasy precious woods have traditionally been traded under local vernacular names.

The project developed accurately identified collections of wood specimens and their associated herbarium vouchers for all Malagasy CITES-listed Dalbergia and Diospyros species housed at the University of Antananarivo. These collections were used for taxonomic revisions and establishing and validating different identification systems. A reference collection was created, including supplemental information for each sample, providing reliable reference samples for developing emerging wood identification methods. Identification systems based on wood anatomy and analytic-based tools, including machine learning, were finalized. To reduce species extinction risk, the team promoted ex-situ conservation at four sampling sites and protected areas, setting up nurseries to grow and plant rosewood, palissander, and ebony throughout Madagascar.

This project facilitated an exhaustive inventory of Dalbergia and Diospyros species in Madagascar, aiding decision-makers in evaluating the current status of precious wood resources. It aimed to replace the unsustainable and often illegal trade with a sustainable and equitable commercial system, benefiting local communities and promoting long-term income generation. By organizing and managing the commercialization of precious woods, the project sought to contribute to economic development, generating significant revenue locally and nationally. These efforts supported the scientific community's commitment to establishing a controlled and well-managed commercial precious woods sector, essential for sustainable exploitation.

FINAL SUMMARY OF PROJECT ACTIVITIES

Seventeen sampling campaigns were carried out in eight regions of Madagascar during the project, resulting in 651 collections, composed of 347 Dalbergia species, 281 Diospyros species and 26 others genus. These collections bring the total to nearly 2206 herbarium specimens, 917 herbarium specimens for morphometry, 2422 leaves in silicagel, 1019 branches, 603 barks, 580 stem woods and 38 flowers in alcohol. These samples contribute significantly to improved species delimitation in both genera, while also informing conservation assessments and providing taxonomically verified material for morphological, anatomical, spectrometric, and DNA sequence research in support of the development of reliable identification tools.

The 2206 herbarium specimens were mounted and labeled MBEV104390 for reference. They were then deposited in the herbarium of the Department of Plant Biology and Ecology. The cross-sectional surfaces of the 580 stem woods were polished. A Gw code "Gasikara wood" was assigned to each wood specimen in the collection at the xylotheque of the University of Antananarivo. Each herbarium specimen corresponds to a wood specimen and the information on these specimens is available in the common database of the G3D project (b3dm 1.0).

Comprehensive data on all target tree species of Dalbergia and Diospyros is available via TROPICOS and the Madagascar Catalogue (potentially sensitive data masked to prevent public access).

Madagascar's first wood library—the Xylotheque of the University of Antananarivo—was inaugurated on December, 18, 2020, and houses around 4500 wood specimens, mainly Dalbergia and Diospyros species and their lookalikes. Forty Dalbergia species among the 48 from the literature (Bosser & Rabevohitra, 2006) are currently in wood reference library. Forty seven percent of Diospyros species (about 114) from 250 species of Madagascar catalogue (www.tropicos.org) are available. Herbarium vouchers, samples for sectioning, and microscope slides are available for scientists and users.

Another output from this project was an anatomical atlas of Dalbergia and Diospyros species from Madagascar, authored by Harisoa B. Ravaomanalina, John C. Hermanson, and Michael C. Wiemann. This second version of the atlas is available and is more thorough, and includes more species and more replicate samples of each, listing 40 species of Dalbergia and 25 species of Diospyros . It focuses on macroscopic wood identification and includes character lists to be used in a proposed identification key. An advantage of this second version is that macroscopic and microscopic features are simultaneously presented. It is useful for both traders and competent authorities who analyze wood specimens as well as for scientists who rely on microscopic anatomy for further identification.

In terms of wood species identification methods, the standardized sampling protocol used for this work includes the preparation of samples to be used for a variety of identification techniques from different laboratories in Madagascar and abroad, including wood anatomy, NIRS, DART-form, DNA analysis, etc. This newly developed and field-approved sampling protocol will expand the existing sample to include all species of Dalbergia and Diospyros and their look-alike species, with multiple samples of most species. The samples are ready to be shared with other scientists.

Beyond their research efforts, the PEER team and its collaborators restored more than 4000 plants in the forests of Ambohidray, Ampasindava, Marolambo, and Tsitongambarika, with 2500 more waiting to be planted. In terms of capacity building for students, seven Master's students took advantage of the project and analyzed scientific data on Dalbergia and Diospyros species anatomy and growth analysis and needed basic documents of Ambohidray Protected area.

As for broader project impacts, thanks to this project and Dr. Harisoa's and her team's research and the scientific advances of the Malagasy Precious Woods Consortium, Dr. Ravaomanalina has been able to identify the list of commercially valuable of Malagasy Dalbergia and Diospyros species action plan in CITES Décision 18.98 in paragraph a), required by the CITES Secretariat. Thanks to the effort deployed in this PEER project, a pilot xylotron wood identification tool based on wood anatomy (macroscopic and microscopic levels) for 19 Dalbergia and 23 Diospyros species was developed.

Finally, with regard to the third objective of the project to promote conservation, a protected area development and management plan has been established for the four sampling sites. This contributes not only to an effective involvement of the local population in the conservation of threatened trees but to a reliable and efficient implementation of the Development and Management Plan for Ambohidray, Tsitongambarika, Marolambo and Ampasindava protected areas.

Now that the project has been completed, in terms of future plans, Dr. Ravaomanalina reports, that she will continue to work on automated anatomical wood identification systems. To put her research results into practice, she will continue and complete the implementation of needed data for all large trees Dalbergia and Diospyros species with her U.S. partners to make the Xylotron machine functional. It is an automated anatomical wood identification system using portable device using both analytic-based wood species tools (xylotron) developed by Drs. Wiemann and Hermanson from USDA and Xylorix identification platform performed by Dr Yong Haur Tay from the Centre for Computing and Intelligent System (CCIS), Malaysia. Two methods have been developed and performed to imitate the capability of a human wood anatomist in different airports, to identify which type of timber the piece of wood belongs to. Both do not require a special competence from the users developed for non-specialists to identify unknown woods in the field.

In terms of capacity building, training of CITES stakeholders was planned within the framework of this project, but because of the pandemic it was not carried out. On the one hand the goal is to facilitate the work of the enforcement authorities and to achieve the compliance of the current listings by equipping them with very practical tools (i.e., the xylotron and xylorix) and performing on-site wood identification with very minimal training within all Malagasy concerned regions. On the other hand, the goal is to train them to enhance their capacity for wood identification which will assist during interdictions, investigations, enforcement of harvested timber and export in order to comply with CITES regulations and to ensure the legacy of the wood at national and international level.

PUBLICATIONS

Ramanantsialonina, R. N., Crameri, S., Sandratriniaina, N. A., Wiemann, M. C., Hermanson, J. C., Rakouth, B., & Ravaomanalina, B. H. 2022. Comparative wood anatomy of 16 Malagasy Dalbergia species (Fabaceae) using multivariate techniques, IAWA Journal (published online ahead of print 2022).https://doi.org/10.1163/22941932-bja10105

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MADAGASCAR - PROJECT 6-134: COMMUNITY-BASED MONITORING AND MANAGEMENT OF MADAGASCAR'S NATIONAL PARK PROTECTED AREAS

PI: Lalatiana Randriamiharisoa, Madagascar National Parks
U.S. Partner: Brett Scheffers, University of Florida (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: December 2017 – December 2022

PROJECT OVERVIEW

Madagascar National Parks (MNP) has a mandate to manage and conserve its protected area network of more than 2 million hectares of land; therefore, MNP needs efficient ways to collect data to inform its management practices. However, the data collected so far are disparate and do not cover the diversity of ecosystems under the park system's purview, a problem that might be rectified by tapping into the biodiversity knowledge of local communities and MNP rangers.

This PEER project focused on improving and streamlining MNP's data collection process via integration of local communities. The project provided local communities the opportunity to participate in the conservation of their local protected areas and helped create a local economy tied to biodiversity monitoring, which creates value for biodiversity outside of traditional natural resource extraction and use. Six protected areas were selected as study sites to cover the diversity of ecosystems and wildlife present throughout Madagascar, as well as a climate gradient to assess possible impacts from the wettest to the driest regions.

This project tested whether local communities can collect data and take leadership and ownership over the management of their protected areas, built up capacity, and assessed the ability of the local community to effectively and accurately monitor biodiversity and ecological parameters by comparing results from the expert team and the community-based team. The PI and her colleagues leveraged local community group (CLP) participants identified by the MNP. At the end of the project, the CLP members had the opportunity to enhance their knowledge and community linkages through training by the PI and the wider research team. The project focused on the conservation impact of the project and the socioeconomic impact of the 65 communities involved.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team began by training CLP members, park rangers, and MNP staff on survey methods, identification of target taxonomic groups, basic principles of climate and climate change, and installation and monitoring of climate stations. The PI and her U.S. partner also installed two microweather stations at each site to help determine whether climate has had an impact on biodiversity. During the first data collections, student researchers followed and collected data alongside CLPs, in order to ensure that CLP practices and data recording were accurate. Once confirmed, CLPs independently collected data monthly for six months. Students from the University of Antananarivo also collected biodiversity data in the same sites as the local community for comparison purposes .

By comparing the species identified by local community members in the six protected areas, the researchers found that community members were able to perform about as well as experts. The results suggest that community members saw about as many species as experts (and on average, a bit more). However, experts saw higher per species abundance on average, in large part because they saw far more individuals of common species. The numbers of species encountered by the CLPs and experts were almost the same across the four protected areas. On predicted species accumulation, after 150 days of monitoring effort, community members reached a plateau of improvement. Overall, the project showed an improvement in the quality of data collected on biodiversity, both by the local communities and by the park officials. This improvement was partly due to access to the identification guides originally produced at the start of the project and partly thanks to enhanced data collection in the field made by the PEER team and their trainees during the project.

The biodiversity monitoring method for this project has been adopted by each park. The monthly rounds by local community members have led to a crackdown on unauthorized people roaming in the protected areas, which may have reduced the number of trees illegally cut. Participating local communities exchange visits in each protected area, which was notable as many people involved had never traveled before. The exchange visits strengthened collaboration between the CLPs and the MNP staff.

The concept of women working as part of the local park committee resulted in a heated discussion during one exchange, as Andohahela National Park has eight female participants. That surprised CLPs at other parks where women are not allowed to participate, and yet, based on women's effective participation in this project, it is evident they are all as capable to work in conservation as men. According to the PI Dr. Randriamiharisoa, the women have been even more effective than the men in raising awareness of the relevant issues. The CLPs received compensation for their participatory work, and for some their earnings became their monthly source of income. Some participating community members were able to increase their livestock or poultry and further their agricultural activities, others were able to buy household supplies, while others used the funds to send their children to school.

The PEER team created and hosted a new workshop on structuring and cleaning databases and data analysis that can serve as a new ecological training program. They presented their findings at the 2022 annual meeting of the Association for Tropical Biology and Conservation in Cartagena, Colombia, and were awarded a new $79,000 grant from the Foundation for Protected Areas of Madagascar (FAPBM) for a similar project focused on vegetation monitoring.

PUBLICATION

Fiona Price, Lalatiana Randriamiharisoa, and David H. Klinges. 2023. Enhancing demographic diversity of scientist-community collaborations improves wildlife monitoring in Madagascar. Biological Conservation 288: 110377. https://doi.org/10.1016/j.biocon.2023.110377

MADAGASCAR - PROJECT 6-125: WILD AND EDIBLE INSECTS TO SUSTAIN FORESTS AND FIGHT MALNUTRITION.

Pi: Andrianjaka Ravelomanana, Madagascar Biodiversity Center
U.S. Partner: Brian Fisher, California Academy of Sciences (Funded by the National Science Foundation)
Dates: December 2017 – August 2021

PROJECT OVERVIEW:

Insects farmed for food can provide an environmentally sustainable and nutritious alternative to traditional protein sources. Insects offer a greater range of nutrients than commonly consumed meats and require a much smaller footprint to produce. In Madagascar, insects are an indispensable part of seasonal diets for many ethnic groups. This research team aimed to strengthen the tradition of eating insects with innovative techniques to make this valuable food resource available year-round while encouraging forest conservation. Their method linked the benefits of insect farming with maintaining a healthy, natural forest habitat. The project aimed to improve the diets of malnourished children by promoting a farming system that increases the forest's value to local people.

The project evaluated suitable insect species for commercialization and created a knowledge bank of edible insects in Madagascar. One species was chosen for protein powder production and another for whole insect consumption. Researchers conducted experiments to determine optimal conditions for commercial-scale farming, including an evaluation of biological cycles, nutrient content, and other technical variables affecting farming costs and conservation impacts. They also assessed local attitudes towards insect consumption to ensure the program's suitability for local markets. The research was conducted in collaboration with local NGOs, the private sector, and a team of international mentors.

FINAL SUMMARY OF PROJECT ACTIVITIES

Insect farming releases much less greenhouse gas, methane, and ammonia than raising cattle and pigs, and requires less water, less space, and less time. Those aspects alone are enough to promote insects for human consumption and to start changing dietary behaviors. Improving the long-standing Malagasy cultural attitudes towards edible insects and promoting their consumption were the main goal of the project. The first two years were focused on gathering knowledge on edible insects and the development of their farming techniques. For the Malagasy people, eating insects is part of their diet but their popularity depends on the region, seasonality, and ethnic groups. Merina and Betsileo are the main ethnic groups in the country with insects being part of their diet. Two graduate students conducted research on this, and part of their commitment remains to publish at least two articles in a scientific journal.

Overall, the project team's findings highlight that human activities with special concern to deforestation associated with climate change are the main factors to the decline of the insect population. This is the case for major edible insect species largely consumed such as sakondry (*Zanna tenebrosa*) and the wild silkworm (*Borocera cajani)*. In late December 2020 the Wildlife Conservation Society in the National Park Makira gave the project team an opportunity to create a few pilot farms. This is one of the team's current activities allowing the project to maximize links to conservation and increasing the perceived value of forests. The team's research in this forest led to understand that the availability and habitat destruction were the main cause of the entomophagy decrease. An important step was also taken in terms of promotion of the project. The team engaged in different dissemination activities including attending national events to promote new tools to fight malnutrition. The project team recommend to use cricket powder and integrate its use into the national food policy.

The team produced 573 kg of cricket powder in 2020, with the same amount produced within the first seven months in the following year. According to the PI, the local market promises new opportunities and enhances the value of the project team's product due to the ongoing food security issues in the south of Madagascar. The main buyer of the cricket powder, Catholic Relief Services, has maintained its continuous procurement of cricket powder for schools, and new investment companies are stepping forward showing their interest in the product.

In terms of cricket nutrient research, convincing consumers to embrace insect consumption is often focused on reporting benefits of its nutrient levels, and lower land use requirements during their production. It was important to highlight the epistemological aspect of consumer acceptance of crickets as food. This step allowed the team to promote their product more effectively. During 2020, the project team sold 85 kg to CRS for supplementing food in schools in the North and to the Tuberculosis hospital in the South of Madagascar, while in 2021, the production grew to 100 kg

As for cricket powder production, the project team refined and developed their technique for large-scale production of native crickets in the course of the project. They are now well positioned to share the principles of cricket farming and will create a pilot farm in the south of Madagascar where the need is the highest. In addition, the project team has received positive feedback from their partners, Paradise Garden, regarding the efficiency of their bio-fertilizer produced from cricket frass. The team produced 1.7 tons of frass, and half of this will be shared with local farmers. The remaining bio-fertilizer will be used for reforestation in Manombo Forest, in the East of Madagascar.

For more information on how the idea of the project was conceived, see the article by Andy Isaacson entitled Farming Insects to Save Lemurs.

MALAWI

MALAWI - PROJECT 9-493: BRIDGING HIGHER EDUCATION AND PRACTICE: ADDRESSING GENDER INEQUITY IN STEM AND SANITATION IN MALAWI

PI: Brighton Chunga, Mzuzu University
U.S. Partner: Francis L. De Los Reyes III, North Carolina State University (Funded by the National Science Foundation)
Dates: April 2021 – September 2023

PROJECT OVERVIEW

Malawi faces significant challenges in the water and sanitation sector. Currently, household sanitation in Malawi primarily consists of simple pit latrines, a basic hole in the ground often surrounded by an enclosure made of local bricks and either a grass or iron sheet roof. Given the increase in population density, this technology is pushed beyond capacity by both high-volume usage (requiring routine emptying) and lack of space for the construction of new pits, especially in urban areas. Women and girls in particular face health and safety risks, as they are primarily responsible for the management of household sanitation and require adequate infrastructure for menstrual hygiene.

A well-trained, expert-led, sanitation sector is needed to meet this challenge. In Malawi, no university offers a four-year bachelor's degree in sanitation and currently, sanitation is only a topic in related STEM degree programs. This project sought to improve sanitation in Malawi, particularly for women and children, through improving gender equality in STEM education, particularly sanitation-focused education, and fostering a more gender-inclusive sanitation policy.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Chunga and his team conducted a comprehensive investigation into the barriers or drivers of gender inequity, especially in sanitation and STEM education in Malawi, starting from high school. The researchers undertook this study in 15 out of 28 districts in the country, involving different high schools categorized as rural, urban, peri-urban, and lakeshore. Among their findings was that while sanitation plays a critical role in the public health and water resources sectors, there is no specific undergraduate degree program in sanitation in any of the higher education institutions in Malawi.

The team therefore developed an undergraduate degree program in integrated sanitation at Mzuzu University in the Department of Water and Sanitation, Faculty of Environmental Sciences. The curriculum is specifically designed to address emerging issues in sanitation and public health in Malawi: COVID-19, the prevalence of cholera, and flooding impacts due to climate change. The program is being vetted by the university's academic planning committee and other relevant units. Once vetted, it will be rolled out in the next academic year, and the national regulatory body, the National Council for Higher Education (NCHE), will be invited to accredit the program.

The team also organized a Girls Science Day at Mzuzu University in which 100 young girls from five schools in Mzuzu City were taught lessons in Water Sanitation and Hygiene (WASH), took part in science laboratory demonstrations, and talked to female college students who were studying science and engineering. The PEER project also supported female postgraduate students with scholarships.

The researchers presented their findings at the 2nd Paris Conference on Education and published an article. The PI has received additional grants worth $28,000 to continue his research, and the project has also led to another WASH-focused project funded by the National Science Foundation to support field-based student research experiences in Malawi.

PUBLICATION

Brighton A. Chunga, David Mkwambisi, Cassandra L. Workman, Francis L. de los Reyes III, and Rochelle H. Holm. 2022. Educating sanitation professionals: moving from STEM to specialist training in higher education in Malawi. Waterlines 41:3, 1–13. https://dx.doi.org/10.3362/1756-3488.22-00662

MALAWI - PROJECT 1-307: SOIL CARBON DISTRIBUTION AND DYNAMICS IN MALAWI: A UNIQUE OPPORTUNITY TO OPTIMIZE SUSTAINABLE LAND USE AND ENHANCE FOOD SECURITY

PI: Jimmy Namangale, Chancellor College

U.S. Partner: G. Philip Robertson, Michigan State University (Funded by the National Science Foundation)

Dates: June 2012 – May 2015

PROJECT OVERVIEW

To ensure food security for the world's burgeoning population and to cope with limited fossil fuel supplies, it is essential to understand how resource-limited farmers can manage soil quality, especially the levels of soil carbon, because of its key role in soil fertility and agricultural productivity. The project aimed to revisit more than 1,000 soil sites in Malawi where soil carbon was quantified at multiple depths in the 1990s to examine patterns of soil organic carbon storage. Such patterns are critical to understanding ecosystem processes and its feedback to the atmospheric composition, rate of climate change, soil fertility, and agricultural production. Carbon credits have been proposed as one way to support African farmers while achieving soil conservation goals and reducing greenhouse gas emissions, but there is a void of knowledge concerning soil carbon status on smallholder fields.

The goal of the project was to understand soil carbon spatio-temporal patterns and processes in Malawi and explore the impact of agricultural land management as it relates to food productivity in the country.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team excavated soil samples from a variety of sites and archived some for future use. In collaboration with the Forest Research Institute of Malawi, researchers undertook a continual chemical and carbon analysis of the soil samples,

Due to the insufficiency of the country coverage in the excavations, only the available baseline data was used to come up with soil maps of Malawi, as this data had a larger coverage. The team also interviewed farmers at soil excavation sites and two Master's students in environmental science finalized their dissertations during the project period.

MALAWI - PROJECT H1-5: INTRODUCING "OPTION B+" IN MALAWI: IMPACT ON CHILD OUTCOMES

PI: Frank Chimbwandira, Malawi Ministry of Health
U.S. Partner: Matthias Egger, University of Bern
Dates: May 2013 – April 2018

PROJECT OVERVIEW

In September 2011, Malawi introduced the "Option B+" strategy to prevent mother-to-child transmission (MTCT) of HIV and started all pregnant and breastfeeding women on lifelong antiretroviral therapy (ART), regardless of their clinical condition or CD4 cell count. Option B+ may also reduce maternal morbidity and mortality, decrease transmission between serodiscordant partners, and raise the rate of child survival by reducing HIV mother-to-child transmission and improving maternal health. However, concerns have been raised about the implementation of Option B+, acceptance of ART, and adherence and retention in care among Option B+ patients, who typically initiate ART in the early asymptomatic stage of an HIV infection. This PEER research project evaluated the Option B+ program in Malawi, identifying challenges to program success by determining and describing the individual-, community- and health-system-level factors that limit or increase ART uptake, adherence. and retention in care.

The researchers analyzed the effects of introducing Option B+ on HIV MTCT rates, HIV testing in infants, ART initiation in children, ART adherence, loss to follow-up, and treatment changes among women who started ART with an Option B+ indication. They also examined the associations between PMTCT interventions and mother and child outcomes, such as HIV testing rates and obstetric and newborn complications.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team digitized routinely collected paper-based antenatal care (ANC), maternity (MAT), and HIV-exposed infants (HEC) records from 13 district hospitals, 2 central hospitals, 3 mission hospitals, and 3 large health centers in central and southern Malawi. Data was double entered and cleaned. Researchers also conducted focus groups and qualitative interviews with Option B+ patients and health care providers. Key findings from the study included the following:

- There was a low rate of confirmed MTCT after the introduction of Option B+, but due to poor retention only about one-half of HIV-infected children were diagnosed.
- One-third of women in the Option B+ program adhered inadequately during pregnancy and breastfeeding, especially soon after delivery.
- Women who stayed on ART through breastfeeding are motivated to continue lifelong ART.
- HIV-exposed uninfected infants born in the Option B+ period experienced faster weight gain than infants born before Option B+.
- Option B+ was more expensive than Option B, but despite the higher costs, Option B+ will likely become a cost-effective strategy in the long term.

- Compared to women who started ART in WHO clinical stage 3 or 4 or with low CD4 cell count, Option B+ patients who started ART during pregnancy were at a five times higher risk to be lost to follow-up at the first follow-up visit.
- Retention on ART across all age groups improved in the early years but remained constant thereafter, despite the burden posed by expansion of ART coverage on the healthcare system.
- The researchers found no association between stillbirth and timing of ART initiation.

The PI Dr. Chimbwandira contributed to the creation of a government working group on improving Option B+ adherence. He and his colleagues also published several papers from their analyses and presented results at both local events (National AIDS Commission and College of Medicine research dissemination conferences) and international conferences (IAS, CROI, IWHOD). They collaborated with partners involved in PMTCT programs and launched a knowledge-sharing platform for government hospitals. The team co-organized a workshop with Mothers to Mothers on promoting translation of PMTCT research into policy and established a PMTCT community of practice (CoP). The PEER project leads wrote a policy brief that proposed strategies that could address the problem of sub-optimal retention in care for Option B+.

The evidence from the PEER project has led to development of strategies aimed at improving retention in care. For example, some research institutions have conducted interventional studies where SMS reminders, expert clients, and mentor mothers have been piloted. The team also received a new grant of $87,000 from the National Institutes of Health to supplement their analysis on growth outcomes of HIV-exposed uninfected infants and cover the rest of their expenses.

PUBLICATIONS

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MALI

MALI - PROJECT 8-207: DEVELOPMENT OF HAY PRODUCTION TECHNIQUES FOR LIVESTOCK FATTENING AND AGRO-PASTORAL RESILIENCE IN THE WESTERN SAHEL OF MALI

PI: Moussa Karembe, University of Sciences, Techniques, and Technologies of Bamako (UTTB)
U.S. Partner: Niall Hanan, New Mexico State University (Funded by the National Aeronautics and Space Administration)
Dates: December 2019 – June 2021

PROJECT OVERVIEW:

The objectives of this project were to strengthen the economic development, food security, and resilience of rural pastoral and agro-pastoral communities in the Western Sahel of Mali. Specifically, the principal investigator and his colleagues designed and implemented demonstration projects in the administrative districts of Koutiala and Yorosso (Region of Sikasso) and Nioro and Dièma (Region of Kayes), providing rural pastoralists and agro-pastoralists with new strategies for small ruminant well-being during the late dry season (or "lean season"), when lack of forage, high livestock mortality, and animal weight loss and reproductive failure are common problems faced by Sahelian producers.

The project began with an assessment of animal nutrition and an economic cost-benefit analysis of hay and/or silage production across a rainfall gradient from the dry Sahel to the mesic Sudanian savannas. The researchers then examined the potential interactions between herbaceous production and nutritional status across the gradient climatic that might favor hay production over silage, or vice versa. They also developed and implemented methods to monitor land use and forage production in the grazing lands of southern Mali using available satellite data and cloud-based computation.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project demonstrated the production opportunities for highly nutritional hay if the biomass is harvested at the end of the rainy season to rural pastoral communities in the Sahelian zones of Dièma and Nioro. This is in contrast to herders of the Sudanese zones, Koutiala and Yorosso, where pastures are rare and of low nutritional value. Herders in these zones were shown that they must cultivate forages during rainy the season in order to provide supplemental feed for their animals during the dry season. Doing so will allow small producers to improve the health, growth, and reproducibility of their animals, and therefore the nutritional well-being of their families, during difficult times. The preliminary results and overall project objectives were shared with stakeholders and received media coverage, thereby reaching a greater number of communities, as well as highlighting how its adoption may protect these communities and the environment by reducing late season bush fires.

The project also contributed to reducing unemployment among young graduates from the livestock sector who did their end-of-cycle internship for the project. After acquiring experience with the project, they moved to promoting innovation in the livestock sector and increasing the value chain in the Sahel.

Additionally, through the project, the team was able to strengthen inter-university collaboration between the UTTB of Mali and the University of Abomey-Calvi of Benin. Promising ideas have been developed for joint research and student exchange programs.

PUBLICATIONS

Kanambaye B., Karembé M., Niall H., Dembélé F., et Diallo S. Détermination du potentiel pastoral herbacé des parcours dans les communes rurales de Dièma et Guétéma du Sahel occidental au Mali. 15ème JSD_C, Dakar Sénégal, 15p.

Kanambaye B., Traoré L., Karembé M., et Niall H., 2020. Impact des changements climatiques sur l'évolution du système d'élevage transhumant au Mali: Cas des zones de Nioro et Diéma dans la région de Kayes au Mali. MSAS, 11ème Conférence du 21-23 déc. 2020 ; Vol 2, pp : 635- 643.

Karembé M., Dembélé F., Kanambaye B., et Diagneo A. Effet du feu et de la pâture sur le potentiel des ligneux en zone soudano-sahélienne au Mali: cas des terroirs de Lakamané et de Korokodio dans la région de Kayes. 1ère JSD-DER-Bio-FST/USTTB, 14 novembre 2020 ; Bamako, Mali, 17p.

Karembé M., Kanambaye B., Dembélé F., et Diallo S. Caractérisation du potentiel fourrager herbacé pour l'embouche ovine au Mali : cas des terroirs de Diéma et de Guétéma dans la région de Kayes. 1ère JSD-DERBio- FST/USTTB, 14 novembre 2020 ; Bamako, Mali, 15p.

MALI - PROJECT 8-102: PRODUCTION OF COMMERCIAL BIOPLASTIC-BASED BIOPESTICIDE TO CONTROL AFLATOXIN CONTAMINATION IN CROPS

PI: Amadou Hamadoun Babana, University of Sciences, Techniques, and Technologies of Bamako
U.S. Partner: Hamed K. Abbas, United States Department of Agriculture/ Agricultural Research Service
Dates: August 2020 – November 2021

PROJECT OVERVIEW

Peanut and maize are important crops in West Africa, mainly due to their contribution to poverty reduction and food security, but contamination of these crops by aflatoxins, produced mainly by *Aspergillus flavus,* constitutes a major constraint. Because of the compound's high toxicity, the European Union has banned the import of peanuts with an aflatoxin content above 4 µg/kg, restricting African peanuts in international trade and raising important health concerns in West Africa and elsewhere for those exposed to these toxins at high levels.

Scientists from the PI's institution have shown that a locally isolated *Bacillus sphaericus* OP6 inhibits fungal growth and aflatoxin production by more than 90% under laboratory conditions but was less effective on peanut crops under field conditions. Granules of bioplastic (cornstarch-based material) have been investigated as an alternative nutritive carrier for biocontrol microbes and compounds. The primary goal of this PEER project was production of commercial bioplastic-based biopesticide to control aflatoxin contamination of crops in Africa, improving the peanut production sector, lowering pesticide expenses, and alleviating smallholder poverty, including women peanut farmers. This project builds on the research experiences of the PI and his project team, as well as a previous PEER grant.

The project sought to include women in the bioplastic biopesticide production and commercialization processes and ensure that they have access to training on the technology. Techniques and technologies developed in this project with peanut farmers can be readily transferable to other crops such as cereals, and relationships developed with farmers built trust to enhance farmer amenability to the adoption of other sustainable agriculture practices.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers isolated an *Aspergillus flavus* strain that cannot produce aflatoxin and *Cyclopropionic acid* (CPA). With training from the U.S. partner, they produced potato starch bioplastic and formulated bioplastic-based biopesticides containing atoxigenic *Aspergillus flavus* or the *Bacillus sphaericus* OP6 spores.

Twenty-five farmers participated in the biopesticide field test, and more than two hundred farmers attended field visits to see results. Results showed that the use of these biopesticides led to the production of peanuts and maize with aflatoxin contents lower than the European standard. The PEER team presented their findings at universities, the Malian Academy of Science, and for farmers, researchers and agricultural dealers. They also organized workshops and a training course, which attracted participants from more than 40 stakeholder institutions in the country on biopesticides for cereal crops.

The PI received two new grants, worth a total of about $220,000, for related work from the Competitive Fund for Research and Technological Innovation (FCRIT). The project results attracted significant attention, and the president of the Malian Association of Users of Research Results contacted the team seeking more information and to obtain the biopesticide, which is now in great demand among peanut producers from the testing phase. After two working sessions, they decided to aim to provide the biopesticide to all producers in the major peanut and maize production areas in Mali. The team met with a biopesticide production company collaborating with the association to facilitate expanded access to the biopesticide. Another biopesticide production company also expressed interest in the product and decided to participate in further field tests. If the results are proven in these additional tests, the company plans to provide financial support to improve the biopesticide further.

MALI - PROJECT 6-157: EVALUATION STUDY OF THE USE OF DIGITAL TECHNOLOGIES FOR AGRICULTURE AND FOOD SECURITY IN MALI

PI: Amadou Sidibé, Institute Politechnique Rural Katibougou

U.S. Partner: Laura Schmitt Olabisi, Michigan State University (Funded by the National Science Foundation)

Dates: January 2018 – October 2019

PROJECT OVERVIEW

Research on technology in a developing world context, particularly in Africa, is sparse, with studies on technology adoption and diffusion focusing mainly on descriptive statistics. However, such statistics do not offer much insight into the process of technology adoption or productivity growth. This project aimed to contribute to theoretical and methodological perspectives on innovation and technology development in Mali. The research focused on understanding not only which digital technologies fit into specific socioeconomic contexts but also the enabling conditions required for their inclusive use across scales.

The NSF-funded project headed by the U.S. partner studied the drivers of food insecurity in West Africa using a participatory modeling approach. Stakeholders at national and local levels were involved in the modeling process and in identifying drivers of food security and coping mechanisms for food insecurity. Digital technologies were proposed in Mali as partial solutions to food insecurity. For example, mobile phones were used to guide farmer decision-making through expert advice on issues such as the right period for sowing crops and market information like the price and demand for different crops. Digital technologies, combining mobile phones and remote sensing, provided extension services, improved agriculture statistics compilation, and helped define and document land rights, reducing conflict and improving tenure security.

The NSF-supported project incorporated data collected under this PEER project to determine the effectiveness of these technologies under different conditions. This PEER project sought to yeald important insights into how farmers altered their decisions after receiving enhanced information, helping to refine the agent-based models under the U.S. partner's project.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main conclusion as highlighted in a paper under review at the time of the final project report was that the development of new technology is not a panacea but the beginning of a long process of matching the intention of designers and the need and desire of users. The uptake and use of technology are therefore a collective performance built around an iterative process of trials, errors, and redesign. The technology diffusion and intake could make a leapfrog if a feedback mechanism between the design and the use is clearly established at the onset and integrated into the diffusion and the adoption process. It is essential to consider that the technology is designed with embodied intentions that need to engage in open discussions and accommodate the needs, aspirations, and desires of the users driven by specific socioeconomic conditions different from the designers 'ones and in which the technology is introduced. In short, the adaptation of technology to users' conditions and aspirations is essential for technology intake.

One positive outcome of their research is that it allowed different stakeholders to jointly discuss the issues of concern around the use of digital technologies. This raised the awareness difference in expectation between stakeholders. For instance, the local telephone company learned of the need to enlarge the network coverage and take additional measures for widespread use of the services they provide including adapting the services to socioeconomic conditions of users in terms cost, as well as, the nature and the quality of the service. Their feedback events pointed to the need for the telephone company to consider the way they communicate with farmers the users of technologies.

PUBLICATIONS

Laura Schmitt Olabisi and Amadou Sidibé. 2023. Observations from a system dynamics modeling field school in Mali. System Dynamics Review, January 2023. https://doi.org/10.1002/sdr.1726

Laura Schmitt Olabisi, Amadou Sidibé,·Elsie Assan,·Jelili Adebiyi,·Edmond Totin, and Mary Thompson-Hall. 2022. Building consensus and increasing self-efficacy: participatory scenarios as a tool for developing food security solutions in West Africa. Regional Environmental Change 22: 21. https://doi.org/10.1007/s10113-022-01893-4

Udita Sanga, Amadou Sidibé, and Laura Schmitt Olabisi. 2021. Dynamic pathways of barriers and opportunities for food security and climate adaptation in Southern Mali. World Development 148: 105663. https://doi.org/10.1016/j.worlddev.2021.105663

Amadou Sidibé, Laura Schmitt Olabisi, Hawa Doumbia, Kadiatou Touré, and Cris Auguste Niamba. Barriers and enablers of the use of digital technologies for sustainable agricultural development and food security: Learning from cases in Mali. Elementa Science of the Anthropocene 9: 1. https://doi.org/10.1525/elementa.2020.00106

MALI - PROJECT 6-142: IMPROVING PARKLAND MANAGEMENT AND AGRICULTURE USING UAV TECHNOLOGY IN MALI

PI: Fadiala Dembele, Institute Politechnique Rural Katibougou
U.S. Partner: Paul Laris, California State University, Long Beach (Funded by the National Science Foundation)
Dates: May 2018 – October 2019

PROJECT OVERVIEW:

This research integrated new theories of disequilibrium ecology and human land use practices to develop a human-ecological model of savanna dynamics. In particular, the study integrated anthropogenic disturbance regimes and disequilibrium ecology principles to determine their impacts on tree establishment and growth. Answers to these questions have clear implications for tree cover, carbon sequestration, and human livelihoods, especially for women, who most often gather, utilize, and sell valued tree products. This study aimed to provide valuable baseline data on tree phenology for an understudied part of the world, and it addressed questions pertaining to the basic science of savanna ecology by answering fundamental questions about competition between grasses and trees at different life-cycle phases. This project advanced human ecology by integrating it with disequilibrium savanna ecological theory to quantify how particular human activities affect plant distributions and vegetation characteristics. It produced spatially and temporally explicit evidence of landscape change and clarified processes through which human activities have affected vegetation characteristics. This study also advanced biogeography by clarifying how socioeconomic and biophysical factors contribute to range expansion for tropical tree species. Finally, this research suggested practical strategies to conserve and enhance parkland vegetation, based on the relationships between indigenous management practices and vegetation diversity. Natural resource management laws in West Africa often emphasize prohibiting particular activities even though the basis for such prohibitions are poorly grounded in scientific or local knowledge of ecological processes. By identifying processes that contribute to parkland development, this project ultimately aimed to improve management of renewable resources, biodiversity, and sequestered carbon.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main aim of this project was to provide valuable baseline data on tree phenology for an understudied part of the world and address questions pertaining to the basic science of savanna ecology by answering fundamental questions about competition between grasses and trees at different life-cycle phases. The project was divided into two themes with students assigned to each The first theme focused on growth monitoring of select wood energy species in the experimental sites in the territory of Tabou, Kati Cercle, and Faradielé, Bougouni Cercle. The other theme was the characterization of the initial state of woody vegetation in the experimental site of in the Kita Cercle. For each student related to the theme, the PI helped establish a study protocol or detailed plan for the students' dissertations. Each student was provided with the reports of the papers made in the laboratory for the bibliographic review.

The project team conducted a field survey to select the trial site. After selecting the site, they delineated the location of the experimental device and installed the fence surrounding the four fire treatment zones (Early Fire, Middle Fire, Late Fire, and No Fire). The experimental device is a mono-factorial device, and the only factor studied is the land management mode comprising 8 treatments with 3 repetitions each for a total of 24 unit plots. Each unit parcel covered an area of 20 square meters. In each unit parcel, the researchers carried out a floristic inventory of ligneous species to determine the initial state of the biodiversity of the ligneous trees and to see how the 8 treatments will influence this diversity over time. They also carried out a dendrometric inventory to determine the initial state of density, structure, and wood production expressed in volume of wood in the site. In time they will observe how the 8 treatments will act differently on all these parameters of woody vegetation in the Kita site. After a few years of experience, the results will inform them about the best treatments to be distributed in order to better manage the wood resources by the rural populations for the satisfaction of their need of wood energy, timber, and agro-forestry species.

The PI and team met with the staff of the National Directorate of Water and Forests (DNEF) and its services, including the Global Alliance for Climate Change (AGCC). The Water and Forests staff were interested in the use of UAVs in the monitoring and inventory of woody resources in classified forests in Mali. The PI will continue working with his U.S. partner on ongoing activities at their three test sites, and the data collected will strengthen their databases. They plan to publish articles from the data they have collected on tree treatments.

PUBLICATION

Kanambaye B., Karembe M., Coulibaly D., Hanan N., Bembele F., Diallo S., and Maiga A.H. 2022. Détermination du Potentiel Pastoral Herbacé de la Commune Rurale de Dièma dans le Bioclimat Soudanien Nord au Mali. European Scientific Journal, ESJ, 18 (33), 165. https://doi.org/10.19044/esj.2022.v18n33p165

MALI – PROJECT 5-148: MORE RICE FOR AFRICA: ENHANCING SMALLHOLDER FARMERS' RICE YIELDS IN AFRICA THROUGH THE USE OF EFFICIENT AND LOW COST ENDOPHYTIC ACTINOMYCETES BIOPESTICIDE

PI: Amadou Babana, University of Sciences, Techniques and Technologies of Bamako (Usttb)

U.S. Partners: David Weller, U.S. Department of Agriculture/ Agricultural Research Service, and Dr. Linda Kinkel, University of Minnesota

Dates: December 2016 – December 2019

PROJECT OVERVIEW

Rice is a crucial and strategic cereal crop for more than half of the population in sub-Saharan Africa, particularly in Mali. Unfortunately, diseases, primarily bacterial leaf blight and rice yellow mottle virus disease, cause the average rice yield to be below the global average. Chemical pesticides can control pathogen growth and dispersal and improve rice yield, but their high cost and harmful effects on human health and the environment limit their use in smallholder rice farms. Endophytic bacteria, which have been shown to promote plant growth or pathogen suppression or to activate plant defense systems, can benefit plants through enhanced resistance to biotic and abiotic stresses and plant growth promotion. The use of these bacteria for disease management has great potential in the agricultural systems of West Africa.

This PEER project sought to increase food security in Mali through the production and integration of environmentally friendly endophytic bacterial biopesticides into rice production systems. Researchers produced a low-cost biopesticide and a strategy for long-term sustainable rice pathogen biocontrol technology, tested by smallholder rice farmers in Africa.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Babana and his colleagues collected baseline information from farmers, traders, and pesticide processors on crop production parameters, including area under rice cultivation, land tenure arrangements, varieties of rice cultivated, rice cropping systems, and cost of rice production. They installed endophytic inoculum production facilities at the PI's institution, where they formulated biopesticides from selected endophytes. The team also organized training courses for farmers and local technicians on modern biopesticides.

The researchers tested their formulation on plots infested with rice gail midge, seeing a 278% increase in rice production in plots treated with the biopesticides versus the control plots. The biopesticide was also efficient in controlling rice yellow mottle virus and bacterial blight. The PEER team also started producing the biopesticides for farmers' field demo trials supervised by Office des Périmètre irrigués de Baguineda (OPIB) technicians and took soil and plant samples to analyze their microbiome. More than 100 rural women, agriculture technicians, OPIB, and Office du Niger staff members were trained on the biopesticides. The success of the project attracted women farmers' associations, which have prepared a business plan and proposal to finance, in part, at least one biopesticide production unit.

The PEER team visited the University of Minnesota, to share their results and plan future research, as well as meet researchers working at the Plant Pathology Department. A bioinformatics student on the team stayed for five months to sequence and analyze DNA from the soil and plant samples. U.S. co-partner Stephen Machado also visited Mali to train farmers in business planning and biochar production to support biopesticide production. The PEER team also shared their results through two published articles and several technical presentations, as well as multiple meetings with farmers and government agricultural agencies. They received many requests from rice smallholder farmers for biopesticides for the following growing season. A journalist from the French network Radio France Internationale visited the experimental fields and did reports on the biopesticide that were published in Morocco, France, and Switzerland. During the project period, the PI and team received several additional grants to continue their work, for a total of $500,000, and Dr. Babana also received a new award under PEER Cycle 8 to continue the work.

PUBLICATIONS

Marina Teixeira Arriel-Elias, Maythsulene I. S. Oliveira, Valacia Lemes Silva-Lobo, Marta Cristina Corsi Filippi, Amadou H. Babana, Edemilson Cardoso Conceição, and Marcio Vinicius de C.B. Cortes. 2018. Shelf life enhancement of plant growth promoting rhizobacteria using a simple formulation screening method. African Journal of Microbiology Research 12(5): 115-126. https://doi.org/10.5897/AJMR2017.8787

Amadou Hamadoun Dicko, Amadou Hamadoun Babana. Adounigna Kassogué, Rokiatou Fané, Djeneba Nantoumé, Djeneba Ouattara, Kadia Maiga, and Sognan Dao. 2018. A Malian native plant growth promoting *Actinomycetes* based biofertilizer improves growth and yield. Symbiosis 75: 267–275. https://doi.org/10.1007/s13199-018-0555-2

MALI - PROJECT H1-85: OPTIMIZATION OF SMC DELIVERY AND ITS EFFECTS ON THE ACQUISITION OF MALARIA IMMUNITY

PI: Alassane Dicko, University of Bamako
U.S. Partner: Patrick Duffy, National Institute of Allergy and Infectious Diseases
(Funded by the National Institutes of Health)
Dates: February 2014 – April 2019

PROJECT OVERVIEW

Malaria is the leading cause of morbidity and mortality in Mali. Despite effective implementation of usual control measures such as insecticide treated nets (ITN) and artemisinin combination therapy (ACT) malaria remains the number one killer in Mali. Seasonal Malaria Chemoprevention (SMC), previously known as Intermittent Preventive Treatment of Malaria in children, reduces malaria infection and disease by more 80% in Malian children, prompting the WHO to approve SMC as policy for countries with seasonal malaria transmission, such as Mali, in March 2012. The strategy is a highly cost-effective approach to reduce childhood mortality in these areas. Despite the huge benefit of the SMC on malaria infection and disease, the optimal approach to deliver SMC remains to be determined and there is no data on the long-term effect of this strategy on the development of immunity to malaria. The objectives of this study were to identify the most effective method to deliver SMC and to obtain information on the long-term impact of SMC on malaria immunity. The design was a cluster-randomized trial over three years. By using a step-wedge design, the investigators aimed to (1) determine the optimal mode (fixed-point (FPD) vs door-to-door delivery (DDD); directly observed treatment (DOT) vs. non-DOT (NDOT)) and frequency (3 vs. 4 doses per season) of SMC delivery; and (2) to compare quantitative measures of immunity in children who do and do not receive SMC over a three year period. The anticipated outcome of the study was a qualified optimal approach to deliver SMC in Mali, and an expanded understanding of its impact on health outcomes and antimalarial immunity.

FINAL SUMMARY OF PROJECT ACTIVITIES

The key objectives of the project were achieved and include the following:

- Determination of the optimal delivery method for SMC: The study demonstrated that door-to-door delivery method resulted in higher coverage compared to fixed-point delivery. Consequently, the government changed the SMC delivery method, leading to increased coverage and better protection against malaria. The findings were published in *PloS One*.

- Assessment of the long-term impact of SMC on malaria immunity: Research showed that administering antimalarials through SMC for 3 or 4 years did not decrease IgG levels to key malaria antigens. These results were published in *Malaria J* with additional findings in preparation.

- Assessment of the long-term impact of SMC on resistance to *P. falciparum*: Molecular analysis indicated that 2-3 years of SMC did not increase the frequency of molecular markers associated with resistance to SMC drugs. However, the detection of the dhps 581G mutation warrants further surveillance.

These findings were presented at national and international meetings, influencing policy discussions on malaria control strategies.

PUBLICATIONS

Amadou Barry, Djibrilla Issiaka, Tiangoua Traore, Almahamoudou Mahamar, Bacary Soumana Diarra, Issaka Sagara, Diakalia Kone, Ogobara K. Doumbo, Patrick Duffy, Michal Fried, and Alassane Dicko. 2018. Optimal mode for delivery of seasonal malaria chemoprevention in Ouelessebougou, Mali: A cluster randomized trial. PLoS ONE 13(3): e0193296. https://doi.org/10.1371/journal.pone.0193296

Almahamoudou Mahamar, Djibrilla Issiaka, Amadou Barry, Oumar Attaher, Adama B. Dembele, Tiangoua Traore, Adama Sissoko, Sekouba Keita, Bacary Soumana Diarra, David L. Narum, Patrick E. Duffy, Alassane Dicko, and Michal Fried. 2017. Effect of seasonal malaria chemoprevention on the acquisition of antibodies to *Plasmodium falciparum* antigens in Ouelessebougou, Mali. Malar J (2017) 16:289. https://doi.org/10.1186/s12936-017-1935-4

Brian Greenwood Alassane Dicko, Issaka Sagara, Issaka Zongo, Halidou Tinto, Matthew Cairns, Irene Kuepfer, Paul Milligan, Jean-Bosco Ouedraogo, Ogobara Doumbo, and Daniel Chandramohan. Seasonal vaccination against malaria: a potential use for an imperfect malaria vaccine. Malar J 16:182. https://doi.org/10.1186/s12936-017-1841-9

MOZAMBIQUE

MOZAMBIQUE - PROJECT 8-173: UNDERSTANDING INTERACTIONS BETWEEN PEOPLE, ELEPHANTS AND FIRES IN THE MIOMBO WOODLANDS OF NIASSA NATIONAL RESERVE IN SUPPORT OF BIODIVERSITY CONSERVATION ACTION

PI: Natasha Ribeiro, Eduardo Mondlane University
U.S. Partner: Fernando Sedano, University of Maryland, College Park (Funded by the National Aeronautics and Space Administration)
Dates: November 2019 – February 2022

PROJECT OVERVIEW

The Miombo woodlands are the most extensive ecosystem in southern Africa, representing an important repository of biodiversity and providing critical goods and services for about 80% of both rural and urban populations in the area. Their ecology is largely determined by a combination of soils, climate, and disturbances, such as fire and herbivory by elephants. The Niassa National Reserve (NNR) is the largest protected area in Mozambique, supporting extensive Miombo woodlands and the largest elephant population in the country. About 60,000 people in the area depend on forest resources, relying on fire as a management tool.

This PEER project sought to improve our understanding about the interaction between people, fires, elephants, and habitat in the NNR in support of management actions to counteract the downward trend in elephant population due to poaching. The PI Dr. Ribeiro and her team integrated ground and aerial observations with multisensory and multitemporal remote sensing data to map, analyze, and characterize Miombo habitats for elephants. The mapping tool produced in this study will be made available to the reserve authorities to quickly assess changes in habitat distribution and quality and ultimately improve adaptive management actions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers developed maps of fire frequency and elephant distribution produced, modeling the spatial distribution of elephants based on habitat characteristics and human activities. The team showed that human activities (including fires) concentrated elephants in particular places. While the combination of fire and elephants produces a range of responses of the ecosystem, overall, the combination of high fire frequency and elephant density produces a more homogeneous woodland. The researchers found these effects were more prominent at the regeneration level, with a significant reduction in species abundance as a result of fires and elephants.

With their research, the PEER team contributed to the fire management plan at the NNR, including traditional knowledge on fires. One of the team members was hired to support fire management activities, and the project supported three Master's and two PhD theses. The team also received a new grant from BIOFUND to extend their research to Gile National Park in Mozambique, as well as two additional grants for a total of $350,000.

MOZAMBIQUE - PROJECT 2-156: ECOSYSTEM CARBON ANALYTICAL LABORATORY

Pi: Salomao Bandeira, Universidade Eduardo Mondlane
U.S. Partner: Ilka C. Feller, Smithsonian Environmental Research Center
Dates: August 2013 – July 2015

PROJECT OVERVIEW

In contrast to the standard PEER projects aimed at supporting research efforts, this project was focused on upgrading the research infrastructure to facilitate future research. Specifically, the project aimed to develop an Ecosystem Carbon Analytical Laboratory (ECAL) at Universidade Eduardo Mondlane in Mozambique. With new equipment purchased with PEER funds, Dr. Bandeira and his team would be able to complete quantitative analyses of carbon content of vegetation, soil, and sediment, supporting a range of complex research associated with climate change, sustainable agriculture and forestry, and bioenergy. Beyond the enhanced equipment, the project was designed to provide a facility for education and training, as well as facilitate increased opportunities for collaboration. Building the lab provided the foundation for subsequent work to assess fluxes of carbon in upland and wetland ecosystems in Mozambique and other East African countries, including pilot Mangrove REDD+ projects in Mozambique, an initiative that would simultaneously address climate change mitigation and mangrove conservation.

FINAL SUMMARY OF PROJECT ACTIVITIES

As part of the lab set-up, PEER team members installed a CHNSO flash analyzer, one of the first of its kind in eastern Africa, as well as additional equipment used in carbon analysis. Several team members were trained in the use of the analyzer, including one designated permanently in charge of the lab. PEER team members also made technical presentations at an Africa PEER meeting, a forum for mangrove research and studies on carbon dynamics and mangrove conservation, and a workshop on mangrove carbon in the Zambezi delta.

Dr. Bandeira reports that the new lab will be extremely useful in supporting his university's participation in two ongoing projects. One is a USAID-funded mangrove rehabilitation program (CCAP USAID) in central and northern Mozambique. It involves replanting and monitoring mangrove forests around Quelimane city, as well as studying the carbon budgets of the forest and how they vary with different forest ages and conditions. The other initiative is the PEMBA Climate Change Adaptation Program, which is designed to improve our understanding of vulnerabilities and areas of intervention, looking at habitat and carbon among other socio-ecological questions. The new lab is also encouraging more Mozambican graduate students to complete thesis research on mangrove carbon stocks and other ecosystems, as well as strengthening the efforts of researchers in the university's marine biology group.

MOZAMBIQUE - PROJECT H1-64: REDUCING LOSS-TO-FOLLOW-UP AMONG HIV-EXPOSED INFANTS IN CENTRAL MOZAMBIQUE

PI: Lucia Da Costa Vieira, Beira Operations Research Center (CIOB)
U.S. Partner: James Pfeiffer, University of Washington (Funded by the National Institutes of Health)
Dates: October 2013 – September 2020

PROJECT OVERVIEW

Diagnosis and care for children exposed to HIV remains a major challenge throughout the developing world. Identifying HIV-exposed infants, diagnosing HIV infection and starting HIV-positive infants on treatment requires a well-coordinated care cascade. This care cascade has proven challenging in many developing countries, including Mozambique. Preliminary research suggests that the current system in Manica and Sofala Provinces in Mozambique retain less than 50% of HIV-exposed infants in appropriate care. Failure to properly identify and treat HIV-positive infants contributes to childhood morbidity and mortality. In addition, the problem of vertical HIV transmission is compounded by limited access to family planning services for HIV-positive women. In Manica and Sofala Province, only 13% of women use family planning methods. In 2012, the WHO adopted a "test-and-treat" approach, referred to as "Option B+", that seeks to streamline the treatment cascade by starting ART in all HIV-positive women at the time of diagnosis in antenatal care services (ANC) regardless of CD4 count to avoid delays and multiple visits that contribute to LTFU. The new Option B+ approach has been adopted by the Ministry of Health (MoH) in Mozambique and is in the early phases of implementation. In Mozambique, antenatal care (ANC) and HIV testing coverage is high but there is substantial loss-to-follow-up (LTFU) at successive stages in the treatment cascade, limited counseling for women and many barriers to actively tracking those women lost to follow-up. Early Ministry of Health data suggests significant challenges remain for long-term adherence for women started on ART via the new Option B+ framework in Manica and Sofala provinces and throughout Mozambique.

This project built off an existing NIH grant– a clustered (facility) randomized controlled implementation science trial to improve the rollout of "Option B+", in which HIV positive pregnant women initiate ART during pregnancy regardless of CD4 count and continue treatment for life. The objectives of this study were to identify causes of loss-to-follow-up of HIV-exposed infants in care cascade and barriers to family planning access and then design and implement an intervention that will increase the proportion of infants tested for HIV and enrolled in pediatric HIV care as well as increase the proportion of HIV-positive women receiving family planning services. This study identified causes of loss-to-follow-up of HIV-exposed infants in the care cascade and barriers to family planning access through qualitative and quantitative formative research. In close collaboration with the Ministry of Health, the investigators designed an intervention based on formative research findings that utilizes three core components: enhanced system tracking and linkages for HIV-exposed infants, improved counseling for infant caregivers regarding appropriate care for HIV-exposed and HIV-positive infants, and integration of family planning counseling in well child, postpartum and child at risk clinic visits. Once this intervention was developed, the study team implemented it through a clustered (facility-level) randomized controlled trial using a stepped-wedge design to test the effectiveness of the intervention.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project proved to be a success in a informing government policy makers on methods to reduce follow-up loss of HIV exposed infants in the country. The intervention sought to improve the retention of the exposed children who have initiated Highly active antiretroviral therapy (HAART) at healthcare facilities and strengthen the link between CPP (post-partum clinic) visits and CCR (children at risk care). The study used community health workers to help the health centers track exposed children and their mothers, as well as cell phones to remind them to return to the health center and to find them if they do not return. The team conducted interventions in six healthcare facilities, arranging numerous Mother-to-Mother group meetings total, working out of each health unit. These aim to share information, challenges, and provide peer-to-peer mentoring, as well as knowledge transfer from health facility staff to mothers at risk. The team also met with study staff at each facility, as well as provided trainings to health professionals on how to follow-up children who were exposed to HIV.

To strengthen the quality of ARV programs in Manica and Sofala provinces, the study team conducted several meetings with the key DPS (Health Provincial Directorate) and other leaders of mother and child and HIV programs about the intervention and the lessons learned throughout the implementation of the research. The health centers in these provinces were receptive to the project results and have implemented the intervention for reducing loss-to follow-up among HIV exposed infants as standard practice. In Maputo dissemination was conducted at the MoH National Directorate of Public Health board meeting. By meeting with all heads of the public health departments, the team was able to transmit the results of the outcome to those who are the key policy makers and have the power to change health policy. The team was pleased to receive the news that the Health Ministry is starting HAART in CCR, which was one of the main recommendations to the Ministry of Health.

The team also organized the first CIOB Conference on maternal and child health. The conference was held in Manica Province, and all institutions and NGOs operating in the area of maternal and child health were invited to submit their work. Additionally, every three years the Mozambique MoH (Ministry of Health) organizes a national health conference. The team presented the formative results in 2015 and intervention results in 2018.

PUBLICATIONS

Vieira, Lúcia et al. 2020. HIV-exposed infant follow-up in Mozambique: formative research findings for the design of a cluster randomized controlled trial to improve testing and ART initiation. BMC Health Services Research 20(1):226. https://doi.org/10.1186/s12913-020-5051-8

NIGERIA

NIGERIA - PROJECT 3-208: SYSTEMS ENGINEERING PERSPECTIVE ON POWER TRANSMISSION FOR NIGERIA

PI: Adegoke Melodi with Co-PI Olatubosun Olabode, The Federal University of Technology, Akure

U.S. Partner: Kevin Tomsovic, University of Tennessee (Funded by the National Science Foundation)

Dates: September 2014 – November 2018

PROJECT OVERVIEW

The aim of this project was to develop an algorithmic model for planning transmission expansion or development in order to achieve acceptable reliability of transmission and maximize cost-benefit ratio of transmission operations under the growing deregulated operating environment of Nigeria and the probabilistic factors affecting power transmission-demand relationship. It is expected that the model would be applicable to power distribution as well. Primarily, the model would enable a dynamic planning process for providing optimal plan options, applicable for implementing transmission installations and operations that will prevent recurrence of historically unreliable transmission problems in Nigeria under a State-regulated environment and ensure sustainable service for the Transmission Company of Nigeria (TCN) under deregulated conditions. The novel concept in this project included the application of a value base reliability approach to transmission expansion planning (TEP) of the Nigerian power transmission network, which was embedded in a developed multi-stage and multi-objective optimization algorithm for the transmission planning. This concept used a state-of-the-art optimization procedure and a new congestion index.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and his project team obtained system data from Transmission Company of Nigeria (TCN) that spanned 2000 to 2014 and covered 2014 network parameters, 2000-2014 bulk supply load records, generation data, 2005-2007 and 2010-2014 line outage data. The data were compiled using software and applied in subsequent tasks. Load dynamics for each TN bus from 2000-2014 were obtained from data sorting and consolidation of monthly records and generation and load data for each region were analyzed quantitatively. Population data was obtained from the Nigerian Population Census agency and was compiled for regions. Forecasts based on Probabilistic Time series Load Dynamics with Monte Carlo random variable concept were generated.

The specified historical transmission network data, obtained from TCN was applied in achieving the specific objective of obtaining probabilistic load forecasts using Monte Carlo, Artificial Neural Networks, and Fuzzy Logic. Based on the first results, the PI and his team presented and published the peer-reviewed conference paper "Probabilistic Long-Term Load Forecast for Nigerian Bulk Power Transmission System Expansion Planning" in the 2016 PowerAfrica proceedings and IEEEXplore.

Based on a second probabilistic forecast results, a journal paper "Specific System Random Load Forecasts and Loadflow Responses on Nigerian 330 kV 38-bus Transmission Grid" was peer reviewed and published in the *Journal of Engineering Research in Africa*. One of the students of the project successfully defended his thesis, “Development of a Probabilistic Transmission Expansion Planning Model for Nigerian 330 kV Transmission Grid.”

The project team has shared results with the power transmission industry, engineers, academia, and the national regulatory body, and they continue to coordinate with these stakeholders post project.

PUBLICATIONS

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NIGERIA - PROJECT 2-504: IMPROVING YAM (DIOSCOREA SPP.) SEED SYSTEMS THROUGH PRODUCTION OF DORMANCY-CONTROLLED SEED TUBERS IN TEMPORARY IMMERSION BIOREACTORS

PI: Morufat Balogun, University of Ibadan

U.S. Partner: Wayne Curtis, The Pennsylvania State University (Funded by the National Science Foundation)

Dates: September 2013 – July 2015

PROJECT OVERVIEW

The production of yams, which are a food security and poverty alleviation staple in West Africa, is constrained by scarcity of planting materials and low multiplication rates, which account for up to 63% of production cost. Tuber dormancy also hampers out-of-season production, while uncontrolled sprouting after dormancy causes storage losses. The use of temporary immersion bioreactors in in-vitro cultures has been recognized as a means to improve plant propagation in other crops, and the idea is adaptable to hundreds of species. Temporary immersion facilitates scale-up of propagation of large masses of plant tissue, which is useful because it does not require costly agar, reduces contamination in cultures, and provides a means for sequential manipulation of the nutrient medium at different developmental stages with minimal labor input.

The goal of this PEER project was to identify optimum conditions for production of seed tubers of white yam whose dormancy can be efficiently controlled. This research sought optimized protocols for seed yam production and increased seed supply and quantities. The immediate uses of the research results included micropropagation of disease-free plantlets, in vitro conservation of plantlets without losses associated with field collections, and in vitro evaluation of yield in transgenic yam. The potential uses of the results include out-of-season production and extension of the storage cycle. Ultimately, the overarching anticipated development impact is enhanced yam productivity will help feed Nigerians while also empowering them through trade.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team studied the growth of yam seeds in Temporary Immersion Bioreactors (TIBs) with various levels of sucrose and carbon dioxide. A sucrose medium formed more new nodes for a longer time than TIBs containing no sucrose. The team also tested different Co2 levels and the use of artificial and natural light in greenhouses. The healthy tubers from the initial harvest broke dormancy and were planted several months later. The team grew a total of 1167 plantlets both in conventional tissue culture and in the bioreactors, and tested automation of the TIBs.

The PEER team held a stakeholder workshop to discuss their results and yam production issues. A total of 165 participants were drawn from academia, farmers, civil society groups, ministries, international organization, media, and government agencies at all levels. The use of temporary immersion bioreactors in order to speed up production of yam was hailed as a welcome development. Attendees offered a variety of comments on adjusting the technology or needed wider developments in Nigeria’s yam market, including support and education for youth and for smaller farmers, as well as cheaper and more reliable sources of power to manage the TIBs given irregular electricity.

The curriculum of an existing course for Master's degree students at the PI's institution now includes storage technologies, in vitro conservation, cryopreservation and freeze-drying. This was prompted by the increased visibility of the possibilities offered by in vitro techniques during the PEER project. Highlighting the importance of the work, in 2015 Dr. Balogun was also recognized as one of Nigeria's 50 most distinguished professionals in the *Guardian* newspapers, including a write up on yam research.

NIGERIA - PROJECT 2-463: RENEWABLE ENERGY: DESKTOP LEARNING MODULE FOR GASIFICATION PROCESSES

PI: Idris Bugaje, National Research Institute for Chemical Technology
U.S. Partner: Bernard J. Van Wie, Washington State University (Funded by the National Science Foundation)
Dates: October 2013 – March 2017

PROJECT OVERVIEW

Gasification is a promising process for commercialization of drop-in fuels produced from renewable sources, but it is also a complex process that can be difficult to comprehend. The research of the U.S. partner Dr. Van Wie has shown that Desktop Learning Modules (DLM) in engineering education increase conceptualization. This PEER project built on Dr. Van Wie's previous work by developing a DLM system for a gasifier process. The DLMs created introduce students and researchers to the field of gasification and enhance their understanding of the process.

The PEER team designed the process to work in Nigeria, including making it self-contained and self-powered, so it can work in domains where electricity and water utilities are intermittent or even non-functional—places where renewable energy is most needed. The researchers designed an inexpensive teaching and learning device that can be used worldwide, especially in programs with low budgets and less than desirable access to utilities. They tested the learning modules, using them as an instructional guide for teaching the concept of gasification with application to industrial processes. This is especially useful to engineering students temporarily attending the National Research Institute for Chemical Technology on industrial attachment.

FINAL SUMMARY OF PROJECT ACTIVITIES

Team members began by surveying literature relating to gasification principles and design and completed a one-week training on the Aspen Plus simulation package. The U.S. partners helped create the gasifier design for the module. One of the key team members, Dr. Abdulazeez Atta, participated in a workshop on science diplomacy organized by the American Association for the Advancement of Science and others, while both Dr. Idris Bugaje and Dr. Atta participated in the PEER Participants' Conference in Tanzania in 2014.

The researchers tested and adjusted the DLM design. The introduction of laggings and shielding of the reactor significantly increased the attainable temperature in the reactor. Analysis showed that painting the inner surface of the reactor with silver paint decreased the heat lost due to radiation in the reactor. In order to reduce variability (maintain quality specifications), increase efficiency, and ensure the safe operation of the proposed DLM, researchers built the setup with various controls.

The PEER team organized a three-day workshop on Hands-on Engineering Learning Pedagogies at the University of Ghana, Legon, joined by faculty members from different departments in the school of engineering, University of Ghana. They made technical presentations and unveiled the DLM for gasification processes. At a separate workshop at Ahmadu Bello University, 90 participants from across 17 Nigerian institutions attended and saw technical presentations on the DLM and its potential for teaching engineering concepts. After a site visit to Washington State University by the co-PIs, the Nigerian team sought to develop capacity to build the DLMs within their own workshops, including fabricating a pyrolysis reactor and designing portable gasifier for use in data collection on biomass gasification. Team members also created a manual on international scientific collaboration.

The researchers conducted a pedagogy study on the gasification DLM with more than 200 students from the Department of Chemical Engineering at Ahmadu Bello University. Students were given pre-test questions to assess their level of understanding on gasification and then tested on their understanding after the introduction of the module. Preliminary analysis showed a significant increase in the level of the students' understanding, with senior-level students doing comparatively better.

NIGERIA – PROJECT SG1-008: FOOD NEOPHOBIA AND WILLINGNESS TO TRY FORTIFIED FOODS AMONG NIGERIANS

PI: Folake Idowu-Adebayo, Federal University Oye-Ekiti

Dates: October 2019 – June 2022

PROJECT OVERVIEW

In order to combat malnutrition in underdeveloped nations, fortified meals are becoming increasingly popular in Africa. People's willingness to try new cuisines, on the other hand, varies widely. This PEER project sought to study food neophobia in different demographics in Nigeria by examining their responses to food they had tasted or eaten before (using familiar Nigerian products) or not (using their fortified counterparts).

This grant also supported mentoring and research projects for several female undergraduate students. Mentorship sessions included discussions on proposal and CV writing, scholarships for postgraduate study, networking, and work-life balance. The project supported thesis work for one mentee, allowing her to pursue an innovative research idea that most students would have abandoned due to financial constraints.

FINAL SUMMARY OF PROJECT ACTIVITIES

Using the Food Neophobia Scale, the researchers asked 500 participants to score their familiarity with 20 samples categorized as familiar foods and unfamiliar foods, as well as their willingness to try them. The study found food neophobia is more prevalent among Nigerians than what has been reported for other developed countries, with a mean food neophobia score of 43.25 (SD = 10.66). The researchers found that women were less neophobic compared to men, and food neophobia rose alongside household income. Respondents with a university education were also the most neophobic among educational groups. The research team published several academic articles on their findings and presented their work at the 44th Nigerian Institute of Food Science and Technology conference.

PUBLICATIONS

Folake Idowu-Adebayo, Vincenzo Fogliano, and Anita Linnemann. 2022. Turmeric-fortified cow and soya milk: golden milk as a street food to support consumer health. *Foods* 11(4): 558. https://doi.org/10.3390/foods11040558

Folake Idowu-Adebayo, Vincenzo. Fogliano, Matthew O. Oluwamukomi, Segun Oladimeji, and Anita R. Linnemann. 2021. Food neophobia among Nigerian consumers: a study on attitudes towards novel turmeric-fortified drinks. *Journal of the Science of Food and Agriculture* 101: 3246–3256. https://doi.org/10.1002/jsfa.10954

Folake Idowu-Adebayo, Mary J. Toohey, Vincenzo Fogliano, and Anita R. Linnemann. 2021 Enriching street-vended zobo (*Hibiscus sabdariffa*) drink with turmeric (*Curcuma longa*) increases its health-supporting properties. *Food and Function* 12: 761. https://doi.org/10.1039/D0FO02888F

SIERRA LEONE

SIERRA LEONE - PROJECT H1-17: LASSA FEVER PATHOBIOLOGY IN CHILDREN AND DURING PREGNANCY

PI: Donald Grant, Lassa Fever Program Kenema Government Hospital
U.S. Partner: Robert Garry, Tulane University School of Medicine (Funded by the National Institutes of Health)
Dates: October 2013 – October 2017

PROJECT OVERVIEW

Eastern Sierra Leone, particularly the Kenema District, has the highest incidence of Lassa Fever, a severe and often fatal viral hemorrhagic disease transmitted by the rodent *Mastomys natalensis*, in the world. The rodents are commonly found in homes and transmission occurs from contact with the rodents. Lassa Fever (LF) disproportionately impacts pregnant women and children. Case fatality rates for LF can reach 70% in children under age 5 and 90% in third trimester pregnancies for both the mother and the fetus. The prevalence and true impact of LF is not well understood. This study addressed key gaps in knowledge of the epidemiology and natural history of Lassa fever. The goals of the study were to (1) characterize and contrast the age and sex distribution of Lassa virus (LASV) exposure in endemic and non-endemic areas and (2) elucidate risk factors for LASV infection in pregnant women and children. The target population consisted of the entire Eastern Province of Sierra Leone and women and children in the Kenema District of Sierra Leone. The age and sex distribution of LASV exposure was determined in a point prevalence study comparing endemic and non-endemic areas. This project also elucidated risk factors for LASV infection in a case-control study of pregnant women and children, which identified points in LF transmission. The study employed field epidemiology, hospital-based surveillance, and advanced laboratory techniques in order to provide informed approaches for treating and controlling LF that can guide evidence-based investments for public health programming and policy.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project addressed transmission and treatment of LF. The focus was on children and pregnant women who are more severely impacted by LF than any other group. Through determination of the age and sex distribution of LASV exposure, the team expected to identify major risk factors for LASV infection and subsequently points for interventions to effectively prevent LASV infection.

The team carried out a point prevalence study on a group of 50 communities that differ according to exposure to LASV. These communities consisted of 20 endemic villages in the Kenema District, 15 emerging villages in the Tonkolili District, and 15 non-endemic villages in the Port Loko District. More than 11,000 samples from 20+ households per village distributed among 5 age groups were collected. Dried blood spots were used to perform Lassa-specific IgG by ELISA for the detection of past LASV exposure. This effort was ongoing as of the end of the project with an interim analysis.

Multiple variables (qualitative and quantitative) were collected in the questionnaire administered to cases and controls. The team also collected GPS data and data on the level of rodent infestation in case and control households. An interim analysis of Lassa seroprevalence was completed for Kenema District, which saw seroprevalence ranges from 10 to 62%. The team also considered Lassa seroprevalence by age and in moderate to high prevalence villages, as Lassa Fever seroprevalence increases with age. There is an increase in incidence in preteens and another increase in young adults. In these villages, adults >45 years of age have the highest seroprevalence. Villages with a lower seroprevalence show a distinct pattern with lower seroprevalence in older adults. The team also looked at Lassa seroprevalence by sex in Kenema District and, with the exception of one village,, there was no significant difference between sexes.

Electronic databases with coded patient diagnostic designations and demographics, clinical, and laboratory data were generated from the project work. Manual curation of the databases was still ongoing at the time project ended, with each entry in the electronic databases cross-checked and confirmed to be consistent with the original clinical and laboratory records. The data set generated was carefully and thoroughly integrated with the wealth of clinical data obtained on each patient throughout their stay in the KGH Lassa Ward.

Overall, Kenema District has long been considered to have the world's highest LF incidence rate and is an established hotspot for carrying out surveillance and LF-related research. Many districts to the north and west of Kenema are believed to have limited LASV circulation, but it is unknown if this is a consequence of limited efforts for detecting the virus, inability of clinical staff to recognize the disease, or if there is truly no virus circulating in the area. This seroprevalence study suggests that LF incidence may be underestimated in certain historically non-endemic areas. This study also uncovered the age and gender distributions of LF in these areas. Further analysis of data will determine if the age and gender distributions of LASV exposure differ between endemic and non-endemic areas and the team plans to finish this analysis over the next six months. This data will inform Lassa fever vaccine clinical trials conducted by partners in the VHFC, as well as new efforts by CEPI.

PUBLICATIONS

Mire, C. E., Cross, R. W., Geisbert, J. B., Borisevich, V., Agans, K. N., Deer, D. J., Heinrich, M. L., Rowland, M. M., Goba, A., Momoh, M., Boisen, M. L., Grant, D. S., Fullah, M., Khan, S. H., Fenton, K. A., Robinson, J. E., Branco, L. M., Garry, R. F., & Geisbert, T. W. (2017). Human-monoclonal-antibody therapy protects nonhuman primates against advanced Lassa fever. Nature Medicine, 23(10), 1146–1149. https://doi.org/10.1038/nm.4396

Gale, T. V., Horton, T. M., Grant, D. S., & Garry, R. F. (2017). Metabolomics analyses identify platelet activating factors and heme breakdown products as Lassa fever biomarkers. PLOS Neglected Tropical Diseases, 11(9), e0005943. https://doi.org/10.1371/journal.pntd.0005943

SENEGAL

SENEGAL - COV-053: DESIGNING AND EVALUATING A WASTEWATER PATHOGEN MONITORING TOOL FOR SEWERED AND NON-SEWERED SANITATION SYSTEMS TO PREVENT DISEASE OUTBREAKS IN DAKAR, SENEGAL

PI: Nouhou Diaby, Université Cheikh Anta Diop

U.S. Partner: William Tarpeh, Stanford University (Funded by the National Science Foundation)

Dates: November 2022 – March 2024

PROJECT OVERVIEW

Wastewater-based epidemiology (WBE) is a rapid, cost-effective tool for tracking, mitigating, and preventing viral disease outbreaks. However, most WBE studies so far have focused on high-income, sewered locations, and WBE currently does not serve low-income countries that often rely at least partially on non-sewered sanitation.

This PEER project team aimed to expand WBE access and application by creating and piloting a novel WBE tool in Dakar, Senegal, through producing a comprehensive map of sanitation systems and sewage flows in Dakar and evaluating pathogen prevalence in wastewater throughout treatment and wastewater-impacted environments. To achieve these aims, Stanford University's Tarpeh Lab, led by the U.S. partner, transferred knowledge and skills for mapping and geospatial modeling, supported methodological development for pathogen monitoring, and co-hosted workshops and stakeholder meetings to train Senegalese students and professionals.

FINAL SUMMARY OF PROJECT ACTIVITIES

With support from the National Sanitation Agency and the company Delvic Sanitation Initiatives, Dr. Diaby and his group were able to obtain updated maps of the sanitation network in Dakar, including maps of the sewer network and the rainwater network, with open drains, pumping stations, and wastewater treatment plants all indicated. The maps allowed them to estimate the populations connected to the network of sites included in the study. The researchers also gathered data on the sewer system's nominal capacity and actual flow data through the sampling period. In the pumping stations monitored in this study, the flow rates were 19,200 m^3/day at the University station, 10,800 m^3/day at the Pikine station and 6,000 m^3/day at the Almadies station. The Pikine and Almadies stations discharge their water into the Camberène water treatment plant, while the University station discharges directly into the sea without treatment.

From the study sites, the researchers gathered 50 samples of water to test for bacteria, parasites, and viruses. Nearly all samples (96.08%) revealed the presence of bacteria, while parasites were present in 84.31% of samples and viruses were present in 68.63%. The team used a subset of samples for SARS-CoV-2 detection. Out of 40 samples analyzed, the virus was detected in 26, equivalent to a rate of 65%. Detection of the virus revealed the presence of SARS-CoV-2 in the month of June 2023 in some locations (Pikine, Almadies, University, and Tivaouane Peulh), followed by a significant reduction, or even absence, during the winter period. On the other hand, SARS-CoV-2 reappeared in December 2023 in greater numbers.

As part of their work, the PEER team organized training courses covering sampling techniques, laboratory analysis and data processing. In total 49 people, 67% of them women, were able to benefit from training on wastewater-based epidemiology tools. The researchers also presented the project to the National High Council for Health Security “One Health” of Senegal, which is a key body bringing together all stakeholders in human, animal, and environmental health. They will continue this work with a $54,000 grant awarded from the Grand Challenge Canada. Thanks to the new equipment provided to Dr. Diaby’s lab with PEER funding, the group is well positioned to move forward with their research activities.

SENEGAL - PROJECT 2-432: RHIZOSPHERE BIOLOGY OF SHRUB CREATED RESOURCE ISLANDS OF SAHELIAN AGROECOSYSTEMS: OPTIMIZATION AND ADAPTATION TO CLIMATE CHANGE

PI: Yacine Badiane Ndour, Institut Senegalais de Recherches Agricoles
U.S. Partner: Richard P. Dick, Ohio State University (Funded by the National Science Foundation)
Dates: August 2013 – June 2018

PROJECT OVERVIEW

Senegal faces a challenge of feeding a rapidly growing population against a background of climate change and low inherent soil fertility. Scientifically validated agricultural systems that optimize crop productivity despite water and heat stresses are urgently needed. With previous support from the National Science Foundation, Senegalese and U.S. scientists discovered two shrub species that can coexist with crops on smallholder farms and have the ability to lift water to dry surface soil and to improve the soil.

This PEER project sought to understand how the harboring of beneficial nematodes (microscopic roundworms) and arbuscular mycorrhiza fungi (AMF) by shrub roots and associated rhizosphere can increase or maintain crop productivity during scenarios of greater water and temperature stress. The project primarily used lab experiments in a climate chamber with humidity and illumination to generate various scenarios. Researchers evaluated both the response of biological assemblages derived from the shrub and millet association to stressful climate simulated conditions and tested selected biological interactions that benefit crop productivity when heat and water stress occurred or increased.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Ndour and her colleagues incubated soil in a climate-controlled chamber for 45 days, after exposure to 10 consecutive days of wet-dry cycles. The applied stress strongly affected biological activities, including basal respiration and enzymatic activities, causing change in the composition of the microbial community influencing the carbon cycle in soil. The presence of the shrub promoted the resilience of microbial communities in soils under its canopy. The researchers noted that decreased rates of basal respiration were more pronounced in soil collected outside the shrub canopy.

Microbial biomass was also strongly influenced by the wet-dry cycles in this study, with soil microbial biomass increasing in stressed soils immediately following disturbance. These results are supported by previous studies. The researchers' findings suggest that shrub canopy in semi-arid zone is the major driving variable that will control the composition of the microbial community and the role of microbial diversity in soil resilience is not linked to the absolute number of species but related to the functional traits of those species.

The PEER team also cultivated millet in mesocosm on soil collected beneath or outside the shrub canopy and inoculated with a cocktail of three mycorrhizal strains from their collection (*Glomus aggregatum*, *Glomus mossae,* and *Rhizophagus irregularis*), as well as native inoculum and uninoculated control. They grew millet in climate chambers for two months in three different conditions representing heat and water stress. The researchers measured the rate of mycorrhization, shoot biomass, and the microbial activities in soil. They found that elevated temperature did not affect millet's shoot biomass, but water stress—and water stress combined with higher temperatures—had a negative impact. Elevated temperature decreased the rate of mycorrhization.

Thanks to PEER support, two team members—researcher Dr. Hassna Founoune and PhD student Ms. Sally Datta—had the opportunity to spend two weeks at Virginia Tech in June-July 2017 receiving technical training and conducting research in collaboration with Dr. Mark Williams. While at the university, they performed DNA extractions from soil samples sent from Senegal and then subjected the extracted material to PCR amplification and analysis. With the new skills they gained, the visitors were able to carry out extraction and purification of other samples back in Senegal and apply the results in their study of the molecular biodiversity of soil fungi.

The researchers discussed their results with local farmers in Keur Matar, the National Agency for Agricultural and Rural Council (ANCAR), and a local research network. They presented their work through a total of 17 technical presentations and two publications. The PEER team won three new grants, totaling $252,000, for new and related work from the World Bank, the Senegalese National Academy of Science, and the Senegalese National Ministry of Higher Education and Research.

PUBLICATIONS

Sally Diatta, Sidy Diakhaté, Hassna Founoune-Mboup, Charlotte J. Alster, Diégane Diouf, Richard P. Dick, Lydie Chapuis-Lardy, Laurent Cournac, and Ndeye Yacine Badiane-Ndour. 2019. Temporal microbial response to wetting-drying cycles in soils within and outside the influence of a shrub in the Sahel. Open Journal of Soil Science 9(12): 284-297. https://doi.org/10.4236/ojss.2019.912018

Sidy Diakhaté, Ndeye-Yacine Badiane-Ndour, Hassna Founoune-Mboup, Sally Diatta, Abdoulaye Fofana Fall, Rebecca R. Hernandez, Laurent Cournac, Richard Dick, and Lydie Chapuis-Lardy. 2016. Impact of simulated drought stress on soil microbiology, and nematofauna in a native shrub+ millet intercropping system in Senegal. Open Journal of Soil Science 6(12): 189-203.
http://dx.doi.org/10.4236/ojss.2016.612018

SENEGAL - PROJECT 2-344: IMPACT OF CLIMATE CHANGE ON FRESHWATER AVAILABILITY FOR SENEGAL: MODELING FUTURE CHANGES IN HYDRO-CLIMATOLOGY OF LAKE OF GUIERS

PI: Mouhamadou Bamba Sylla, Ecole Supérieure Polytechnique de l'Université Cheikh Anta Diop

U.S. Partner: Jeremy Pal, Loyola Marymount University (Funded by the National Science Foundation)

Dates: August 2013 – March 2016

PROJECT OVERVIEW

This project aimed to study climate change effects on the Lake of Guiers, the main freshwater reservoir for Senegal. The water is mostly used for irrigated cropping in the basin and domestic use in Dakar. It is unknown how its hydroclimatology might evolve in the future, but changes in surface runoff over the basin and in the amount of water in the lake could produce significant disturbances for end-users. The researchers in this project analyzed past and present-day climate and water resources, elaborated climate change projections over the lake basin, and produced future scenarios of water resources for the lake. A series of three workshops were organized at the end of each task to engage, inform, and exchange information with the end-users.

As for development impacts, this project will generate a unique dataset in the field of climate change modeling over Senegal. This dataset can serve as input for more high-impact studies beyond the activities included in the project, for example in the fields of health and ecosystems. Policy makers could also use the datasets generated to develop adaptation and mitigation strategies. Thanks to the project's expected results, Senegal's government will for the first time possess robust short-term (2021-2050) and long-term (2071-2100) projections of the amounts of freshwater available in the lake and thus potable water for domestic use in Dakar. In addition, production of future estimates of surface runoff in the lake basin is a great asset for agricultural policy makers, as these conditions can either depress or favor irrigated cropping.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main aim of this project was to characterize the impact of anthropogenic climate change on water availability in Senegal with a focus on the Lake of Guiers basin. This was modeled and analyzed for the middle (2041–2060) and late twenty-first century (2080–2099). The team undertook to create a high-resolution multi-model ensemble based on regional climate and hydrological model experiments that considered two core Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCP4.5 and RCP8.5). The results indicated that an elevated warming, leading to a substantial increase of atmospheric water demand, is projected over the whole of Senegal. In the lake basin, these increases in potential evapotranspiration (PE) range between 10 and 25 % in the near future and for RCP4.5 while for the far future and RCP8.5, they exceed 50 %. In addition, mean precipitation unveils contrasting changes, with wetter (10 to 25 % more) conditions by the middle of the century and drier conditions (more than 50 %) during the late twenty-first century. Such changes cause more or less evapotranspiration and soil moisture respectively during the two future periods. Furthermore, surface runoff shows a tendency to increase in most areas (amid few locations including the lake basin with substantial reduction) probably due to the intensification of precipitation events. It was also found that while semi-arid climates develop in the RCP4.5 scenario, generalized arid conditions prevail over the whole Senegal for RCP8.5. These conditions will lead to less available water and more crop water uptake. It is thus evident that these future climate conditions substantially threaten freshwater availability for Senegal and irrigated cropping over the lake basin.

In addition, the project promoted teaching and learning in a broader context and increased the participation of female students in geosciences research. Two courses have been introduced in the lab, Climate Modeling with Practical (hands-on sessions) and West African Monsoon Dynamics.

In conclusion, the principal investigator has recommended that the government of Senegal should implement policies that will help in designing response options to cope with the challenges posed by the projected climate change for the country. These policies should aim at encouraging end users to diversify their activities at the basin by practicing fishery and livestock husbandry. Stakeholders should also use the lake water only during the dry season and sow during the rainy seasons to ensure that the cultivars are more resilient to hotter and drier conditions with a shorter growing season. Users should be sensitized and provided users with means to properly measure the amount of water they draw from the lake. To disseminate their findings and recommendations, the team met and developed strong collaborations with the Direction de la Gestion et de la Planification des Resources en Eau (DGPRE), the ministry department that manages and plans for water resources in Senegal, the Senegalese Consumers Association, Department of Geography of the University Cheikh Anta Diop, The Organisation pour la Mise en Valeur du Fleuve Senegal, the Office of the Lake of Guiers and two communities practicing at the Lake of Guiers basin (Diokhor and Diaminar). They are working together with these institutions to exchange information, carry out surveys, and collect data.

PUBLICATIONS

Sylla MB, Nikiema M, Gibba P, Kebe I, Klutse NAB. 2016. Climate Change in West Africa: Recent Trends and Future Projections. In Joseph A. Yaro and Jan Hesselberg (Eds): Adaptation to Climate Change and Variability in Rural West Africa. Springer, ISBN: 978-3-319-31497-6. https://doi.org/10.1007/978-3-319-31499-0_3

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SOUTH AFRICA

SOUTH AFRICA - COV-100: IMPACT OF COVID-RELATED DISINFECTANTS IN THE FOOD PROCESSING SECTOR ON THE DOWNSTREAM IMPACT OF ANTIMICROBIAL RESISTANT PATHOGENS AND ENDOCRINE DISRUPTING CHEMICALS INTO WASTEWATER SYSTEMS

PI: Lise Korsten, University of Pretoria, South Africa

U.S. Partner: Charles Gerba, University of Arizona (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Dates: November 2022 – March 2024

PROJECT OVERVIEW

Since the onset of the COVID-19 pandemic, the food-processing sector has been under enormous pressure to ensure that processing facilities and food handlers do not contribute to the spread of the virus. Good hygienic practices that involve washing, rinsing, cleaning, and disinfecting were amongst the areas that received special attention. To date, most disinfectant-related research studies have focused on the efficacy of disinfectants in deactivating pathogens, often without consideration for their downstream impact on the environment and public health.

Quaternary ammonium compounds and chlorine-based disinfectants are used routinely as disinfectants in food production facilities. Due to varying resistance to disinfectants, some antimicrobial resistant bacteria can survive disinfection and release free-living DNA in wastewater treatment plants through the sewer lines of food processing facilities. Residual disinfectants and soaps and their degradation products can end up in the environment through wastewater treatment plants, and their endocrine disruptive mechanisms as well as their genotoxic and teratogenic properties to mammals and aquatic organisms raise considerable concern.

This PEER project sought to assess the contribution of food safety control practices and COVID-19 hygiene measures to the downstream quality of non-sewage wastewater from a food processing facility. The project monitored the wastewater discharge from a previously sampled processing facility for the release of targeted microorganisms and chemicals. The selected study site was a food-safety-compliant fresh cut vegetable processing facility, where multidrug resistance human pathogenic *E. coli* will be isolated by the project team.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers sampled seven different water sources in the facility to determine the presence of foodborne pathogens (*E. coli*, *Listeria* monocytogenes, and *Salmonella spp.*) and detect the prevalence of a microorganism indicator, *E. coli*, that produces a specific resistance mechanism conferring resistance to third-generation cephalosporins (ESBL), in a food processing environment.

They shared reports of their findings from all four sampling trips with the Technical and Environmental Manager and the Food Safety Manager of the processing facility, serving as a guide on levels of risk in the facility, informing them of the success of their current hygiene regime, and highlighting where improvement is needed. The researchers characterized a selection of microorganisms obtained during the four sampling visits using Whole Genome Sequencing (WGS) technology. As of June 2024, papers on the microbiological sampling were forthcoming, and a research fellow was expected to present findings at the International Association for Food Production's (IAFP) annual conference in Long Beach, California, in July 2024.

The PEER team also measured endocrine disrupting activity and chemical screening (including pesticides, disinfectants, and their by-products) of six sampling points in the processing facility, assessing and quantifying estrogenic and androgenic activity in the water samples from the facility.

The researchers replaced a plan for a desktop review with a paper on antibiotic profiles of some pathogens that are the leading cause of nosocomial infections throughout the world, as an unexpected number of these potentially pathogenic microorganisms were found in the study.

The PEER team held two online workshops alongside the U.S. partner's food safety experts. In partnership with the University of Pretoria's Drama Department (School of Arts), information about food safety practices in the informal market was presented to factory workers at the sampling site in the form of an interactive play that addressed topics on food safety practices in the informal food sector.

The PI and her team are part of projects that received more than $6 million in additional funding in total across six new grants, including a major grant from the European Union Horizon program. Knowledge generated during the course of the project will also contribute to the international Global Water Research Coalition project to develop an effect-based monitoring tool for water quality safety in line with World Health Organization recommendations. Data from these projects may ultimately be used to inform policy. The Whole Genome Sequencing results for the bacteria that were selected in this study were published on the NCBI's data website.

PUBLICATIONS

Richter, L., E.M. Du Plessis, S. Duvenage, and L. Korsten. 2023. Prevalence of extended-spectrum β-lactamase producing Enterobacterales in Africa's water-plant-food interface: A meta-analysis (2010–2022). Frontiers in Sustainable Food Systems 7:1106082. https://doi.org/10.3389/fsufs.2023.1106082.

Iwu, C. D., N. Nontongana, C.U. Iwu-Jaja, B.O. Anyanwu, E. Du Plessis, L. Korsten, and A.I. Okoh. 2023. Spatial diarrheal disease risks and antibiogram diversity of diarrheagenic *Escherichia coli* in selected access points of the Buffalo River, South Africa. PLoS ONE 18(8): e0288809, https://doi.org/10.1371/journal.pone.0288809

SOUTH AFRICA - COV-079: FRICTION AND FLOWS: UNDERSTANDING COVID-19 IMPACTS ON THE WILDLIFE ECONOMY IN SOUTHERN AFRICA

PI: Annette Hübschle, University of Cape Town
U.S. Partner: Meredith Gore, University of Maryland (Funded by the National Science Foundation)
Dates: November 2022 – March 2024

PROJECT OVERVIEW

USAID has invested substantial resources in helping to build the wildlife economy in South Africa, ensuring that benefits reach traditionally marginalized groups, including women. Unfortunately, an illegal wildlife economy persists and appears to have grown since the onset of the pandemic, undermining sustainable development and biodiversity conservation. Increased understanding of COVID-19 impacts on the wildlife economy can improve targeting of solutions that address inequalities, inform decision-making about economic empowerment activities for women and youth, support opportunities to mitigate threats to biodiversity, develop national capacity to adapt to impacts of climate change, and promote evidence-based policies and practices that promote employment. Without understanding how COVID-19 and related public health measures have impacted the wildlife economy, including friction and flows, it is impossible to reinforce, reset, or recalibrate strategies to positively impact development.

This PEER project sought to enhance understanding about the impacts of the pandemic and lockdown restrictions on the wildlife economy of southern Africa. The team leveraged insights, concepts, and methods from criminology, sociology, and conservation biology, as well as the U.S. partner's expertise in risk mapping and behavioral analysis, conservation criminology, and human dimensions of global environmental change.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers conducted fieldwork in Zanzibar (Tanzania), Zambia, and South Africa, including interviewing affected local communities, especially rural women, to get a sense of COVID impacts on wildlife economy-related livelihoods. A highlight was a focus group with six women who were married to convicted poachers who had jobs in the tourism sector before COVID. Once the pandemic hit, they were laid off and had to find new ways of supporting their families and themselves. They got involved in poaching networks, recruited by intermediaries from Lusaka. In South Africa, the PEER team targeted a wide spectrum of research participants, including a case study on succulent poaching.

As part of this project, the researchers developed the "frictions and flows" framework to understand the dynamics of illegal wildlife trade (IWT) under varying conditions, particularly in response to the exogenous shocks such as those presented by the COVID-19 pandemic. Flows refer to the movements of goods, money, information, and people that facilitate the operation of illegal markets. These can include the adaptation of routes, the shifting of market operations to online platforms, and diversification of traded goods. Conversely, frictions represent obstacles or disruptions to these flows, such as law enforcement actions, changes in regulations, or broader socioeconomic impacts like those from a pandemic.

During the COVID-19 pandemic, South Africa, Tanzania, and Zambia exhibited varied responses, which in turn affected the illegal wildlife trade differently in each region. In South Africa, strict lockdown measures temporarily disrupted traditional trafficking routes, but traffickers quickly adapted by shifting to online platforms and utilizing less monitored logistic options like private vehicles and postal services. Without strict lockdowns in Tanzania, the usual flow of IWT faced fewer frictions compared to countries with stringent measures. The market adapted by integrating into other local economic activities and using alternative medicine markets as cover. In Zambia, moderately strict responses led to a blend of disruptions and continuations in wildlife trafficking. Innovations included increased use of digital communication to coordinate transactions and the diversification into new wildlife products.

The PEER team believes the resilience of illegal networks could inform strategies to improve the resilience of legal economic systems and environmental conservation efforts. For example, understanding how illegal networks shift operations could help in designing more flexible and responsive legal frameworks and conservation strategies that are capable of adjusting to sudden socioeconomic changes.

The researchers published their framework findings in *Science of the Total Environment* in March 2024, and the PI presented the initial findings at several conferences, including the American Geographical Society's annual Conference and the Savanna Science Conference in South Africa. As of May 2024, the PEER team members had received three additional grants from the World Wildlife Federation, Wildlife Trade Challenge Fund, and the University of Cape Town for a total of $147,345. Although the project has ended, the team is now undertaking a participatory virtual mapping exercise with the U.S. partner that will seek to clarify friction and flow points and country-specific illegal wildlife trade.

PUBLICATIONS

Hübschle, A., and M.L. Gore. 2024. Lessons in resilience from the illegal wildlife trade during COVID-19 lockdowns. Science of The Total Environment 916: 170365. https://doi.org/10.1016/j.scitotenv.2024.170365

Hübschle, A., Kerina, K., Mogende, E., & Suping, K. 2024. Voices from the Frontlines in the Okavango River Basin: Towards a Cooperative Model of Environmental Activism in the Global South. International Journal for Crime, Justice and Social Democracy, 13(1), 51–68. https://doi.org/10.5204/ijcjsd.3317

SOUTH AFRICA - COV-060: EARLY CHILD DEVELOPMENT DURING A GLOBAL PANDEMIC: INDIRECT EFFECTS OF COVID-19 IN SOUTH AFRICA

PI: Roisin Elizabeth Drysdale, University of the Witwatersrand
U.S. Partner: Chris Desmond, University of Kwazulu-Natal (Funded by National Institutes of Health)
Dates: November 2022 -December 2023

PROJECT OVERVIEW

Evidence of the impact of pandemics and national responses to them on early child development and growth is limited, particularly on the important first 1,000 days of life. Available data from the United States, the United Kingdom, and China indicate that exposure to lockdown conditions is associated with delays in cognitive, motor, and language skills in infants at six months. Preliminary data from South Africa show similar findings, with additional evidence suggesting that infants exposed to strict lockdown conditions in-utero were more likely to be born at low birthweight. In order to mitigate these negative effects, maintain any improvements in child learning outcomes, and reduce future educational inequalities, there is a need to improve understanding of how the pandemic has affected child growth and development.

In this study, the PEER team assessed the extent to which the COVID-19 pandemic and the national response to it have affected early child development and growth among young children up to 2 years of age in South Africa. The researchers had already collected data from a cohort of infants aged 12 months who were exposed to lockdown conditions in-utero and born during the second wave of COVID-19 infections in South Africa. In this PEER study, the team followed up with the same infants at 24 months and recruited additional mother-infant pairs of similar age from routine health visits to increase the sample size. These infants spent much of their first 1,000 days living under lockdown conditions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project collected data on socio-demographic characteristics of the household, caregiver, and infant; child development; child feeding practices; clinic attendance; caregiver experiences of parenting through the pandemic; and household experiences of COVID-19 illness and death. Child development was measured through the Ages and Stages Questionnaire, Third edition (ASQ-3). The ASQ-3 identifies developmental delays among children aged from two months to five years in five domains (communication, fine motor, gross motor, personal-social, and problem solving). However, this tool is based on parent reporting. To limit bias, when able to, a trained data collector “tested” the infant on some of the questions to ensure the parent did not over-report. These can include, but are not limited to activities with a ball, a mirror, or some vocal activities. To capture the home environment and how it promoted young children’s development, researchers used the Home Screening Questionnaire (HSQ). This is a 30-item parent-report tool that measures features of the home environment related to child development.

The data from this as-yet unpublished study included findings on developmental delay risk levels and factors associated with such delays. Stunting, wasting, and food security issues were also highlighted. A high number of the caregivers reported that they faced challenges during the COVID-19 lockdown and stated that they struggled to parent due to financial issues or feeling sad or depressed. This is also evident in the maternal health questionnaire, with half the caregivers experiencing distress. Dr. Drysdale and her colleagues are continuing to analyze the data and prepare manuscripts for publication.

SOUTH AFRICA - COV-054: YOUTHCAN - CO-DESIGN AFRICAN NEEDS: EXPLORING STRATEGIES TO INCREASE THE UPTAKE OF A SARS-COV-2 VACCINE IN YOUTH: A CO-DESIGNED STUDY WITH YOUTH

PI: Janan Dietrich, Perinatal HIV Research Unit, Division of the University of the Witwatersrand
U.S. Partner: Avy Violari, Perinatal HIV Research Unit, Division of the University of the Witwatersrand (Funded by the National Institutes of Health)
Dates: September 2022 – March 2024

PROJECT OVERVIEW

Less than 30% of the South African population had received a COVID-19 vaccine as of February 2022, and just under 1.3 million South African children aged 12-17 years had been vaccinated. Although much work has been conducted to understand vaccine hesitancy and misconceptions among South African adults, the youth voice has largely been neglected. Prompted by conversations with young South Africans, this PEER project entails three linked objectives, informed by continuous consultation with a youth-led community advisory board. The project sought to better understand how information about COVID-19 is accessed to circumvent vaccine hesitancy in young people and understand and explore ways to increase the uptake of a SARS-CoV-2 vaccine, while identifying ways to offer tools and resources to build resilience against economic and emotional toil of the pandemic. The final output was an intervention co-designed with youth to support vaccination rates in adolescents and young adults.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted two transect walks in Soweto, South Africa, in collaboration with Adolescent Community Advisory Board (ACAB) members. These walks helped familiarize researchers with the study area and allowed them to observe the resources available in each community that could affect vaccine uptake. The researchers subsequently conducted community outreach and convened eight focus groups of residents ages 15-24 between two sites in Soweto. One was an urban area, Diepkloof, and one was an informal settlement area called Motsoaledi. The focus groups were stratified by ages 15-19 and 20-24 and male and female groups. During the focus group discussions, the team explored young people's thoughts, experiences, and perceptions of the COVID-19 pandemic and the COVID-19 vaccine. They also explored participants' thoughts on youth inclusivity, as well as campaigns and strategies they thought would work to get youth involved in decisions and conversations about important procedures should a future pandemic occur again.

Community leaders in both sites were interviewed to understand their experiences on the ground about the pandemic, as well as the wider community's views on the COVID-19 vaccine. The project team contacted primary and secondary stakeholders via email to inform them about the project and how they could be involved with the research results, promoting communication and engagement with stakeholders to create awareness on the research project.

The researchers also conducted a mobile online survey of 532 youths. Questions included socio-demographic information, knowledge of COVID-19, sources of COVID-19 information, COVID-19 anxiety, and experiences of lockdown measures. The team also led six workshops with youth to co-design interventions and strategies for uptake of future vaccines amongst youth. This intervention was focused on broad objectives identified from the PEER research as areas that affected vaccine hesitancy and uptake among youth, specifically effective communication tools for health information and actions the government could take to build trust.

The team presented their initial findings at Johannesburg Research Day 2023, as well as to the Rena le Lona Creative Centre for Children and the Diepkloof Learning Center, developing new relationships with local NGOs. They also conducted a community engagement meeting where study results were shared with key influencers in both communities for their feedback and input. The PI was awarded a $500,000 grant from the Vaccine Confidence Project to continue her research strategy and develop new work focused on economic empowerment opportunities for young adults in the study areas. Several academic manuscripts are forthcoming.

SOUTH AFRICA - COV-041: UNDERSTANDING THE IMPACT OF COVID-19 AND THE NATIONAL LOCKDOWN RESTRICTIONS ON SEX WORKER UPTAKE OF HEALTH SERVICES IN FOUR SITES IN GAUTENG, SOUTH AFRICA: A RETROSPECTIVE RECORD REVIEW

PI: Khuthadzo Hlongwane, Perinatal HIV Research Unit (PHRU), Division of the University of the Witwatersrand and Co-PI Jenny Coetzee, African Potential Foundation

U.S. Partner: Glenda Gray, South African Medical Research Council and Perinatal HIV Research Unit, Division of the University of the Witwatersrand (Funded by the National Institutes of Health)

Dates: November 2022 – March 2024

PROJECT OVERVIEW

HIV prevalence among sex workers in South Africa is among the highest globally, with national estimates suggesting that more than two-thirds of female sex workers were HIV-positive before the COVID-19 pandemic. Pandemic restrictions implemented to curb the spread of SARS-CoV-2 may have impacted access to antiretroviral treatment (ART) and pre-exposure prophylaxis (PrEP). Controlling the HIV epidemic, especially among key populations such as sex workers, is vital to reducing its incidence and prevalence in the country. This PEER project aimed to understand the impact of COVID-19 and the subsequent national lockdown on the uptake of health services offered by sex work programs and how these restrictions have affected the UNAIDS 95-95-95 targets in Gauteng, South Africa. In collaboration with their programmatic partner, Wits RHI, the project team conducted a retrospective record review from four sex work sites across three districts in Gauteng. The review covered two periods: the year preceding the national lockdown (March 1, 2019 – February 29, 2020) and the two years following the start of the lockdown (March 1, 2020 – February 28, 2022). This study sought to evaluate changes in health service uptake and progress towards the UNAIDS targets amidst the pandemic restrictions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The results from the researchers' study showed that COVID-19 had a generally negative impact on healthcare services accessed by female sex workers. Strict lockdown levels, such as Levels 5 and 4, were significantly associated with a negative impact, particularly on outreach visits. These outreach visits are crucial as they provide female sex workers with the opportunity to test for HIV at any time and place. However, some services did improve during the pandemic, including the number of viral loads measured and access to PrEP, but further data collection is needed for a definitive conclusion.

In May 2023, the PEER project team hosted representatives from USAID, the National Academies, and the Department of Science and Innovation of South Africa on a community outreach visit to a district where female sex workers reside and work. The project researchers also participated in the South African AIDS Conference in June 2023 in Durban, discussing the project with other researchers interested in key population studies. The PI presented her findings at the Southern African HIV Clinicians Society Conference in Cape Town in late 2023. As of the final report submission in April 2024, further data analysis was underway, and the team expects to publish a paper on their findings.

SOUTH AFRICA - PROJECT 6-450: WATER SECURITY AND SOCIAL-HYDROLOGICAL RESILIENCE FOR RURAL SMALL-SCALE CROP VALUE CHAINS

PI: Marizvikuru Manjoro Nee Mwale, University of Venda
U.S. Partner: Brian Chaffin, University of Montana, Missoula (Funded by the National Science Foundation)
Dates: March 2018 – February 2022

PROJECT OVERVIEW

A value-chain approach can answer important research questions for sustainable agriculture, food and water security, and social-hydrological resilience. This PEER project sought to identify ways to secure scarce water resources of rural small-scale crop farming value chains at a river basin scale and promote water security that supports small-scale agricultural productivity, specifically in the Limpopo and Zambezi River basins. The PI and her team applied the value-chain analysis framework to assess water use in the production, post-harvest handling, and consumption of selected crops in the Limpopo and Zambezi River Basins. In addition, by estimating the water footprint for selected crops within the Limpopo and Zambezi River Basin, this project produced regional data sets to inform policy and to be used in post-harvest application.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team began with a detailed literature review on agricultural water use, security, productivity and footprinting, seeking to better understand water utilization in rural small-scale crops in South Africa and the broader region. They used value-chain mapping to identify and characterize actors and their linkages, from the producer to the final consumer, and compared variations of water use for selected smallholder crops. They found that most value chains studied were short in nature and dominated by informal trading arrangements based on trust and long-term relations. There were no formal contracts and in most cases, prices were mainly negotiated, based on prevailing market prices in nearby towns. The exception was tomatoes in the Limpopo River Basin, which were grown for commercial purposes and processed into tomato paste.

The researchers used study sites in Zambia and South Africa that grew maize, tomatoes, sugarcane, soybeans, groundnuts, sugar beans, butternuts, and leafy vegetables to calculate the blue water footprint—water sourced from rivers, lakes, dams, and irrigation—of the selected crops. They also identified that most of the water used was in the production phase of the value chain. Researcher interviews with farmers identified their awareness of global water scarcity and documented how they controlled their water use to save water. But they also had inadequate knowledge on water footprints and how they contribute to understanding water usage. The PEER team found the farmers largely don't measure the amount of water they use for growing their crops. This meant that the researchers had to use existing estimates from other studies within southern Africa to calculate the water footprints. Additional water security risks identified by farmers included low volumes of water, low water pressure, old irrigation techniques, poor water infrastructure, algae growth in water jugs used to wash harvested food, and water quality issues, primarily salinity and pollution.

The PEER team developed three policy briefs, including one on managing water risk along crop value chains, as well as farmer handbooks and short courses, which were translated into the local languages. They also held a conference on their research, which led farmers to form an irrigation scheme cooperative and a commitment from the local government to help farmers mentor each other on water security.

The PI Dr. Manjoro was nominated as an Africademics Scholarship Ambassador and to be a member of the Research and Postgraduate Studies Committee for the Faculty of Science Engineering and Agriculture at her institution. Another team member, Linda Downsborough, was named researcher of the year at The Independent Institute of Education, and the PEER project contributed to mentorship and continued research of a number of students, including two PhD candidates and a Master's student. The PEER project also led to the development of a strategy to use solar energy to generate power to drive the water pump machines that channel water from the source to the field.

PUBLICATIONS

Rophinah T. Lebepe, Marizvikuru Mwale, Simbarashe Kativhu, and Jethro Zuwarimwe. 2022. Reviewing the impact of the interventions to reduce water scarcity among smallholder farming Practices. Journal of Kadirli Faculty of Applied Science 2(2): 281-305. https://kadirliubfd.com/index.php/kubfd/article/download/25/42

Simbarashe Kativhua, Marizvikuru M. Mwale, and Jethro Zuwarimwe. 2020. Agricultural resilience under increasing water security threats: insights for smallholder farming in Limpopo Province, South Africa. Water Practice & Technology 15(4): 849-862. https://doi.org/10.2166/wpt.2020.068

SOUTH AFRICA - PROJECT 6-448: DESIGN OF METAL-OXIDE NANOPARTICLE REINFORCED NANO-FIBROUS BIOPOLYMER COMPOSITES FOR WATER TREATMENT

PI: Wilson Gitari, University of Venda

U.S. Partner: James Smith, University of Virginia (Funded by the National Science Foundation)

Dates: January 2018 – January 2020

PROJECT OVERVIEW

The overall objective of this project was to fabricate multifunctional, biopolymer-metal oxide nanoparticle, reinforced composites for fluoride and pathogen removal in groundwater. Previously reported materials have low fluoride adsorption capacity, and there is no information on their capacity for disinfection of the treated water. The biopolymer composite that the PI and his team planned to develop was expected to have high fluoride adsorption capacity and at the same time remove pathogens, resulting in a powerful treatment system to deliver safe, fluoride-free drinking water. These electrospun chitosan-cellulose hybrid nanocomposites are intended to provide active sites for reduction and introduction of Ag-MgO engineered nanomaterials that would be instrumental in imparting pathogen removal capacity. A component of this project was the formation and loading of various metal oxide nanoparticles on the biopolymer composites, testing their effectiveness in simultaneous defluoridation of the groundwater and pathogen removal. The U.S. partner on the project, Dr. James Smith, contributed his expertise in nanomaterial synthesis, as well as his experience in pioneering the application of silver-coated ceramic water filters and ceramic tablets loaded with silver nanoparticles for water treatment in a rural community in South Africa.

This project was intended to help promotes equitable distribution and supply of water by improving access to clean, safe water for rural residents at an affordable cost. It was also intended to lead to more efficient groundwater utilization as an option to satisfy the huge water demand of South Africa. Ultimately, access to safer water would also help improve the health of rural communities, reducing the disease burden on the health infrastructure.

FINAL SUMMARY OF PROJECT ACTIVITIES

In this project, design, synthesis, and testing through batch fluoride adsorption optimization conditions and application of impregnated engineered nanomaterials on a biopolymeric matrix using a sol-gel biosynthesis approach were carried out. The developed biopolymeric nanocomposites sorbents were evaluated and applied for potential application in removing fluoride and pathogens from groundwater on a lab-scale.

Technical experimental protocols on fluoride and microbial removal from simulated contaminated solutions (both laboratory and field water-scale) with the biosynthesized adsorbent are in advanced stages as this project wraps up. Consultations and updates on the material developmental stages are ongoing and have been submitted to the university intellectual property office which is affiliated to the National Intellectual Property Organization (NIMPO), a government entity that funds patenting, technical evaluation of any prototype emanating from research work and potential commercialization. Results have also been shared at conferences and workshops including the 1st International Conference on Sustainable Management of Natural Resources (October 2018), IUPAC Postgraduate Summer School on Green Chemistry (May 2019), and the New Frontiers in Separation Processes & Membranes Development workshop (July 2019).

PUBLICATIONS

Ayinde, Wasiu B., et al. 2018. Biosynthesis of Ultrasonically Modified Ag-MgO Nanocomposite and its Potential for Antimicrobial Activity." Journal of Nanotechnology 2018, Article ID 9537454, pp. 1-10. https://doi.org/10.1155/2018/9537454

Ayinde, Wasiu B., et al. 2018. Biosynthesis of Ag-MgO-nanohydroxyapatite on nanofibrous cellulose for fluoride and bacterial removal in groundwater. Proceedings of the 1st International Conference on Sustainable Management of Natural Resources (ICSMNR 2018), Bolivia Lodge, Polokwane, Limpopo, South Africa, October 15-17, 2018, pp. 68-76. ISBN 978-0-620-82267-1.

SOUTH AFRICA - PROJECT 6-447: EFFECTIVENESS OF POINT-OF-USE WATER TREATMENT TECHNOLOGIES TO PREVENT CHILD STUNTING IN SOUTH AFRICA

PI: Pascal Bessong, University of Venda

U.S. Partner: James Smith, University of Virginia (Funded by the National Science Foundation)

Dates: March 2018 – August 2021

PROJECT OVERVIEW

In low-resource settings, lack of safe water and adequate sanitation has long-term detrimental consequences for child health and development. Continuous exposure to unclean water can lead to poor linear growth among children. Stunting early in life is an important marker of long-term morbidity and has been associated with cognitive impairment, poor school performance, low adult economic productivity, and increased risk of chronic disease later in life. In a recent study, the prevalence of stunting increased from 12% in the first month of life to 37% at 2 years of age in the Dzimauli community of Limpopo, South Africa. Interventions that improve access to safe water and sanitation have the potential to make a significant impact on child stunting but have not been well-studied towards this aim. The municipal water supply for the Dzimauli community is not consistent, and community-level water treatment systems are not available. Less than 20% of households reported treating their drinking water in 2009, which suggests that there is a clear need for an acceptable drinking water solution.

U.S. partner James Smith and his team have helped develop two point-of-use water treatment technologies with demonstrated technical efficacy, sustainability, and social acceptance in several low-resource communities: the silver-impregnated ceramic water filter and the silver-impregnated ceramic disk, called a MadiDrop. This PEER project, led in South Africa by Dr. Pascal Bessong, tested the effectiveness of these technologies on improvement in child health outcomes, specifically reducing pathogen exposure and preventing stunting among children in Limpopo.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER researchers identified and enrolled 400 eligible households from villages in the Dzimauli community. Each household's caregiver was given a container to collect a stool sample from their youngest child, and households were randomized to receive one of three interventions or no intervention. All subjects were advised regarding water health, sanitation, and hygiene practices to follow in the home, and the researchers conducted a baseline questionnaire on demographics, socioeconomic status, water sources, and sanitation and hygiene practices.

Intervention households were visited every month for two years to ensure that the intervention technologies provided were in working condition and being used properly. At three-month intervals, the monthly home visits were extended for further data and sample collection, and all households were visited, including those who received no intervention. At these visits, researchers took height and weight measurements on all children under 15 in the household and collected a stool sample from the youngest child. The PEER team also collected treated water samples from the safe-storage water container at a random subset of 50 households receiving the filter or ceramic disk, and they replaced the ceramic disks every six months.

Stool and water samples were tested for the presence of pathogens, as well as biomarkers for levels of gut function. The researchers found that silver-impregnated clay water filters did significantly remove germs from household water, but this did not correlate with a reduction in stunting in young children. The team also observed how seasonal changes in drinking water availability and the type of drinking water sources affected enteric infections in young children, and they concluded that home-based filters alone were not enough to provide health benefits to young children. They recommended a multi-pronged approach to reduce the load of intestinal pathogens in young children, including the provision of sanitation facilities in the communities and at school.

The PEER team hosted two workshops for high school students and teachers on the consequences of enteropathogenic infections on health growth and cognitive development in children. The researchers published their results in three peer-reviewed papers and received an additional two grants, for a total of $90,000, during the project period.

PUBLICATIONS

David D. Meyer, Courtney Hill, Kelly McCain, James A. Smith, Pascal O. Bessong, Elizabeth T. Rogawski McQuade, and Natasha C. Wright. 2021. Embedding usage sensors in point-of-use water treatment devices: sensor design and application in Limpopo, South Africa. Environmental Science and Technology 2021 55, 13, 8955–8964. https://doi.org/10.1021/acs.est.0c08683

Kathy H. Nguyen, Darwin J. Operario, Mzwakhe E. Nyathi, Courtney L. Hill, James A. Smith, Richard L. Guerrant, Amidou Samie, Rebecca A. Dillingham, Pascal O. Bessong, and Elizabeth T. Rogawski McQuade. 2021. Seasonality of drinking water sources and the impact of drinking water source on enteric infections among children in Limpopo, South Africa. International Journal of Hygiene and Environmental Health 231:113640. https://doi.org/10.1016/j.ijheh.2020.113640

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SOUTH AFRICA - PROJECT 5-432: DEVELOPING EXPOSURE AND TOXICITY DATA FOR TRACE ORGANIC CHEMICALS IN WASTEWATER, BIOSOLIDS, AND SOILS

PI: Bice Martincigh, University of Kwazulu-Natal
U.S. Partner: Natalie Mladenov, San Diego State University (Funded by the National Science Foundation)
Dates: February 2017 – December 2021

PROJECT OVERVIEW

Contemporary lifestyles and the extensive use of organic chemicals in personal care and consumer products (PCCPs) leads to the constant discharge of enormous quantities of chemical residues from industries and homes into wastewater streams and, ultimately, the environment. In contrast to heavy metals, pathways of trace organic chemicals (TOrCs) derived from manufacturing and use of PCCPs are varied in the wastewater stream. The majority of TOrCs that reach wastewater treatment plants are destroyed through treatment and sludge processing, but recalcitrant TOrCs and their metabolites can pass through the treatment process intact and partition, dependent on their physico-chemical properties, in biosolids and aqueous media. Very little is known about the fate of TOrCs in the climatic context of South Africa.

This team chose to study a set of four classes of potential pollutants: flame retardants, the broad-spectrum herbicide glyphosate (Roundup®, ubiquitously used in the local sugarcane industry), antibiotics, and HIV anti-retrovirals. Effluents from wastewater treatment plants in the Durban area, sewage sludge, biosolids, soils from effluent-irrigated farmland, and sludge and/or biosolid-amended soils will be analyzed and characterized for the presence of these TOrCs.

This project had access to the local DEWATS wastewater treatment plant, which allowed for detailed studies on the fate of the TOrCs during their passage through the plant and subsequent agricultural areas, providing a confined and controlled environment. Comprehensive target and non-target analytical techniques were developed to detect and quantify the four classes of compounds in the selected matrices. Furthermore, the team planned to develop a simultaneous extraction and clean-up method for each chemical compound class in the above-mentioned matrices.

FINAL SUMMARY OF PROJECT ACTIVITIES

This research project investigated the presence and behavior of trace organic chemicals (TOrCs) in wastewater and biosolids across South Africa, with a particular focus on compounds derived from everyday personal care and consumer products. These chemicals, including pharmaceuticals, herbicides such as glyphosate, and illicit drugs, are continually discharged into wastewater systems, leading to environmental contamination. Unlike heavy metals, TOrCs exhibit diverse pathways through wastewater treatment plants (WWTPs), where some are effectively removed while others persist through the treatment process and accumulate in biosolids and water bodies.

A critical aspect of the study was the examination of five WWTPs in the Durban area, assessing influents, effluents, biosolids, and biosolid-amended soils for the presence and concentration of TOrCs. Of particular interest was the comparison between conventional centralized WWTPs and decentralized

DEWATS systems, which utilize longer residence times and anaerobic processes, potentially offering superior removal of TOrCs. This research underscored the importance of understanding treatment efficiencies and the environmental risks posed by residual TOrCs in various wastewater treatment contexts.

Moreover, the project delved into risk assessments of selected antibiotics, revealing potential hazards to aquatic organisms and the emergence of antimicrobial resistance in receiving rivers. The innovative use of wastewater-based epidemiology (WBE) provided real-time insights into community drug consumption patterns within the eThekwini Municipality, offering a novel approach to public health monitoring.

The project advanced analytical techniques for both targeted and non-targeted analysis of TOrCs in complex environmental matrices, aiding in comprehensive risk assessments and informing strategies for water reuse in water-scarce regions like South Africa. This development of analytical methodologies has broader implications for global water management practices.

Beyond scientific advancements, the project contributed significantly to human capital development by fostering doctoral and master's research, promoting knowledge exchange through international collaborations, and enhancing the capabilities of local water authorities in policy formulation and environmental stewardship. The PI's recognition, including election as a Fellow of the Royal Society of South Africa and leadership roles in international scientific conferences, underscores the project's impact and influence in the global scientific community.

Future research endeavors include innovation of nanotechnology-based solutions for polishing wastewater effluents, exploring adsorption and chemical oxidation/reduction technologies. These efforts aim to enhance the removal efficiency of recalcitrant micropollutants, ensuring safer wastewater reuse and contributing to sustainable water management practices globally.

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SOUTH AFRICA - PROJECT 5-48: CHARACTERIZING AND TRACKING OF ANTIMICROBIAL RESISTANCE IN THE WATER-PLANT-FOOD PUBLIC HEALTH INTERFACE: AN EMERGING WATER, SANITATION AND HYGIENE ISSUE

PI: Liza Korsten, University of Pretoria

U.S. Partner: Manan Sharma, Environmental Microbial and Food Safety Laboratory, United States Department of Agriculture/ Agricultural Research Service

Dates: December 2016 – November 2019

PROJECT OVERVIEW

Since its onset, the food-processing sector has been under enormous pressure to ensure that processing facilities and food handlers do not contribute to the spread of the virus. Good hygienic practices that involve washing, rinsing, cleaning, and disinfecting were amongst the areas that received special attention. To date, most disinfectant-related research studies have focused on the efficacy of disinfectants in deactivating pathogens, often without consideration for its downstream impact on the environment and public health.

Quaternary ammonium compounds and chlorine-based disinfectants are used routinely as disinfectants in food production facilities. Due to varying resistance to disinfectants, some antimicrobial resistant bacteria can survive disinfection and release free-living DNA in wastewater treatment plants through the sewer lines of food processing facilities where they are usually not removed. Of additional concern is that residual disinfectants and soaps and their degradation products can end up in the environment through wastewater treatment plants where their endocrine disruptive mechanisms as well as their genotoxic and teratogenic properties to mammals and aquatic organisms raise considerable concern.

The main aim of this research project was to assess the contribution of food safety-control practices and COVID- 19 hygiene measures to the downstream quality of non-sewage wastewater from a food processing facility. The project monitored the wastewater discharge from a previously sampled processing facility for the release of targeted microorganisms and chemicals. This is paramount, since a fresh-cut vegetable processing facility may provide an ideal setting for the acquisition and dissemination of antimicrobial resistant organisms and endocrine disrupting chemicals. The selected study site was a food-safety-compliant fresh cut vegetable processing facility where multidrug resistance human pathogenic E. coli will be isolated by the project team.

FINAL SUMMARY OF PROJECT ACTIVITIES

This research project embarked on an extensive investigation aimed at understanding the prevalence and characteristics of antimicrobial resistance (AR) within the intricate nexus of water, plants, food, and public health in South Africa. It had several specific objectives: to determine the prevalence and dissemination of AR, both phenotypically and genotypically, across these interconnected domains; to conduct a comprehensive literature review on fecal contamination indicators, antibiotic resistance profiles, and dissemination in microorganisms across the aforementioned interfaces; to organize workshops involving stakeholders from academia, farming communities, and governmental bodies to assess existing knowledge, potential contamination sources, and select sites for assessment; and to disseminate research findings through various channels such as peer-reviewed publications, conference presentations, and workshops with stakeholders.

Collaborations with international partners were established, with successful submissions for workshop sessions at the International Association of Food Protection's European Symposium on Food Safety. These collaborations extended to training initiatives, with access to food safety training videos. Additionally, stakeholder engagement was a key aspect, with workshops involving academics, policymakers, and representatives from various governmental entities including the Department of Health, Department of Agriculture, and Water Research Commission. Discussions centered on interpreting research findings and developing mitigation strategies based on scientific evidence.

The research findings highlighted concerning levels of antimicrobial resistance across different environments, including water sources, vegetables, and agricultural produce. Notable findings included the identification of ESBL/AmpC-producing Enterobacteriaceae in various samples, indicating potential health hazards for consumers. Furthermore, efforts were made to bridge knowledge gaps and enhance food safety practices through training initiatives and collaboration with government departments, including involvement in a ministerial advisory committee on AR.

Overall, the research contributes valuable insights into the prevalence and characteristics of antimicrobial resistance in fresh produce and agricultural environments, emphasizing the need for continued risk analysis and the development of effective mitigation strategies to safeguard public health. Training initiatives and collaborations served to disseminate knowledge and enhance food safety practices, ultimately benefiting both consumers and the broader community.

SOUTH AFRICA - PROJECT 4-153: GRECHLIM

PI: Tamiru Abiye, University of the Witwatersrand
U.S. Partner: Richard Healy, United States Geological Survey
Dates: November 2015 – March 2019

PROJECT OVERVIEW

As groundwater resources are increasingly impacted by human development, understanding their sustainability and renewability is crucial. Groundwater recharge, the process of water reaching the water table, governs the replenishment of aquifers. This is a critical but difficult-to-quantify part of the water budget. The Limpopo River Basin (LRB) relies on both high-yielding dolomite aquifers and smaller, less productive crystalline aquifers, each with distinct recharge processes and management issues. Emerging research suggests that recharge in these semi-arid environments is episodic and driven by climate extremes, challenging the assumption of continuous replenishment. Recharge often occurs through preferential pathways like fractures, intermittently flooded areas, and flow channels, rather than uniformly across the landscape. Understanding groundwater renewability and sustainable exploitation limits in an environmental context is still developing.

This project aimed to better determine recharge processes, quantities, and locations in the LRB, and use this information for groundwater development and management at selected sites. A key objective of the GRECHLIM Project was to enhance the capacity of young scientists and local and national authorities to assess groundwater recharge through applied field investigations. This capacity development was integrated into students' theses and supported by hands-on training at the U.S. Geological Survey (USGS) facilities. The project also fostered strategic partnerships with stakeholders involved in water resources management, including the transboundary LRB organization LIMCOM, local farmers, and water utilities, to augment resources and improve services.

Findings from the project were intended to be synthesized into guidelines and tools for managed aquifer recharge, predicting groundwater availability based on climate and land use, and assessing sustainable groundwater exploitation limits. These tools and guidelines were to be developed in collaboration with relevant stakeholders and disseminated through consultations and workshops. Collaboration with climate and seasonal forecasting entities, such as the Southern Africa Regional Climate Outlook Forums, was explored to support incorporating groundwater information into forecasts.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project investigated groundwater recharge rates and processes, particularly in Johannesburg, highlighting the influence of climate variables on baseflow and the balance between natural stream flow and wastewater contributions. Johannesburg's rainfall, sourced from various sources, presents challenges in groundwater assessment due to isotopic variations. Recharge predominantly occurs in the south of the Upper Crocodile River Basin through fractures and cavities in quartzites and dolomites. The study's outcome, shared through stakeholder meetings and publications, emphasizes the sensitivity of stream flow to climate changes and predicts increased wastewater alongside decreased baseflow, leading to heightened pollution risks.

Additionally, the International Water Management Institute conducted physico-chemical water quality analysis and employed various methods to estimate river flow contributions and groundwater-surface water interactions in the Letsitele Catchment. Understanding these interactions is crucial due to commercial farming and water supply infrastructure in the area, aiding in evaluating aquifer sustainability and informing water resource management decisions.

The PEER team continuously engages the Department of Water and Sanitation (DWS) so that they can start to use the recharge methods and groundwater-surface exchange methods that they tested in this study. They will also encourage DWS to continue monitoring groundwater for management and planning purposes and policy development.

PUBLICATIONS

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SOUTH AFRICA - PROJECT 4-149: PROMOTING COMMUNITY AND REGIONAL FOOD SYSTEMS IN THE EASTERN CAPE, SOUTH AFRICA

PI: Michael Aliber, University of Fort Hare

U.S. Partner: Stephen Ventura, University of Wisconsin-Madison (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Dates: October 2015 – September 2017

PROJECT OVERVIEW

The goals of this project were to (1) better understand the market failure in the ex-Bantustans of the Eastern Cape, South Africa, where food consumption relies little on local food production despite significant production capacity, and (2) determine the extent to which innovations from the United States and elsewhere can address this issue. South African literature largely overlooks this market failure, focusing instead on small-scale farmers' inadequate access to formal markets outside the ex-Bantustans. This perspective ignores that effective food demand within the former homelands is substantial (with over half of all food expenditure in the Eastern Cape accruing to households in the ex-Bantustans) yet mainly catered to by large-scale commercial farmers outside these areas. The reasons for this have been largely unexplored.

This project aimed to fill this gap through various fieldwork activities, enriched by comparing and contrasting marketing arrangements for different commodities within and between ex-Bantustans, commercial farming areas, and urban areas. Researchers planned to examine successful strategies such as promoting farmers' markets, aggregation, and innovative use of third-party logistics operators, determining their applicability to South Africa's ex-Bantustans. By addressing these issues, the project sought to understand and potentially rectify the disconnect between local food production and consumption in the Eastern Cape's ex-Bantustans, fostering a more self-sufficient and sustainable food system.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project found that the majority of consumers prefer to buy from small-scale farmers (73%) compared to large-scale farmers (16%), with 10% having no preference. Among those who prefer small-scale farmers, 64% do so to support black farmers and the local economy. However, much of the food expenditure of black consumers goes to formal shops in towns, mostly belonging to national chains. Another important finding is that most shopping occurs at the end or beginning of the month, aligning with wage and social grant disbursements. Many social grant recipients prefer to shop on the second or third of the month to avoid long queues.

The area-based studies involved interviews with retailers, categorized as supermarkets, independent shops, and petty traders ('hawkers'). The interviews aimed to understand their target markets, food procurement sources, and the advantages and disadvantages of dealing with small-scale farmers. It was found that retailers often use small-scale farmers as secondary sources to fill gaps left by main suppliers. Advantages of small-scale farmers include willingness to deliver weekly and fresher produce. However, the inconsistency in supply volume is a major drawback for larger retailers.

The team also interviewed farmers to understand their marketing experiences and perspectives on different markets. While formal markets are seen as more lucrative, many farmers are satisfied selling to villagers or hawkers due to consistent demand, reasonable prices, low transport costs, and immediate payment. Selling to supermarkets is beneficial for larger harvests but requires consistent supply, which is challenging for most small-scale farmers. The findings suggest that appropriate interventions, such as promoting marketing cooperatives over production cooperatives, could help small-scale farmers increase business with local retailers.

Despite the challenges, the results are encouraging. The barriers preventing small-scale farmers from doing more business with local retailers—and the reasons retailers avoid relying on local farmers—can be addressed through suitable interventions. One effective strategy could be promoting proper marketing cooperatives, which can help small-scale farmers overcome the disadvantages of their size by collaborating in marketing. This approach would address issues of quantity, consistency, and communication, as many retailers are unaware of local small-scale farmers due to their lack of marketing skills and resources.

While the project has ended, the PI and team plan to publish their findings and continue researching potential interventions. Apart from the farmers' market idea, they are exploring other strategies, such as unlocking existing incentive schemes to empower local entrepreneurs in agro-processing. Another possibility is revisiting conventional approaches to address the disadvantages of small-scale farming, such as developing a cluster development agent approach. As supermarkets in rural towns are here to stay, improving their ability to interface with small-scale farmers remains a priority.

SOUTH AFRICA - PROJECT 3-120: MANAGING FIRE AND GRAZING TO MAXIMIZE CARRYING CAPACITY IN AFRICAN RANGELANDS

PI: Sally Archibald, University of Witwatersrand
U.S. Partner: Todd M. Anderson, Wake Forest University (Funded by the National Science Foundation)
Dates: October 2014 – September 2017

PROJECT OVERVIEW

Fire and herbivory are key ecological and evolutionary processes shaping savanna landscapes. While fire is more prevalent in high-rainfall savannas, and herbivory in low-rainfall savannas, over much of the rainfall gradient both of these two disturbances are present. How these two consumers interact to create and maintain savanna heterogeneity across rainfall gradients is not well understood. Fire cannot spread in short-grazed grassland, but details of how this works in a spatio-temporal context are unclear. Alternative systems representing either heavily grazed or frequently burnt habitats can occur in savanna landscapes depending on the mix of fire and herbivory, and the extent of these system states can be altered by fire and grazing.

Using manipulative field experiments and regional-scale analyses, this research project sought to address the following questions: (1) How easy is it to manipulate the proportion of short grass: tall grass habitat in an ecosystem? (2) How applicable can these results be across rainfall gradients and in terms of the types of herbivores present? (3) What is the appropriate ratio of short-grass and tall-grass habitat?

FINAL SUMMARY OF PROJECT ACTIVITIES

This project had three main objectives, all of which were achieved:

- Determine whether concentrated short-grass grazing patches could be created through careful application of fire and use of pyric-herbivory.
- Assess the value of these short-grass patches to different grazing animals (including livestock) and overall biodiversity in terms of NPP
- Explore how prevalent these short-grass grazing systems are across different parts of tropical Africa and along gradients of rainfall and soil fertility.

The team demonstrated that it is possible to create patches in two very different ecosystems through the application of small, repeated fires and saw massive responses of wildebeest and other short-grass species to these patches. They also observed changes in grass, wildflower, and insect communities with the spread of these patches (i.e. increased beta-diversity). The team have yet to finalize the role of these patches in livestock systems, but it is clear that in communal rangelands, most cattle depend on these for their growing season forage and that commercial farmers are becoming interested in creating such habitats on their farms.

With the help of their U.S. collaborator, this project produced a unique dataset of grazing lawn occurrence across south and east Africa, which has so far given unexpected results (e.g., the expected relationship with soil fertility was not apparent). The PI and her team collected data from more than 40 sites across South and East Africa and ran a regional analysis of fire-grazer interactions, as well as developed and published a conceptual model on this.

Through the PEER project, the team developed a memorandum of understanding with the Herding for Health program run by the University of Pretoria in the Welverdiend communal rangeland near the Kruger National Park, and they will be collaborating on implementing their ideas in these rangelands. The PI and her team will continue to build their relationship with Working on Fire (part of the South African Government's expanded public works job creation program). They will apply all of their experimental burns and advise them on the research application of their work. The team also presented their work at two international conferences (Ecological Society of America and the Association for Tropical Biology Conservation) and have published numerous articles in scientific journals and the media.

The team's work received international recognition, with colleagues from Texas A&M interested in setting up similar experiment in their ecosystems and collaborating on the socioeconomic aspects. It has also received recognition from the South African National Parks, who have altered their fire management plans based on their results. They are working with both commercial and communal farmers to explore the implications of their ideas in livestock areas.

The PI will continue to carry out this research project. The team is currently working on the cattle-wildlife comparison through a grant from the Global Change Grand Challenge and will be engaging communal and commercial farmers to assess the impacts of grazing lawn habitat for their livestock. They also have funding from the South African National Parks to continue monitoring the effects of the drought on their experimental site in the Kruger National Park, which will give them a much broader insight into the value of these short-grass ecosystems in relation to the natural variability of semi-arid grazing systems (all indications so far are that the history of grazing has a big impact on the trajectory of recovery after a drought event). Lastly, the team has funding from the Royal Society Newton Grant to expand their assessment of the distribution of these grazing-lawn systems across environmental gradients, their evolutionary history, and their role in increasing resilience of African ecosystems to human activities (livestock) and climate change.

PUBLICATIONS

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SOUTH AFRICA - PROJECT 2-512: MAMMALMAP: THE AFRICAN MAMMAL ATLAS PROJECT

PI: Lesley Gordon Underhill, University of Cape Town, with Co-PI Robert Peter Millar, University of Pretoria
U.S. Partners: Walter Jetz, Yale University, and Robert Guralnik, University of Colorado at Boulder (Funded by the National Science Foundation)
Dates: August 2013 – November 2015

PROJECT OVERVIEW

Africa is home to an incredible abundance and diversity of life. However, protecting this biodiversity, especially in the face of global climate change and increasing human pressures, requires a solid understanding of the current geographical distribution of species across the continent. Much of our knowledge of African mammal distribution is based on outdated or unverified information, hindering effective conservation efforts. To address this, MammalMAP (the African Mammal Atlas Project), an initiative by the University of Cape Town (UCT) and the University of Pretoria (UP), aimed to create up-to-date range maps for all African mammal species.

By collaborating with scientists, conservation organizations, wildlife authorities, and citizen scientists across Africa, MammalMAP consolidated reliable evidence of current mammal occurrences into a single open-access digital database. The software automatically generated online distribution maps that are instantly visible and searchable. This database was crucial for shaping species and landscape conservation policies and served as an excellent educational tool for raising public awareness about the challenges facing Africa's biodiversity.

This PEER project sought to facilitate data sharing and collaboration between MammalMAP and the Map of Life, an online biodiversity integration and visualization infrastructure led by U.S. partners Prof. Walter Jetz and Prof. Robert Guralnik. The collaboration also integrated 15 million records of southern African biodiversity distribution data curated by UCT into the Map of Life database, enhancing the overall understanding and management of Africa’s biodiversity.

FINAL SUMMARY OF PROJECT ACTIVITIES

Objective 1. Consolidate mammal distribution data: The project assembled more than half a million records of mammal distribution from a large number of sources. This incredible resource is available in a single, open-access repository.

Objective 2. Involve and educate citizen scientists: The team averaged around 4,000 submissions of records of distribution to the MammalMAP section of the Animal Demography Unit (ADU) Virtual Museum. They put effort into maintaining and providing leadership to the large MammalMAP group on Facebook. One of the weekly highlights in relation to MammalMAP was Mad Mammal Monday, which is an important component of the education and involvement of the public.

Objective 3. Effective data processing: High standards in the identifications of records submitted to MammalMAP have been maintained. Ten ID panel members have been responsible for the identification and confirmation of identification of MammalMAP records in the reporting period.

Objective 4. Improvements to technology: The ADU's information systems team (and especially Nosipho Mali) developed software, including APIs, which enable communication both into and out of the MammalMAP database. The software team in their NST partner was incredibly helpful in providing guidance on this. Continuous enhancements have been made to the website.

Objective 5. Ensure relevance and usefulness: All the ADU's taxon databases are continually used by the biodiversity assessment component of environmental impact assessments. The downloadable databases are the best of their kind in the country, and the ADU Virtual Museum is the resource of choice for most EIA consultants.

Objective 6. Integrate with Book of Life: MammalMAP data has been transferred to the Book of Life project of their NST partner. The entire ADU database, consisting of some 20 million records, will shortly be available through GBIF. They have recently installed and successfully tested their IPT server, linked to Global Biodiversity Information Facility (GBIF) through South African Biodiversity Information Facility (SABIF).

One other success of the project is that the team is engaged with the Department of Environmental Affairs helping them to develop systems that generate "flags." If a developer wants to develop a site, the website will flag the concerns that relate to the site. In other words, if a rare or threatened mammal occurs at the site, the flag will provide an alert regarding the biodiversity assessment conducted for the EIA, and the developer must specifically address the issue of this species. The development of this tool enabled the outcomes of the Mammal Red Listing exercise.

SOUTH AFRICA - PROJECT 2-445: APPLICATION OF COSMIC RAY PROBES FOR THE VALIDATION OF HYDROMETEOROLGICAL AND REMOTE SENSING MODELS

PI: Colin Everson, University of Kwazulu-Natal
U.S. Partner: Marek Zreda, University of Arizona (Funded by the National Science Foundation)
Dates: October 2013 – February 2017

PROJECT OVERVIEW

The vulnerability of South Africa to climate and environmental change is increasing as demands on resources continue to rise in conjunction with rapidly growing populations. Disaster management agencies will have to adapt to the increasing number of natural disasters, including droughts and floods. In addition, water resources management, crop modeling, and irrigation scheduling all require accurate, spatially distributed, daily estimates of soil water (SW) and total evaporation (ET) from catchment to national scale. This will only be feasible through remote sensing technologies, and it is therefore essential to further the development and integration of space-based technologies within already existing national disaster management plans.

This PEER project leveraged the development of the Cosmic Ray Probe (CRP) as part of a National Science Foundation-supported project. The CRP uses cosmic-ray neutrons to measure soil moisture content over an area of tens of hectares. The PI and his research team tested the suitability of a cosmic ray moisture probe in providing data for the continued support of soil moisture modeling of South Africa using a hydrologically consistent land surface model, accurate field and satellite-scale estimates of soil moisture for the calibration of hydrometeorological models, and estimation of the spatial variability of soil moisture at catchment scale.

This new technology can be employed in water demand forecasting and promises to improve the utilization of irrigation water, especially in water scarce regions like South Africa. The probe can also be used for predictive weather and climate models by measuring soil water content. The project improved the quality of soil moisture data that feed into the South African Flash Flood Guidance System, which provides alerts to the public based on current and predicted rainfall. The system currently uses a relatively crude evaporation model. Therefore, the application of CRP data should help in validating evaporation estimates with better temporal and spatial resolution, thus improving the accuracy of flash flood predictions.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Everson and his team selected three different sites with contrasting land uses for this study: agricultural crops at Baynesfield (soybean and maize) near Pietermaritzburg; natural grassland vegetation at Cathedral Peak in the KwaZulu-Natal Drakensberg; and commercial forestry at the Two Streams catchment, afforested with Acacia mearnsii (Black wattle) in the KwaZulu-Natal midlands. The PEER team also purchased a CRP rover to obtain estimates at a scale suitable to validate remote sensing.

Cosmic ray probes were installed on tripod masts in each of the three research catchments, connected to a datalogger with an antenna used to send data via satellite link. The CRP estimates were validated against in-situ SW datasets to test the suitability of the CRP to provide spatial estimates of SW. At the Cathedral Peak Catchment site, the CRP followed the same seasonal trend as the in-situ SW estimates. The CRP correlated to the in-situ SW dataset better in the wetter periods, when the SW values were higher (above 30%) compared to the drier periods. Overall, this data correlated well with the in-situ SW dataset. The Satellite Applications and Hydrology Group (SAHG) SW was obtained in Standardized Soil Moisture Index format and converted to SW by using a representative porosity value. The SAHG SW estimates followed the same seasonal trend as the CRP estimates with a close correlation between the two datasets, in terms of general increases and decreases in SW content. The CRP had more variation in SW from day-to-day. The researchers also back-calculated SW from relative evaporation and evaporative fraction estimated using the Surface Energy Balance System (SEBS) model, but the SEBS model performed poorly against the CRP validation data.

The PI and team members presented methodology and findings of their studies through several technical presentations both in South Africa and internationally. The CRP equipment acquired through this PEER project has created a platform for a PhD student's ongoing doctoral studies. The team also was awarded a $20,000 grant for continued hydrometeorological monitoring at the Two Streams catchment.

PUBLICATIONS

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SOUTH AFRICA - PROJECT 2-181: CLIMATE CHANGE AND ARID-ZONE BIRDS: VALIDATION OF A BEHAVIORAL INDEX FOR ASSESSING SPECIES' RELATIVE VULNERABILITIES TO RISING TEMPERATURES

PI: Andrew McKechnie, University of Pretoria

U.S. Partner: Blair Wolf, University of New Mexico (Funded by the National Science Foundation)

Dates: August 2013 – March 2016

PROJECT OVERVIEW

Predicting the impacts of climate change on birds is one of the greatest challenges currently facing ornithologists. Bird communities inhabiting hot desert environments may be particularly vulnerable to rising temperatures due to thermal stresses and unpredictable water and food resources in these habitats. Increasing temperatures in hot deserts are predicted to cause bird range changes, but there is currently no capacity to predict which species will respond first or when. Making such predictions requires a mechanistic understanding of the links between the physical/environmental characteristics of habitats and organismal performance. The physiological research needed to elucidate these links requires time-consuming and intensive study of individual species, making this approach generally unsuitable for anything more than a small subset of the species that make up arid-zone bird communities.

The research carried out as part of this PEER project sought to validate a behavioral index of vulnerability to heat stress in birds inhabiting hot desert environments. Dr. McKechnie and his team tested predictions that related heat dissipation behaviors to underlying changes in body temperature and hydration status in model species that varied in terms of the relationship between environmental temperature and heat dissipation behaviors. The overarching aim of this research was to develop a rapid assessment tool, whereby the relative vulnerabilities of birds making up arid-zone communities to more frequent and severe heat waves could be assessed largely based on behavioral observations.

The development of such a rapid assessment tool meant that the species most vulnerable to the impacts of climate change could be identified in any desert environment, anywhere in the world, on the basis of readily collectable behavioral data.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the final year, the graduate team member spent three months at their field site near Askham in the Kalahari Desert. During this time, she obtained behavioral and body temperature data for two species: Namaqua Dove and White-backed Mousebird, using the same approaches as during the first and second field seasons. The data collected consisted of body temperatures using VHF temperature-sensitive transmitters, behavioral observations to quantify the temperature-dependence of heat dissipation behavior, and experimental manipulations of hydration status to test hypotheses concerning the interacting effects of hydration status and thermoregulation.

Behavioral analyses and body temperature data collected revealed several key findings. One major question for the project was establishing whether HD50 values vary between captive and free-ranging birds. The data suggests that, for all but Cape Turtle-Doves, HD50 is either slightly higher or slightly lower under captive conditions. Omnivorous species tend to have lower HD50 in captivity whilst granivores and frugivores have higher HD50 in captivity. Of the four species examined, no changes in heat dissipation behavior with water restriction were observed for the two frugivorous species. For these two species, HD50 on water restricted (WR) days was almost identical to ad libitum (AL) HD50, where water was freely available. There remains more than 10 °C variation in captive HD50 values, providing the interspecific variation necessary to test hypotheses concerning the physiological basis of these behavioral differences. Frequency distributions of daytime body temperatures for eight species reveal relatively high body temperatures, with modal values between 41 and 43 C for all species investigated.

As expected, the three columbids (i.e., doves and pigeons) appear to show slightly lower values compared to passerines. Preliminary data of body temperature for the water restriction experiments do not reveal any obvious differences in patterns of thermoregulation on hot days between conditions of ad libitum water availability (AL) and water restriction (WR). There appear to be no major shifts in modal body temperature with water restriction for any species tested. There are interesting interaction effects between air temperature and water restriction, suggesting that on only on water restricted days body temperature increases with increases in air temperature.

In summary, the team collected data for nine species, which was the total envisaged in the original proposal. At the time the final report was submitted, the PhD student was in the process of analyzing this very large dataset (the number of body temperature data points, for instance, runs into many thousands for each species).

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SOUTH AFRICA - PROJECT 2-176: DEVELOPMENT OF ADVANCED COMPOSITE MATERIALS AND GEOPOLYMERS FOR THE REMOVAL OF URANIUM AND TOXIC ELEMENTS FROM GOLD MINE-POLLUTED WATER

PI: Hlanganani Tutu, University of the Witwatersrand

U.S. Partner: Edward Rosenberg, University of Montana (Funded by the National Science Foundation)

Dates: October 2013 – September 2016

PROJECT OVERVIEW

The Witwatersrand Basin in South Africa faces significant water pollution challenges due to acid mine drainage (AMD) from gold mining activities. AMD in the region contains a wide range of toxic elements, including uranium, arsenic, lead, mercury, and other metals, primarily emanating from inactive or abandoned mine facilities like tailings storage facilities, tailing ponds, waste rocks, abandoned mine shafts, and open pits. Due to a lack of funding for treatment, surface and groundwater resources are continuously contaminated, impacting communities that rely on these water sources.

This PEER project studied two remediation approaches for the polluted water. The first focused on treating tap water used by households drawing from mine-polluted aquifers. Silica polyamine composites (SPC) were developed for the removal of uranium and other toxic elements, intended for use in faucet filters and columns that could be inserted into drinking water containers like kettles and jars. Since commercially available adsorbents are often expensive and out of reach for affected communities, and affordable options like activated carbon are not very effective for removing uranium and arsenic, the study explored augmenting activated carbon with SPC to improve element removal.

The second approach concentrated on bulk remediation at contamination sources, developing cost-effective geopolymeric materials using fly ash from coal mining, slag from furnace smelters, and a silicate binder. This material was used in concrete mixes to form porous reactive barriers at mine-polluted sites to intercept polluted water flow, providing an adsorption surface for toxic elements and improving water quality. The project also investigated the potential recovery of low levels of precious metals, such as gold and silver, from gold mine-polluted water. By allowing these metals to load onto the adsorbents over time, they could be desorbed by an acid leach and concentrated using SPC selective for precious metals and uranium, enabling economic recovery and possibly reducing or eliminating remediation costs. This study may have broad applications in South Africa's mining industry and provided opportunities for students to engage in applied and fundamental academic research.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Tutu and his team achieved several milestones that can be summarized as follows:

Water is a scarce resource in South Africa, as it is in most of the countries. The few available resources tend to be contaminated, leaving communities with little choice but to use such contaminated resources. This research explored the possibility of using cost effective methods to remediate mine contaminated water and to recover any potential value from it. A variety of adsorbents that can now be deployed to the sites were developed and tested at laboratory scale. These adsorbents showed potential to remove toxic elements such as uranium, mercury and lead from contaminated water, thus rendering the water safe to use by households. Recovery of low levels of gold from the mine leachates was found to be possible using modified zeolites that tend to be very selective.

Through PEER funding, Bronwyn Camden-Smith graduated with a PhD in July 2016. Her research work was based on water chemistry characterization and modeling of processes related to the distribution, transport and speciation of elements in mining environments. Six publications and a book chapter were realized from her work.

Two BSc Honors students were also recruited, Tshepiso Mpala and Tshegofatso Mabilane. Ms. Mpala's project focused on using modeling to predict changes in water chemistry in an acid mine drainage treatment plant. The findings showed that it is possible to reduce the amount of neutralizing agents (e.g., lime) without compromising the quality of the resulting treated water as long as the sludge produced within the process was recycled and used to condition the incoming acidic water. Furthermore, the work showed that it is possible to use modeling as an integral part of the process design and optimization.

Ms. Mabilane contributed to a project on recovering low levels of gold in mine leachates using a sulphur modified zeolite. The project was predicated on the premise that gold that was left over by metallurgical processes and disposed in tailings leaches out over time as a result of weathering of the host ores. This gold can be salvaged by using selective adsorbents such as those containing sulphur groups as they tend to have a high affinity for gold. The adsorbents have also been found to have a high affinity for mercury, a toxic element that is usually contained in gold mine leachates.

The team's connections and collaborations with AngloGold Ashanti and the Cancer Association of South Africa (CANSA) have been strengthened. AngloGold Ashanti are interested in the possibility of reclaiming the contaminated water and the recovery of value from the water e.g. recovering low concentrations of gold from mine leachates. CANSA are interested in the effectiveness of the adsorbent materials in removing carcinogenic contaminants. Other organizations that have been engaged through the project are Mintails (a gold mining company) and the Trans Caledon Tunnel Authority (TCTA) that operates the acid mine drainage treatment plants in the Witwatersrand Basin.

In summary, the research findings have shown that it is possible to develop cost effective materials based on natural materials such as fly ash and zeolite to remove toxic elements e.g. uranium from mine contaminated water and that it is possible to use the developed materials to recover value (e.g. gold lost through leachates) from such water. The findings have also demonstrated the potential application of these materials on a large scale (e.g. fly ash-cement composite) and on a small scale (e.g. functionalized zeolite in column systems deployed in household water containers).

The PI plans to continue the deployment of adsorbents in the field, i.e. both at mine sites (bulk adsorbents) and households (small scale adsorbents). A variety of adsorbents (that have been identified as one of the spinoffs of this project) will also be studied in further projects. These have been extended to include the recovery of precious metals such as gold and silver as well as the rare earth elements.

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TANZANIA

TANZANIA - PROJECT 9-456: MOROGORO YOUTH EMPOWERMENT THROUGH ESTABLISHMENT OF SOCIAL INNOVATION (YEESI) LAB FOR PROBLEM-CENTERED TRAINING IN MACHINE VISION

PI: Kadeghe Fue, Sokoine University of Agriculture
U.S. Partner: Glen Rains, University of Georgia (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: May 2021 – February 2024

PROJECT OVERVIEW

This project established a social innovation lab (YEESI) for a machine vision program that will be used by youth in the Morogoro region of Tanzania. The idea for the effort arose because there were young people in the area who had studied information technologies and allied sciences, and while most of them can write computer programs, they cannot solve machine vision problems. This project aimed to increase awareness among the youth of Morogoro and nearby regions to address machine vision problems in agriculture. Machine vision is a new and understudied practice in Tanzania; hence, this project will contribute to efforts in the creation of scientific societies that address the most pressing problems faced by the more than 80% of Tanzania's population who engage directly in farming.

The main agricultural problems that could be addressed using machine vision may be classified into five categories:

1. Disease Detection and Classification: The project intended to develop experts who will solve problems in disease identification using machine vision for most of the diseases in crops and livestock, which are misdiagnosed by farmers.

2. Weed Classification: The project set out to develop algorithms that accurately identify weeds and contribute to the growing scientific database for automatic weed detection.

3. Pest Detection and Classification: Appropriate tools using machine vision for Integrated Pest Management (IPM) are needed in Tanzania, as IPM has been hindered due to a lack of extension officers to train farmers on mitigation and identification of pests in agriculture.

4. Crop Seedlings Stand Count and Yield Estimation: Use of machine vision and drones instead of scouting manually to estimate stand counts would provide appropriate mitigation strategies for replanting that would be beneficial to commercial farmers. Also of importance are algorithms to sort and estimate yield by counting the fruits and to estimate the amount of other agricultural products.

5. Crop Vigor Estimation: Most farmers apply inputs evenly across the farm because they cannot predetermine crop vigor. Accurate estimation of crop health would help farmers to mitigate the problems earlier and improve crop performance and avoid failure. Algorithms to determine crop vigor developed in this project are anticipated to contribute to the improvement of the methods to estimate crop performance earlier.

FINAL SUMMARY OF PROJECT ACTIVITIES

The YEESI Lab at Sokoine University of Agriculture is a center of excellence for advancing ICT education in Tanzania. Supported by PPER, the lab has been at the forefront of innovation and has designed problem-based and student-centered methodologies that have helped bridge the gap between theoretical knowledge and practical skills. The lab's hands-on approach to learning has enabled it to host training workshops and engage students in competitions that provide essential skills needed in the tech industry. These skills include startup establishment, fundraising, and specialized training in Machine Learning (ML), Machine Vision (MV), and Natural Language Processing (NLP) applications. This approach has not only enhanced the technical proficiency of students but also fostered significant personal growth.

Furthermore, the lab has been committed to promoting gender equality in the tech industry by encouraging female students to participate in competitions and challenges, such as those presented by Zindi African Challenges and hackathons, making them more competitive in job markets. These competitions have helped showcase the capabilities of students on various scales, and they have gained recognition and awards that validate their skills and increase their visibility and credibility within the tech community.

One of the exceptional aspects of the YEESI Lab's efforts is its focus on technological advancement and community impact, which has facilitated substantial local development. By fostering innovation and building capacity, the lab has contributed to sustainable agricultural practices and economic growth within Tanzania. The lab has helped establish five Artificial Intelligence start-ups that develop technologies to assist farmers in making data-driven decisions. This integration of diverse disciplines has also cultivated an entrepreneurial mindset among students, positioning them well for future endeavors in technology and entrepreneurship.

The YEESI Lab has trained students and worked with start-ups and NGOs to establish the first comprehensive machine vision dataset suitable for central regions of Tanzania. The dataset has been open-sourced to allow more collaborators to work on it while developing Machine Learning models that would be useful in Tanzania and Morogoro region. The startups can use the data for free. The lab has also collected more data using drones, which involved training farmers on the beneficial use of drones, since it is a new technology to most remote areas where most farmers are located. The farmers were able to understand how drones work and present problems that they think drones may help solve, including issues on salinity and floods.

It is worth noting that the YEESI Lab's approach to problem-based learning has yielded exceptional results, and some achievements have been made by students who were not enrolled in ICT degree programs. This demonstrates the effectiveness of involving multiple disciplines in ICT-related problem-solving and innovation. Through these comprehensive efforts, the YEESI Lab has enhanced the educational landscape in ICT and contributed significantly to community entrepreneurship, empowerment, and sustainable development. The lab has positioned itself as a leading center of excellence in ICT education in Tanzania, and its innovative methodologies have become a benchmark for other institutions seeking to improve their education systems.

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TANZANIA - PROJECT 9-257: SOLAR DRYER INTEGRATED WITH ENERGY STORAGE SYSTEM: AN ENERGY EFFICIENT AND ENVIRONMENTALLY FRIENDLY TECHNOLOGY FOR DRYING BIOMATERIALS IN TANZANIA

PI: Thomas Kivevele, Nelson Mandela African Institution of Science and Technology (NM-AIST)

U.S. Partner: Sunghwan Lee, Purdue University (Funded by the National Science Foundation)

Dates: July 2021 – October 2023

PROJECT OVERVIEW

More than 40% of agricultural produce in developing countries is wasted, not only due to lack of storage and processing facilities, but also due to limited knowledge of processing technologies. Biomaterials, which are traditionally sun-dried, are often of poor quality due to the complexity in controlling drying parameters. Presently, most farmers in Tanzania use biomass and natural sun for drying their farming products, but biomass is becoming increasingly scarce and farmers, especially woman, have to walk long distances to fetch firewood (Mwema and Gheewalaa, 2011). Tanzania receives abundant solar radiation that can be used for drying agricultural produce. Solar dryers have the potential to exploit this renewable resource, and the technology is attractive because of its ability to rapidly, uniformly, and hygienically meet drying standards with zero energy costs. Despite development of solar drying technology in sub-Saharan Africa, most countries like Tanzania have seen limited market penetration because of a need for further research. Many solar dryers are only useful on sunny days and useless at night or during cloudy days. To facilitate drying in the absence of sunlight, dryers must have the capacity to collect and store heat for later use (e.g., overnight drying).

This project was intended to develop an inexpensive, effective, and reliable solar dryer integrated with a thermal energy-storage system made of locally abundant and affordable materials (rocks) with favorable thermal and mechanical properties. The dryer prototype includes a solar collector and bed storage made of carbonate (dolomite and limestone) and granitic rocks. The project further theoretically and experimentally investigated in-situ performance and economic feasibility of the developed dryer.

FINAL SUMMARY OF PROJECT ACTIVITIES

Before designing their solar dryer, the team studied challenges of existing solar dryers that were developed in Tanzania by the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) based in Arusha-Tanzania. The team found that CAMARTEC were constructing passive solar dryers, which become useless in the absence of sunlight, thus interrupting the dehydration process at times of low light or at night when solar radiation is unavailable, resulting in a bad quality of the dried products. In addition, since temperature control in drying using this type of dryer is difficult, at high temperature a product can be dried too quickly resulting in surface hardening, which increases resistance to moisture diffusivity. Heat sensitive agricultural produce is therefore recommended to be dried using appropriately lower temperatures to lessen or avoid case hardening of the product.

The team in this project managed to design and construct a prototype of solar dryer integrated with natural rocks as energy storage materials to prolong the drying process when the sunlight is unavailable. The project analyzed the selected rock samples (soapstone and granite) to be used as energy-storage materials in the proposed dryer and in the concentrated solar power generation. Caton soapstone performed the best as a thermal energy storage material, effectively absorbing, storing, and transmitting heat while maintaining good chemical stability and mechanical strength, a sign that soapstone is a strong contender for energy storage in drying applications and concentrated solar power generation.

The developed dryer was installed at a Tanzania Horticultural Association (TAHA) training center, where tests were carried-out and groups of small-scale farmers involved in drying agricultural produce have being granted access to use it. According to the results, the drying temperature within the drying chamber ranges between 45 and 65 °C. The team patented the developed dryer with the Business Registration and Licensing Agency (BRELA) in Tanzania.

The quality analysis tests of dried vegetable (carrots) and fruit (pineapples) were done at Sokoine University of Agriculture based in Morogoro, Tanzania. The fresh and dried carrot and pineapple were grounded into fine paste and powder form by using an electric blender. The fine paste/powder was then used in the analysis. The dried products retained micronutrients (vitamins and minerals) and had concentrated proteins and carbohydrates as compared to fresh products and those dried using traditional open sun methods, as detailed in the team's second published paper.

The first project awareness workshop was conducted on December 10, 2021, which helped to enhance the knowledge of stakeholders on solar drying technologies due presentations made by the project principal investigator and students. The workshop was attended by 29 stakeholders (12 females and 17 males) from government institutions, nongovernmental organizations, and community groups. The participants were informed on the importance and expected impacts of this project especially on reducing post-harvest loss through drying and environmental friendliness of the technology. The second workshop to demonstrate the developed dryer prototype was held on October 21, 2022, where staff from USAID and NASEM also attended to oversee progress of the project.

A mentorship program on STEM was organized to assist secondary and primary schools in developing drying and biofuels innovations. The team visited these schools for mentorship programs, which included raising awareness about clean energy technologies and their projected contribution to greenhouse gas reduction. Five primary and five secondary schools within Arusha region were engaged in this program. The purpose of the program is to mentor and motivate the young science students to come up with innovations in clean energy technologies. One technical research presentation was made at the World Science Forum held in Cape town, South Africa in December 2022.

U.S. partner Prof. Sunghwan Lee and Prof. Richard M. Voyles from Purdue University visited NM-AIST in June 2023 to discuss project progress and develop further collaborations beyond life time of this project. They visited a prototype of the developed dryer and presented a seminar to NM-AIST scientists. A number of stakeholders from NM-AIST, Tanzania Horticultural Association (TAHA), Arusha Technical College (ATC), Centre for Agricultural Mechanization and Rural Technology (CAMARTEC), Tanzania Commission for Science and Technology (COSTECH), and invited groups of small-scale farmers attended the meetings, where key findings from the project were presented by the principal investigator of the project and the students supported by the project.

The techno-economic assessment and life cycle analysis indicate that the payback period for the dryer for drying pineapple is 1.5 years, and for carrots 1.6 years, which is a short period as compared to the estimated 20-year lifespan of the dryer. The dryer is also environmentally friendly with negligible emissions. Based on thermal and economic performance assessment results, the developed solar dryer is technically and economically viable and is currently being piloted by two groups of women engaged in drying agricultural products for business (Mwambesi in Arusha and Efeso from Moshi-Kilimanjaro).

PUBLICATIONS

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TANZANIA - PROJECT 8-81: ENHANCING POSTHARVEST TECHNOLOGIES AND FOOD SAFETY INNOVATIONS IN FRESH TOMATO VALUE CHAIN

PI: Yasinta Muzanila, Sokoine University of Agriculture
U.S. Partner: Yaguang Luo, United States Department of Agriculture/ Agricultural Research Service
Dates: November 2019 – December 2021

PROJECT OVERVIEW

Although tomato is the dominant vegetable crop produced in Tanzania, it exhibits amongst the highest postharvest losses in the horticulture sector, ranging between 30% and 60%. Various initiatives have shown limited success and no marked effect on postharvest loss reduction in Tanzania. Most of these initiatives are based on a single component of postharvest loss solutions. While past studies suggest the use of a holistic model for postharvest loss reduction, the impact of this model has not been tested in the tomato value chain. By working with partners across the public and private sectors, this PEER project model integrated the building of local capacities through innovative training; the uptake of innovative, small-scale, appropriate postharvest technologies; and research into intersectoral collaboration. The goal of the study was to contribute to improving the productivity of smallholder farmers and reducing postharvest losses through capacity building and uptake of innovative postharvest technologies. The key activities of the project included (1) assessing farmers' knowledge and behavior regarding postharvest technologies in the tomato value chain; (2) developing a postharvest technology plan in the tomato supply chain; (3) evaluating food safety improvements and quality changes of the postharvest technology plan; and (4) providing training on suitable postharvest handling practices.

FINAL SUMMARY OF PROJECT ACTIVITIES

Task 1: Assess farmers' knowledge and behavior on postharvest technologies in the fresh tomato value chain. The project team comprehensively evaluated the current postharvest loss of tomatoes, as well as farmers' beliefs, attitudes, and perceptions of conventional and improved postharvest technologies. They found that perceived benefit and costs, absorptive capacity, complexity, and compatibility of postharvest technologies chiefly influence their adoption. The team also surveyed the social aspect of the postharvest technologies and focused on gender-related issues, such as dynamics of power in the tomato value chain, ownership of the technologies, and the extent to which the reduction of postharvest losses excludes people from the value chain. The research team established the scientific evidence for fundamental gender and environmental issues underpinning the adoption of postharvest technologies by smallholder farmers. This information has formed the basis for a database on the status of postharvest losses in Kilolo Districts.

Task 2: Develop a post-harvest technology plan for improving fresh tomato safety and quality. The project applied a participatory research approach to select an appropriate postharvest technology plan for reducing post-harvest loss based on smallholder farmers' needs and priorities. Farmer participants worked together with the research team and a horticultural specialist from the horticultural unit of the Department of Agriculture of Kilolo District Council to select local and impactful postharvest handling practices. A thorough analysis of the existing situation was conducted in the three-agroecological zones of Kilolo. Under impact analysis, farmers proposed an intervention that constitutes a set of postharvest handling practices that would make a real difference to their farm performance. The impact analysis was quite useful in identifying areas for interventions with low-cost postharvest technologies and avenues for capacity building in these areas. Based on the farmers' needs, the team proposed postharvest handling practices, which can have the greatest impact on reducing post-harvest loss such as proper harvesting, precooling after harvest (on-farm cooling (eg. ZECC), proper packaging (plastic crates), cleaning or disinfecting, sorting and grading, storage, appropriate mode of transportation, and sanitation. The research team therefore developed the comprehensive postharvest technology plan that covers two major areas for improvement: (1) postharvest handling practices for tomatoes at harvesting, pre-cooling after harvest, cleaning or disinfecting, sorting and grading, packaging, storage, and transportation; and (2) postharvest treatment techniques for maintaining the quality of fresh tomatoes.

Task 3: Training on pre-harvest and gender-based postharvest technology and practices. The research team set up an innovation demonstration farm (IDF) after designing the facility in collaboration with Kilolo District horticultural management team after a brief visit to Mahenge ward for site identification in November 2020. The site set-up was implemented by a private company, TONE Irrigation Co. Ltd. of Arusha, Tanzania. The IDF was installed with low-cost and gender-based postharvest technologies such as thatch shade, improved packages such as plastic crates, field packing, grading/packing stations, and simple postharvest equipment such as a washing station, sand, and brick-based evaporative cooling (zero-energy cool chamber). The IDF was managed by a team composed of the Mahenge ward agricultural officer, Irindi agricultural extension officer, and farmers' group steering committee. The IDF management team was trained by the project team and Kilolo district horticultural management team on basic skills such as inventory control, supervision, and recordkeeping. The team's preliminary studies under Task 1 revealed that postharvest losses in Kilolo District are intensified by smallholder farmers' lack of knowledge of good agricultural practices, especially during seed selection, seedling production, land preparation, pest management, and fertilizer application. The project team provided several demonstrations and training programs on pre-harvest and good agricultural practices. Twenty-five young farmers (17 men, 8 women), the Kilolo District horticultural management team, two agricultural extension officers, and an irrigation engineer from TONE Irrigation were involved in the demonstrations. In addition, the PEER teams also conducted several training workshops on postharvest technologies to support farmers and build their capacity. The project recruited and trained 16 agricultural extension officers from Kilolo District as post-harvest horticulture trainers. The project team organized 5 training workshops and onsite training of farmer group, with a total of 147 beneficiaries, including smallholder farmers, traders, packers, and transporters.

As for research outputs, the Innovation Demonstration Farm (IDF) as a tool to offer on-farm demonstrations to the horticultural industry. The project also resulted in a trainers manual and other training materials that provide an overview of postharvest handling practices and treatment methods, as well as gender, social, and environmental considerations in the tomato value chain. This document has been produced for use by concerned government agricultural extension systems and private sector persons interested to understand the principles of post-harvest handling in the tomato value chain. Along with the manual, the team also produced a series of booklets for extension personnel and leaflets for farmers, traders, and transporters on postharvest technologies and safe vegetable production. The leaflets are in Swahili, the language of the majority of the smallholder farmers.

All in all, the PI Dr. Muzanila reports that her project resulted in improved knowledge on farmers' behavior regarding postharvest technologies in the tomato value chain. Postharvest technology delivery systems were strengthened through innovative training and demonstration, and smallholder farmers gained improved knowledge and skills on postharvest handling practices. The project showed how implementing simple, gender-based postharvest technologies can help women and smallholder farmers in Tanzania successfully improve the quality and extended availability of fresh tomatoes with an impact on productivity. Building from the PEER project, the PI plans to take the initiative to harness cloud data benefits and customize its use by combining farmers' data (crop, market, socioeconomic) with daily weather data series. After that, she and her colleagues will characterize the tomato crop response to the target agronomic practices and weather patterns in different agro-ecological zones. The researchers are considering collaboration with farmer-centric organization in particular, the Tanzania national networks of farmers' groups in Tanzania (MVIWATA) and the Enterprise Technology Platforms (e.g. Esoko) that already have established mobile agri-advisory services to farmers. They will be applying for additional grants and exploring the use of a social franchise model for support.

TANZANIA - PROJECT 6-263: EXPLORING THE FATE OF MERCURY IN ARTISANAL GOLD MINING OF THE LAKE VICTORIA GOLD FIELD

PI: Clavery Tungaraza, Sokoine University of Agriculture
U.S. Partner: Mark Cohen, National Oceanic and Atmospheric Administration
Dates: December 2017 – June 2023

PROJECT OVERVIEW

This study investigated quantitative and qualitative mercury availability in the environment surrounding artisanal and small-scale gold mining (ASGM) locations in Tanzania, where mercury contamination is of concern with regard to the health of community members and others who consume food products originating from the area. Although mercury contamination can be lessened by appropriate controls and proper handling methods, such measures are not routinely applied in Tanzania, where mercury has been documented in different environments and studies. Mercury can be transported away from emission sources by riverine systems to large water bodies like Lake Victoria. The resulting fish contamination can be significant, which is a particularly serious issue as fish are the major protein source in the region and the whole country. In Tanzania, very little data is available on levels of methylmercury in biota and sediments and on the contribution that ASGM activities make to these levels. Further, there is little information on the relative importance of riverine and atmospheric processes in transporting mercury from sources to ecosystems.

All these aspects must be taken into account in order to understand the magnitude of mercury impacts on the environment and on human beings. This project developed data on levels of mercury downwind and downstream from ASGM activities in water, suspended particulate matter, sediments, and fish and improve understanding of spatiotemporal variations of mercury levels. Inclusion of methylmercury in the analysis represents a significant extension of the PI's earlier work.

FINAL SUMMARY OF PROJECT ACTIVITIES

The primary focus of this project was on mercury analysis in soil, sediments, vegetables, water, and fish samples. Specifically, the sites were located in the Lake zone encompassing Mgusu, Nyarugusu, and Rwamgasa in the Geita region; the central region in Singida, including London and Sekenke; and the southern highlands spanning Iringa (Nyakavalanga, Itengulinyi, and Ilhanzutwa) and Mbeya (Makongolosi and Itumbi) regions. The sampling strategy was designed to cover distinct weather seasons known to influence mercury distribution in diverse environments. One significant milestone was the establishment of a functional laboratory at the PI's university. Thanks to the support from the PEER program, the laboratory was equipped with a new automated total mercury analyzer, an automated methyl mercury analyzer, a distillation system, a freeze dryer, and associated reagents and supplies. Comprehensive training for technical staff and researchers was conducted on the new equipment to enhance capacity. This training even extended to the team's project partners at NOAA and the Smithsonian Environmental Research Center (SERC).

While notable achievements have been made, some setbacks were encountered due to various factors. The study area scope was reduced by excluding the Iringa region (Nyakavalanga, Itengulinyi, and Ilhanzutwa) because of the diminishing mining activities there. Similarly, the Mbeya region

(Makongolosi and Itumbi) saw limited coverage due to shifting land use from mining sites to settlements. The collected samples from these areas reflected lower residues resulting from past activities. It was noted that activities in Itumbi were relatively new and not as intensive.

Dr. Tungaraza and his team also successfully customized the method for total mercury and methyl mercury analyses, though the analysis of methyl mercury faced delays due to postponed installation of the analytical instrument. Furthermore, the onset of the COVID-19 pandemic proved to be a major obstacle, significantly impacting the project's timely progress. The pandemic not only hindered movement but also disrupted the supply chain for essential chemicals and materials from abroad. The imposed travel restrictions affected not only the MSc student but also the entire research team, leading to the cancellation of some fieldwork and global workshops on mercury.

With regard to broader impacts, the establishment of a reliable mercury analytical laboratory at Sokoine University of Agriculture presents significant advantages for enhancing understanding of mercury distribution within the Tanzanian environment. Given that one of the major sources of mercury contamination is the element’s use for gold extraction in artisanal mining activities, having a facility for accurate and accessible analysis is crucial. This laboratory not only ensures greater certainty in assessing mercury levels but also acts as a catalyst for further research on mercury-related matters. Moreover, the successful setup of this laboratory has attracted interest from various institutions seeking analytical support. This broader recognition underscores the laboratory's capability and expertise, encouraging collaborations and partnerships that contribute to a comprehensive understanding of mercury's impacts and mitigation strategies. The University has become a member of the Global Observation System for Mercury (GOS4M) and the Global Mercury Passive Network (Canada), actively participating in atmospheric mercury sampling. This network employs an alternative and cost-effective approach using Mercury Passive Air Samplers (MerPAs) to sample and analyze atmospheric mercury. Project researchers regularly receive mercury samplers every three months, which are employed for sampling in Tanzania and later analyzed at the University of Toronto in Canada. Lastly, active engagement has been established through a monthly atmospheric sampling program organized by the Ministry of Environment of Japan. This program involves four regional countries--Tanzania, Namibia, Ghana, and the Republic of South Africa. Each country was provided with sampling instruments, which were first deployed for sampling on July 31, 2023. The program aims to contribute atmospheric mercury data to support the implementation of the Minamata Convention.

The project team collaborated with a student from Mbeya University to finalize a publication on mercury, and Dr. Tungaraza and colleagues have two draft publications in process at the time the final report was submitted in August 2023. Although the project has ended, the PI indicates that related activities will continue with the support of new initiatives accessed during the implementation of the PEER project. These include the Global Mercury Passive Network and the atmospheric sampling program. These two initiatives will help to undertake atmospheric mercury sampling, which was not done during the PEER program. They will be integrated with PEER achievements through the knowledge of the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model gained through PEER-supported collaboration with the project partner at NOAA. Dr. Tungaraza also expects to continue his collaboration with NOAA researchers to highlight the problem of mercury contamination in the Lake Victoria basin and the need for regional monitoring of this pollution problem as an element of overall regional health monitoring efforts.

TANZANIA AND KENYA - PROJECT 3-80: WASTE TO RENEWABLE ENERGY: BIOGAS CLEANUP (UPGRADING) IN TANZANIA AND KENYA

PI: Cecil King'ondu, Nelson Mandela African Institution of Science and Technology, with Co-PI Owino Joseph Hazael Odero, South Eastern Kenya University

U.S. Partner: Puxian Gao, University of Connecticut (Funded by the National Science Foundation)

Dates: December 2014 – May 2017

PROJECT OVERVIEW

The adoption of small and large-scale biogas production technology is on the increase in Africa, first, due to the need to supplement conventional power, which is inadequate and unreliable in the urban centers and missing in rural areas, and second, due to the growing environmental concerns associated with the use of fossil fuels. However, despite the growing biogas generation and utilization, there is no technology available for biogas cleanup. In Kenya and Tanzania, biogas is utilized as-produced, with no attempts to clean it, mostly by households, schools, flower farms, and other establishments. This project was intended to create awareness among the general public of the contaminants in biogas and their effects on human health, the environment, and infrastructure; build capacity of academic staff and graduate students in biogas cleanup; and develop inexpensive, effective, and reliable technology for domestic and large-scale biogas cleanup. Biogas contains a plethora of toxic compounds such as siloxanes, hydrogen sulfide, carbonyl sulfide, carbon disulfide, dimethyl sulfides, and halogenated compounds. Hydrogen sulfide is the major contaminant in biogas and is highly toxic when inhaled. When uncleaned biogas is burnt for cooking or electricity, the sulfur compounds are converted to SOx gases, which corrode epithelial linings of human respiratory system. Additionally, SOx gases are associated with acid rain that wreaks havoc on our infrastructure.

This project involved fundamental studies of biogas cleanup and development of a cheap and effective technique for biogas desulfurization at room temperature. The Nelson Mandela African Institution of Science and Technology (NM-AIST) and South Eastern University of Kenya (SEKU) collaborated on a tandem oxidative-adsorptive desulfurization process to remove both the H_2S and more refractory organic sulfur compounds from biogas at room temperature.

FINAL SUMMARY OF PROJECT ACTIVITIES

The synthesis of manganese oxide and water hyacinth-derived carbon nanomaterials that showed good performance during screening tests was scaled up, and enough material for first generation prototype filters was successfully prepared. In addition, the first generation of the prototype filters was fabricated and their performance in removing hydrogen sulfide tested at Banana Investment Limited. The results obtained from these studies are promising.

Both prototype and pilot filters for tandem oxidative-adsorptive or adsorptive-oxidative sulfur removal were successfully fabricated with help from the Center for Agricultural Mechanization and Rural Technology (CAMARTEC) and using filter cartridges, both locally made and purchased from the market.

Upon rigorous testing of the oxidative-adsorptive filters, those that had 2.5Fe-OMS-2 materials at the biogas inlet and hyacinth-derived carbon materials at the biogas outlet side were found to be more effective in both sulfur and ammonia removal compared to their adsorptive-oxidative counterparts. Although, these filters gave better performance in terms of sulfur and ammonia removal, the filters were severely deactivated by water in the form of moisture in the biogas. Deactivation by water was expected but the extend/degree of deactivation encountered was not anticipated in the initial proposed work. To circumvent this deactivation, the team explored strategies to reduce, if not eliminate, moisture in the biogas before it enters the filter.

The project created huge awareness of the need to clean up biogas in local, business, and academic communities. The interest in research around biogas clean up has heightened both at NM-AIST and SEKU and new proposals by graduate students and staff on new materials for biogas clean up have been developed as CAMARTEC is keen on fabricating portable and effective biogas filters from new materials to replace large biogas filters made of low activity materials for schools. The PI plans to develop new research projects together that can be carried out using the facilities developed under PEER. Through this partnership he will be able to supervise more graduate students and work closely with Ngorongoro conservation group in exploring the potential of the Ngorongoro crater volcanic ash in biogas clean up. Preliminary tests with these materials are promising.

PUBLICATIONS

L.J. Kivuyo, K.N. Njau, and C.K. King'ondu. 2017. Eggshells-assisted hydrolysis of banana pulp for biogas production. African Journal of Environmental Science and Technology 11(1): 71-78. https://doi.org/10.5897/AJEST2016.2155

E. Makauki, C.K. King’ondu, and T.E. Kibona. 2017. Hydrogen Sulfide and Ammonia Removal from Biogas Using Water Hyacinth-Derived Carbon Nanomaterials. African Journal of Environmental Science and Technology 11: 375-383. https://doi.org/10.5897/AJEST2016.2246

TANZANIA - PROJECT 3-17: COOPERATION AND COMPROMISE IN DEVELOPING RURAL COMMUNITIES—CASE STUDY: SOLAR-ELECTRIC MINI-GRIDS FOR THE MAASAI

PI: Kisioki Moitiko and Co-PI Robert Lange, The International Collaborative for Science, Education, and the Environment (Tanzania)
U.S. Partner: Krister Andersson, University of Colorado (Funded by the National Science Foundation)
Dates: September 2014 – February 2016

PROJECT OVERVIEW

The Maasai Stoves and Solar Project, another ICSEE(T) effort, provides household-scale solar power systems along with clean cookstoves. There are 750 homes in Maasai villages with these improvements. A Maasai community is organized in bomas which consist of the houses of the wives of one man, and of others arranged around a corral. The people want solar power--they are off the electric grid and won't get on it anytime soon. To introduce solar electrical systems in rural settings, it may be better to work with groups of houses rather than each one alone, in the process learning some general principles that could have application in scaling and in other communities. This project studied this assumption by creating boma-wide mini-grid solar electric systems that are likely to better serve their needs if done well. A boma represents a larger-scale social and economic formation. In spite of its apparent homogeneity, there are complexities of status and of relationships among women, among children, and between everyone and the dominant and subdominant men. This makes a boma a microcosm that can reveal issues that are of importance to development actors and scientists. In the course of the project, this research team introduced and studied shared renewable energy resources to see if they better meet development and social goals. The research required ideas from the community, collaboration and agreement, and finally the physical labor to install the trial mini-grid elements that were the basis for study in the research. Women participated and led in all stages and tasks.

FINAL SUMMARY OF PROJECT ACTIVITIES

This research was done in the course of installing micro-grid solar systems in 10 bomas. The leadership of the ICSEE(T) and their staff were deeply involved in this and still are. In addition, the research leader and students from the Community Development Training Institute (CDTI), were brought in and collaborated on the project as well. Their NSF-funded partners were experts in studying the social and political issues that arise in cooperative use of commonly valued resources when interests and resources among the people are diverse and potentially in conflict.

The project team was also very interested in, and concerned about, the technology itself and the design and utility of a micro-grid in a social unit like the boma. Because of the way pastoralists organize their living structures, bomas are the natural and proper unit for bringing renewable and off-the-grid electricity to the pastoralists, which has applications more broadly across Africa. The project team provided training to Maasai men and women in the science and engineering of solar energy, solar electrifications, photovoltaics, and the basics of electricity. A total of 22 people attended the team's intensive three-day workshop in December 2015 and subsequently became the installers of the micro grids made possible by the Putnam Foundation grant and the payment by the Maasai boma owners.

CTDI categorized both the population and the conditions of life in selected bomas prior to the micro-grid installation. The team had originally been concerned that the social inhomogeneity of even the small population of a boma might give rise to interesting social phenomena of the type studied by their U.S. partners at the University of Michigan and the University of Colorado in other development contexts. If such differences in ideas and participation in boma electrification were important, then they would need to be taken into account in scaling and proliferating such electrification campaigns. But because of the three points above dominating the social and technological aspects of such electrification, there were no significant issues arising related to differences of status in the bomas.

The CDTI research team also visited bomas after electrification and interviewed residents at some length. Not surprisingly, what they found was an awareness in the people of just the improvements of conditions and as would be predicted by those who know Maasai traditional living conditions and who know what a clean, smoke-removing, cookstove and electric lighting can be for people living under basic conditions far from the electrical grid, with 12 hours of darkness per day, and with heavy burdens of gathering fuel and water and child care. The boma residents noted several immediate changes for the better. There was less need for wood, allowing people to devote time saved on wood gathering to pursue other activities, and with less wood smoke, eye and chest ailments were reduced or eliminated. People were also able to safely keep food and veterinary items in the boma refrigerator. Electric lighting gave schoolchildren extended study times in the evening and also improved safety, reducing the need to kill wild predators.

In order to maintain the micro-electric grids established under this grant, and in future scaling of this program, there have to be more people who have an understanding of basic physical science and electricity living in the bomas that are receiving and benefiting from the micro-grid electrification. In proposals for scaling they are now including explicit development of learning opportunities that will make up, in part, for the poor technical education found in the schools most Maasai have attended, and for the fact that most Maasai women have had very little schooling of any kind. The project team is very positive and excited about finally finding a way for the outstanding technical work of the ICSEE to have a pathway into educational improvement. They have the context, the technology, the growing local experience, and the contact with international experts in science and technology education that will make this not just possible, but a ground-breaking success.

TANZANIA - PROJECT 2-343: COMPUTATIONAL MATHEMATICS, MODELING AND ANALYSIS OF BIOLOGICAL, BIO-INSPIRED AND ENGINEERING SYSTEMS

PIs: Madundo Mtambo and Burton Mwamila, The Nelson Mandela African Institute of Science and Technology

U.S. Partner: Padmanabhan Seshaiyer, George Mason University (Funded by the National Science Foundation)

Dates: October 2013 – September 2014

PROJECT OVERVIEW

East Africa is greatly in need of capacity building for educational excellence in science, technology, engineering, and mathematics (STEM). The ultimate goal of this PEER project was to promote capacity building by creating a broad network of knowledgeable scientists and researchers who can collaborate to tackle some of the most urgent problems in food security, environment, education, water and global health affecting Tanzania and neighboring countries.

The PEER grantees organized a three-week course on multidisciplinary applications of mathematics for members of the mathematical, biological and engineering community in Tanzania, especially early career researchers, graduate and post-graduate students. The goal was to create much-needed awareness on how to pursue multidisciplinary real-world problem-solving using STEM. The project was modeled after and built upon a successful National Science Foundation Research Experiences for Undergraduates program that the U.S. partner directed. In particular, the selected participants had the opportunity to learn about new content, software, and tools and apply them to solve real-world problems.

FINAL SUMMARY OF PROJECT ACTIVITIES

Fourteen Master's and doctoral students attended the training course, which was by the PIs and the U.S. partner, exposing them to mathematical modeling of biological and bio-engineering systems. Each student formulated thematic research topics in the areas of applied math, sustainable energy, science and engineering, and water and environment. They received stipends for field work during the data collection portion of their research. Some of these projects that the participants learned about and worked on include fish harvesting and its economic impact, social process modeling and bioconservation, optimization models for energy security, enhancement of student learning in STEM, sensor networks to detect petroleum adulteration, mutualism models for rhizobia legume interaction, and prediction of tobacco concentrations using contaminant transport models coupled with disease dynamics.

During the PEER project, the PI Dr. Mwamila visited the United States and met a wide variety of people and organizations for potential collaborations, including the George Mason University, National Institutes of Health, the World Bank, and Millennium Challenge Corporation.

TANZANIA - PROJECT 1-232: CHARACTERIZATION OF CASSAVA MOSAIC GEMINI VIRUSES AND THEIR SATELLITES IN CASSAVA AT THE CELLULAR LEVEL

PI: Joseph Ndunguru, Mikocheni Agricultural Research Institute
U.S. Partner: Linda Hanley-Bowdoin, North Carolina State University (Funded by the National Science Foundation)
Dates: June 2012 – August 2014

PROJECT OVERVIEW

Cassava is an important staple crop in Africa and Asia, consumed by more than 700 million people daily. It is grown by subsistence farmers in the poorest villages and often serves as the only food source when other crops fail or are destroyed by conflict. Cassava can thrive under drought, high temperatures, and poor soil conditions, but its production is severely limited by viral diseases. Cassava mosaic disease (CMD) is caused by a DNA virus complex consisting of seven geminivirus species that synergistically enhance disease severity. Recently, two associated satellite DNAs have been shown to break resistance and worsen symptoms.

Cassava mosaic geminiviruses (CMGs) induce diverse symptoms in cassava depending on factors such as host genotype, age of infection, virus inoculum amount, virus strain, vector activity, and environmental conditions. Research on CMGs has provided extensive information on viral diversity, genome sequence, replication, transmission, disease epidemiology, and control. However, no reports have described the cellular-level changes in cassava leaves in response to CMG infection. The goal of this project was to establish cell biology infrastructure and expertise at Mikocheni Agricultural Research Institute (MARI) in Tanzania and use these resources to characterize CMG infection in cassava.

Using a combination of light and fluorescent microscopy, researchers examined CMD processes at a cellular level in cassava leaves. They employed in situ hybridization to detect CMG and satellite DNAs in cassava leaves, aiming to determine if different CMGs infect different leaf cell types and if the nature and number of target cells change in mixed infections and/or in the presence of satellites. The research team examined the cellular architecture of infected leaves to understand the physiological basis of the extreme leaf deformation phenotypes associated with CMD satellites. This application of cell biology to CMD provided a unique opportunity to study the interactions of different viruses with a common host and with each other and satellite DNAs. The knowledge gained from the project was expected to contribute to understanding this important plant virus and to developing sustainable strategies to control it, thereby limiting its economic and nutritional impact.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project proved to be successful both locally and nationally. The information generated from this project has helped to design cassava virus disease diagnostic tools resulting in efficient and accurate disease diagnostics to inform the formulation of disease management strategies. Proper virus diagnostics have resulted in the development of virus distribution maps in the country that are now used by decision makers to decide (1) where to deploy clean cassava planting materials; (2) where to evaluate cassava materials (hot spot areas); (3) where to multiply clear cassava materials (low disease pressure areas); and (4) how to strengthen plant health regulations by restricting unsafe movement of cassava germplasm. Furthermore, cassava farmers in Tanzania have received virus-free planting materials that have resulted into a significant yield increase, and the microscopy has enabled regular virus monitoring in the planting material.

Locally, both the human and infrastructural capacity at MARI was significantly enhanced through training of local scientists and acquisition of the lab equipment thanks to PEER funding. University students who should have gone abroad to conduct their research work are now conducting their research at MARI. With this, more students can be trained and the availability of the microscopy facility at MARI has inspired many young scientists to undertake research in the areas of biotechnology, including disease diagnostics using molecular techniques, as well as detection of plant viruses using the immuno and in situ hybridization techniques. Finally, this project also has stimulated more collaboration among MARI research scientists and other institutions within and outside Tanzania.

UGANDA

UGANDA - COV-096: THE IMPACT OF THE COVID-19 PANDEMIC ON GBV AMONG WOMEN AND GIRLS IN INFORMAL SETTLEMENTS IN KAMPALA

PI: Juliet Kiguli, Makerere University, School of Public Health
U.S. Partner: Julia Dickson-Gomez, Medical College of Wisconsin (Funded by the National Institutes of Health)
Dates: September 2022 – December 2023

PROJECT OVERVIEW

Gender-based violence (GBV) and intimate partner violence (IPV) have increased since the beginning of the COVID-19 pandemic, affecting one-third of all women across the globe. Estimates of IPV are between 18% and 36% worldwide and 22% among women in Uganda. Women residing in informal settlements live in extreme poverty and thus are especially vulnerable to GBV/IPV. The pandemic disrupted residents' ability to make a living because of mandated country-wide lockdowns. A recent longitudinal study conducted by the PI Dr. Kiguli and her team in three informal settlements in Kampala found that 78.2% reported food insecurity during the first wave of COVID-19 and that rates of IPV increased over time.

The main objective of this PEER project was to explore the impact of COVID-19 on GBV among women and girls in informal settlements in Kampala, with a view to identifying entry points for testing the SafeBangle innovation. The SafeBangle is wearable technology similar to a smartwatch that will send an alarm by SMS to people chosen by the woman herself if she feels threatened. The project researchers believe that the SafeBangle innovation will be effective to enhance reporting and response to GBV survivors. The project explored the acceptability of the SafeBangle innovation as a solution to GBV among at-risk women in informal settlements.

FINAL SUMMARY OF PROJECT ACTIVITIES

The core project team, including researchers at Makerere University School of Public Health (MaKSPH), Medical College of Wisconsin (MCW), SafeBangle Technologies, and Somero Uganda, a community-focused NGO, began the project by designing their research protocol and taking a CITI Program course on human subjects social/behavioral research. Team members also met with the Ministry of Gender, Labour, and Social Development (MGLSG) in support of the gender-based violence policy process. They also established relationships with the Kampala Capital City Authority (KCCA) and Nakawa and Kawempe probation offices to support legal processes for the GBV survivors.

The researchers conducted a survey among 644 girls and women in Kinawataka (Nakawa Division) and Bwaise (Kawempe Division) to gain insights into the awareness and understanding of sexual and gender-based violence among adolescent girls and women in informal settlements. The survey measured socioeconomic factors, mental health symptoms, and exposure to GBV. The researchers also conducted focus group interviews with a separate sample of women over age 18 in the settlements to explore responses to GBV. The team found the overall prevalence of GBV was 34.1%. But half of those between 15-19 years old were more likely to experience GBV, and generally an increase in age was associated with a lower tendency to suffer from GBV. Women who were not employed were also more susceptible to GBV.

Upon profiling the prevalence of GBV in the study participants, the researchers further reclassified areas of low-risk and high-risk for GBV, mapping these high-risk GBV areas in Kawempe and Nakawa divisions. They selected 20 study participants at high risk for GBV to participate in a community risk assessment where they were able to show the hotspots for GBV in the community and share photos of happy and sad moments.

The team identified and documented features of the SafeBangle interactive web platform that required updates and enhancements. This activity was crucial to improving the functionality and usability of the platform, which plays a significant role in supporting the SafeBangle bracelets' effectiveness. The PEER team distributed a total of 72 SafeBangle bracelets, split between Nakawa and Kawempe. The team on-boarded users to the SafeBangle interactive web platform and successfully implemented remote monitoring of the bracelets, promptly responding to alerts and notifications from users.

Of the 72 adolescent girls and women who received the SafeBangle, 22 activated the reporting button and 19 received necessary support based on the type of violence experienced. All adolescent girls and women who experienced GBV received a phone call from Somero Uganda to discuss the most appropriate intervention, including counseling, police cases being handled by the probation office, referral for health services, and post-exposure prophylaxis. All the GBV survivors received support and are still receiving continuous follow-up.

The PEER team members are preparing manuscripts on their findings for future publications. Meanwhile, the SafeBangle received an award at the Defender's Protection Initiative 2023 expo.

UGANDA - COV-027: THE IMPACT OF COVID-19 ON SCHOOL ENROLLMENT AND MENTAL HEALTH OF CHILDREN IN THE MANAFWA WATERSHED AREA IN UGANDA

PI: Charles Batte, Makerere University
U.S. Partner: Trishul Siddharthan, University of Miami (Funded by the National Institutes of Health)
Dates: August 2022 – December 2023

PROJECT OVERVIEW

The Manafwa watershed is the largest watershed on the slopes of Mountain Elgon in Eastern Uganda, with three districts (i.e., Bududa, Manafwa, and Butaleja), whose vulnerable communities have continuously been affected by natural disasters, mainly floods and landslides. Besides the high rate of mortality from these events, these natural disasters also leave homeless families and orphaned children, destroy farms, which serve as the main source of economic welfare, and leave long-lasting effects on mental health and wellbeing. The negative effects of COVID-19 were also disproportionately experienced by households and children in the vulnerable communities in the Manafwa watershed.

This study aimed to collect household-level data about the impact of COVID-19 on school enrollment and mental health of children in the watershed. Dr. Batte and his colleagues used a mixed-methods approach to determine school attendance before and after lockdown, as well as assess mental health and coping methods among students. They sought to conduct interviews with selected key informants from household heads, local leaders, and schoolteachers to collect qualitative data on perspectives, views, and opinions on the impact of COVID-19. This project aimed to provide crucial information on how schoolchildren dealt with natural disasters and the COVID-19 pandemic and guide the development of psychological support systems in schools to improve the overall experience of children.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team recruited and trained research assistants for the project. They collected enrollment and other data from schools in the three target districts, as well as held focus group discussions with students. The researchers found that 65% of adolescents in school had a current mental health challenge, with anxiety being the most prevalent. Significant gender differences were observed in anxiety, disruptive behavior, and negative self-concept, with female students reporting higher levels on all indicators. Middle-aged adolescents were more likely to use negative-emotion regulation, while early adolescents were found to employ distraction as a coping mechanism more often.

The findings of this study highlighted the significant prevalence of mental health challenges among school-going adolescents. Understanding the prevalence and specific types of mental health challenges provided valuable insights for educators, parents, and mental health professionals to tailor interventions and support services. The findings also call for tailored support mechanisms to address the unique needs and challenges faced by both male and female students, as well as different intervention strategies around identification of substance abuse problems.

The team members disseminated their results during the Health and Climate Change symposium 2023 organized by Tree Adoption Uganda, the Ministry of Health, and the World Health Organization, which was attended by more than 100 professionals, including government officials, NGOs, youth organizations and health practitioners. They have developed manuscript drafts on their findings for future publication.

The researchers have also connected with the administrative and educational boards of the target districts, and who have expressed interest in the results of the study and are willing to implement changes. The PEER team plans to continue collaborating with their U.S. partner on future manuscripts and the formulation of new research projects.

UGANDA - COV-012: SCALING COST-EFFECTIVE, SAFE, AND QUALITY BLACK SOLDIER FLY INSECT LARVAE ENTERPRISE FOR COVID-19 LIVELIHOOD RESILIENCE IN UGANDA

PI: Deborah Ruth Amulen, Makerere University
U.S. Partner: Jennifer Pechal, Michigan State University (Funded by the National Science Foundation)
Dates: November 2022 – April 2024

PROJECT OVERVIEW

The black soldier fly larva (BSFL) is recognized as one of the most environmentally friendly sources of insect protein for animal production. Researchers have demonstrated that BSFL is highly nutritious, making it a potential replacement for more expensive animal-protein feed ingredients. In Uganda, BSFL farming is growing rapidly despite a myriad of challenges. The Centre for Insect Research and Development (CIRD) has piloted small-scale commercial BSFL farming under the leadership of the principal investigator on this project, Dr. Amulen. The major milestones achieved by CIRD includes setting up a small-scale BSFL unit producing one ton of BSFL weekly, supporting establishment of 100 BSF farming business, establishing market channels for both BSF equipment and breeding seeds such as eggs and pupae, and creating demand for dry BSFL among poultry and pig farmers.

However, several scientific questions were asked by the Center's farmer clients. These included questions about the nutritional content of the BSFL produced, the mixing ratio for BSFL with other feed ingredients, the growth rate or performance of chickens fed on BSFL-based poultry feed, and the safety and quality of BSFL produced for chicken and consumers. The farmers also struggled with the lack of a designated market or supply system for BSFL farming equipment or inputs. This PEER project sought to address these technical questions while supporting more than 100 youths and women BSFL farmers to profitably earn money from BSFL as a COVID-19 resilience strategy in Uganda.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project's launch event was attended by high-level stakeholders, including the Commissioner of Entomology and his staff at the Ministry of Agriculture Animal Industry and Fisheries (MAAIF). The event attracted media attention, including an article in the Monitor newspaper and a local radio show interview. The researchers subsequently undertook an assessment of the impact of COVID-19 on livestock feed protein sources and mapped actors in the BSF value chain in peri-urban Kampala. They conducted two surveys with 256 respondents on the value chain. The team also began work on assessing the quality and safety of BSF larvae reared with an eye on providing practical measures for safe post-harvest handling practices. They piloted a cost-effective production model of BS by reviewing different production and marketing models and conducting a Cost-Benefit Analysis by incorporating agricultural economist partners from Gulu University Uganda.

The PEER team conducted a range of trainings, after which they began offering continuous support to 100 women and youth in commercial black soldier fly rearing, assisted by the entire CIRD community of practice and other technical support services. The team also provided safety kits and information about how to work with organic waste to 30 women organic waste collectors and conducted business coaching clinics for 40 BSF farmers. The project also supported training four students and lab laboratory technical staff at Makerere University on the use of Atomic Absorption Spectrophotometry (AAS) and funded one Master's student involved in the field study. The CIRD was expanded as a one-stop knowledge center, including improving their commercial BSFL farming training manual to include personnel and environmental safety measures. The Center has launched monthly technical support meetings and conducted online and one-on-one coaching services.

The project PI met with the Parliament Committee of Agriculture to submit views on integration of black soldier fly in the new animal feeds bill, and used project data to justify why the BSF value chain should be included in a new World Bank project about Ugandan agriculture. Two manuscripts on their findings are forthcoming, and in the meantime the team presented their work in a variety of conferences and meetings, including the Excellence in Insect Science conference, as well as to representatives of the governments of Denmark and Saudi Arabia.

UGANDA - PROJECT 8-187: IMPROVING HAND HYGIENE PRACTICE AMONG HEALTHCARE WORKERS THROUGH MHEALTH AND ENVIRONMENTAL CUES IN KAMPALA METROPOLITAN AREA

PI: Richard Kibirango Mugambe, Makerere University School of Public Health
U.S. Partner: Christine Moe, Emory University (Funded by the National Institutes of Health)
Dates: April 2020 – November 2022

PROJECT OVERVIEW

Water, sanitation, and hygiene (WASH) in healthcare facilities are critical in the provision of quality healthcare. Good WASH infrastructure and practices should reduce healthcare-associated infections, increase trust and uptake of healthcare services, and increase efficiency and improve staff morale. This PEER project addressed two key questions: why healthcare workers don't adhere to hand hygiene guidelines in Uganda, and what are simple, effective, and inexpensive interventions to enhance hand-hygiene practices among healthcare workers in Uganda. The PI Richard Mugambe and the research team studied the impact of mobile phone WASH text messages and environmental cues on hand hygiene practices among healthcare workers in the Greater Kampala Metropolitan Area.

The researchers determined the barriers and opportunities for enhancing healthcare workers' hand hygiene practices, tracking outcomes, including the ratio of completed hand hygiene events to hand hygiene opportunities and increased knowledge on hand hygiene practices.

U.S. partner Dr. Christine Moe provided critical assistance in the project by training faculty from the Makerere University School of Public Health and staff from the Ministry of Health on using the specified hand hygiene interventions, monitoring outcomes, and conducting laboratory procedures for determining microbial contamination on the hands of healthcare workers.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team started with semi-structured interviews with 30 people to discuss barriers and facilitators to healthcare workers hygiene practices. They also observed WASH procedures at selected facilities in the study area. After this initial study, the researchers held a stakeholders' workshop to share their findings and engage the stakeholders in developing the design principles for the text messages and environmental cue intervention. Among the attendees at this workshop were representatives from Uganda Ministry of Health, the Ministry of Water and Environment, Uganda Protestant Medical Bureau, WaterAid Uganda, and Oxfam Uganda, among others.

The researchers conducted a baseline study in healthcare facilities, collecting both quantitative and qualitative data on infection prevention and control (IPC) and WASH. In addition, they used the WHO hand hygiene observation tool to assess hand hygiene practice among the health workers. The PEER team subsequently implemented both messaging and environmental cues intervention for six months across multiple health facilities, measuring at the halfway point and at the end of the intervention. The researchers found improvements in a variety of measures, including a 14% increase in attending to hand hygiene before handling the patient, a 4% increase in handwashing instead of hand rubbing, and a 14% increase in practicing hygiene after touching the patient.

During the project, the PI helped develop curriculum for a Master's in Environmental and Occupational Health program, including a component on IPC and WASH in healthcare facilities, as well as a diploma course on IPC. The PI also worked with WaterAid Uganda on additional papers on IPC and WASH in healthcare facilities. Combined with the findings from the PEER project baseline study, this provided part of the critical evidence that informed the WASH guidelines for health facilities in Uganda.

The PI has also received more than $4 million in additional grants to supplement and continue work begun during the PEER project, including grants from the Gates Foundation, the Dutch Research Council, WaterAid Uganda and the Wellcome Trust.

PUBLICATIONS

Tonny Ssekamatte, Richard K. Mugambe, et al. 2022. Using the Behaviour Centered Design to understand the facilitators and deterrents to hand hygiene among healthcare providers in the greater Kampala metropolitan area: Qualitative findings from a formative phase of a cluster-randomized trial. Research Square. https://doi.org/10.21203/rs.3.rs-1604259/v1

Richard K. Mugambe, Jane Sembuche Mselle, Tonny Ssekamatte, Moses Ntanda, John Bosco Isunju, Solomon T. Wafula, Winnifred K. Kansiime, Prossy Isubikalu, David Ssemwanga, Habib Yakubu, and Christine L. Moe. 2021. Impact of mhealth messages and environmental cues on hand hygiene practice among healthcare workers in the greater Kampala metropolitan area, Uganda: study protocol for a cluster randomized trial. BMC Health Services Research 21: 88. https://doi.org/10.1186/s12913-021-06082-3

UGANDA - PROJECT 8-186: PROMOTING HAND HYGIENE THROUGH PRODUCTION AND USE OF LOCALLY PRODUCED ALCOHOL HAND-RUB IN HEALTH FACILITIES IN UGANDA

PI: Esther Buregyeya, Makerere University School of Public Health

U.S. Partner: Christine Moe, Emory University (Funded by the National Institutes of Health)

Dates: April 2020 – December 2022

PROJECT OVERVIEW

Water, sanitation, and hygiene in healthcare facilities (HCFs) are critical for the provision of quality health care and prevention of hospital-acquired infections (HAIs), which are often transmitted through contact with contaminated hands of healthcare workers. HAIs represent the most frequent adverse event affecting hospitalized patients, resulting in increased morbidity and mortality. These infections are even more dangerous in this era of increasing anti-microbial resistance (AMR). Hand hygiene is recognized as the single most important practice to reduce HAIs and has been associated with sustained decrease in the incidence of AMR infections in healthcare settings. Though the importance of hand hygiene is well documented and recognized, evidence shows healthcare workers' compliance is suboptimal in many settings, including Uganda. Factors found to affect hand hygiene compliance include poor access to sinks and hygiene supplies. Availability of an alcohol-based hand-rub at the point of care has been shown to increase hand hygiene. Alcohol-based hand-rub is currently recommended as the primary tool for hand hygiene action and promotion because it reduces bacterial counts on hands more effectively and can be more accessible than sinks. In addition, it can be locally produced at the HCF, making it even more accessible. However, locally made alcohol hand-rub intervention and research is limited in Ugandan UCFs.

To address this problem, the PI Dr. Esther Buregyeya and her team devised this project to develop a behavioral intervention to foster hand hygiene compliance using locally-produced alcohol- based hand-rub and assess the acceptability, feasibility, effect, and cost of using such hand-rub on compliance among health care workers in primary HCFs in Uganda. Expected outcomes of the study included improved hand hygiene and newly acquired skills in alcohol hand-rub production.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project on hygiene and infection control ended up being extremely timely, as it began in April 2020, at the start of the COVID-19 pandemic. The study involved three rounds of unannounced hand hygiene compliance observations in the four study facilities to establish the level of compliance with hand hygiene guidelines among the health workers in the study units. Those compliance rates ranged from a low of 35% to a high of 57%. The team found that a lack of sinks, water, and single-use towels was often a significant hindrance, highlighting the important role that could be played by increasing the use of alcohol-based hand sanitizers. One publication by the team is under review as of August 2023, and Dr. Buregyeya and her team are still analyzing their findings to prepare additional manuscripts. In addition, they conducted the bi-monthly continuous medical education (CME) training sessions in all the four study facilities, with the participants including laboratory technicians, clinicians, midwives, nurses, pharmacists, infection prevention and control (IPC) committee members, and health facility leadership representatives. During the CMEs, they emphasized the need for hand washing, disseminated results from the previous hand hygiene observations, and awarded the best performing health facility units with certificates of recognition and tea supplies.

Because of this project's work in promoting hand hygiene among health workers, the PI Dr. Buregyeya was invited to join a team funded by the U.S. Centers for Disease Control and Prevention (CDC) working on the development of an Infection Prevention Control (IPC) Fellowship and a postgraduate diploma IPC curriculum for health workers in Uganda. This is being done at a national level, and the PI's department will host the program. The IPC fellowship had its first intake of seven fellows in June 2023. Relatedly, the PI used her experience on this project to apply for and receive a Tropical Health and Education Trust (THET) grant in the amount of 55,000 UK pounds to train healthcare workers in IPC, including local production of alcohol hand-rub and antimicrobial stewardship. Dr. Buregyeya also won a $100,000 grant from Pfizer on using a behavioral approach to design an antimicrobial stewardship intervention in healthcare facilities in Uganda.

Master's of Public Health student Ms. Eunice Ekyakunda used her experience on the PEER project to help her prepare her recently submitted dissertation, which she also aims to submit for publication in a peer-reviewed journal. In addition, the chemist on the study team, Mr. Fred Twinomugisha, was inspired by the project activities to select as his PhD dissertation topic "The role of patient involvement in promoting hand hygiene practices among healthcare workers in Mukono and Kagadi districts: a mixed methods study."

Outreach was a large part of the project to ensure that the team's findings reached policymakers and clinicians. In designing their intervention, the researchers convened a stakeholder insight workshop to refine and co-create their plans. Later, they presented two posters virtually to the 2021 International Meeting on Emerging Diseases and Surveillance (IMED) and disseminated the study findings in the four participating health facilities. The team also made a project presentation the National IPC community of practice hosted by the Ugandan Ministry of Health in which they raised awareness of the project activities and achievements and disseminated some of the findings to several stakeholders. This was a countrywide event attended by more than 100 health workers and policymakers from across the country.

Overall, Dr. Buregyeya points to several key achievements from her project. She and her team built capacity in the production of alcohol-based hand sanitizer in settings where hand hygiene infrastructure is poor and such sanitizer offers the most feasible alternative. Their PEER-supported work has also translated into long-term effects of developing a curriculum in IPC for health workers, in which training in the local production of alcohol-based hand rub is a key practical component. Finally, work on this project has translated into key AMS interventions aimed at improving the quality of healthcare services, including containing the development of antimicrobial resistance, a growing challenge in Uganda.

UGANDA - PROJECT 7-471: REPRODUCTIVE HEALTH EMPOWERMENT THROUGH TELEHEALTH (REHEAT)

PI: Agnes Kiragga, Infectious Diseases Institute, Kampala, Uganda
U.S. Partner: Keith Horvath, University of Minnesota (Funded by the National Institutes of Health)
Dates: February 2019 – May 2021

PROJECT OVERVIEW

This initiative built on the Information, Motivation, and Behavioral Skills (IMB) model and a novel telehealth information dissemination method. The IMB model suggests that health behavior change results from accurate information, personal and social motivation, and appropriate behavioral skills. The project aimed to develop a Family Planning (FP) information package using a human-centered approach involving end users and experts. This method ensured culturally and scientifically appropriate content. The telehealth services leveraged an existing platform by The Medical Concierge Group (TMCG) in Uganda, which provides health services through voice calls, SMS, WhatsApp, email, and social media, supporting voluntary family planning among other health areas.

The researchers evaluated users' knowledge before and after implementing the FP intervention. With input from a community advisory board, they designed an information pack delivered through the existing telehealth platform and assessed its impact on FP uptake among men. The evaluation also provided guidance for future implementations of FP and other sexual and reproductive health interventions using similar platforms. Given the barriers men face in accessing traditional FP services, telehealth has the potential to increase young men's access to reproductive health information, offering a model for delivering such services countrywide. With more than 70% of Uganda's population being youth, the project was timely, using youth-friendly platforms like SMS and social media to deliver crucial family and reproductive health information, thereby increasing voluntary uptake and use of services.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Kiragga and her team developed a fully detailed study protocol and study tools with the objective of assessing the feasibility and acceptability of using a Telehealth platform for men involved in family planning. The study was also designed to assess if Mobile Telephone Information Packages (mTIP) increase knowledge, attitudes, and uptake of family planning and to determine the impact of mTIP on couple communications about family planning. These objectives were achieved through the formation of a Community Advisory Board (CAB) consisting of members from different backgrounds who helped in the development of message content (mTIP) about family planning, which subsequently was sent out to study participants. The content was categorized into Motivational, Behavioral, and Informational messages. Motivational messages were meant to inform about, attract to, and demystify any information surrounding family planning. Behavioral messages were meant to check the attitudes of men towards family planning, and Informational messages were meant to give more educational information about family planning.

A total of 461 men were screened, of whom 450 were enrolled into the study. Of that total, 415

(92.9%) were followed up at one month after enrollment, 404 (89.8%) at four months after enrollment, and 432 (96.0%) at six months after enrollment. A total of 399 (88.7%) completed the one-month, four-month, and six-month follow-ups. The study also enrolled 100 spouses of the 450 enrolled men to help assess couples' communication about family planning and decision making on family planning. A total of 26,988 short mobile messages (SMS) were sent out over the six months, with an average of 66 messages received by each study participant. Out of the 450 males (primary study participants) onboarded onto the SMS program, 426 (95%) successfully received the messages and only 24 reported not to receiving the mobile health content. The average response (participation) rate to the weekly quizzes was 23% for periodic quizzes.

The research team also conducted qualitative in-depth interviews to assess knowledge and attitudes towards family planning and evaluate couples' communication as a result of the mTIP intervention. The study established that there was a 58% increase in knowledge about family planning after six months of follow up from baseline, an 18% increase in family planning uptake after six months of follow up from baseline, and an improvement in couples' communication and information sharing. The male participants and their spouses admitted to having candid conversations about family planning, unlike before, when such discussions were not possible and women were afraid to talk about family planning. Following the couples; communication, women felt supported and keen to use family planning services without fear of spousal violence.

The study reduced poor attitudes toward family planning among men. For example, at the beginning of the study, 25% of men believed that family planning and contraception is solely a woman's business. At the end the study this was reduced to 2%. Similarly, at the start before receipt of the family planning messages, 10% believed that women who use family planning are promiscuous. At study end, none of the men still had this misconception, and this underscores the effect of the intervention on men's attitudes. Additionally, one of the greatest achievements that was highlighted from the qualitative in-depth interview was the delineation of decision making with regard to family planning. Prior to the study, men preferred to make the final decision on when and whether their spouse should use any family planning method. At the end of the six-month study period, men preferred a joint decision model that allows a couple to decide together regarding the preferred method of family planning. This is a step towards women's empowerment and increased and supported use of family planning services.

As a result of the mTIP intervention, it was also established that men preferred interventions and modes of communication that gave them privacy, as opposed to the traditional way of seeking health services. Educating men would enable them to act as agents to champion the use of family planning, and using a clear, precise language enabled them to comprehend all the information presented. Although the PEER project has ended, the study team has continued to work on publishing their results in scientific journals, as well as disseminating the results in other formats to different stakeholders in order to attract more funding. The ultimate aim would be to ensure that the study objectives are rolled out countrywide to include perceptions of people in rural settings.

PUBLICATION

Kamulegeya LH, Bwanika J, Banonya J, Atuhaire J, Musinguzi D, Nakate V, Kyenkya J, Namatende L, Horvath KJ, and Kiragga A. 2022. Feasibility and Acceptability of a Ugandan Telehealth Engagement Platform for Informational Messaging on Modern Contraception: Pilot Cross-sectional Study. JMIR Formative Research 2022;6(6): e34424. https://formative.jmir.org/2022/6/e34424. DOI: 10.2196/3442

UGANDA - PROJECT 6-158: SCALED DEPLOYMENT OF SMART-PHONE AGRO-APPLICATIONS FOR FIELD BASED DIAGNOSIS AND REAL-TIME SURVEILLANCE DATA COLLECTION

PI: Ernest Mwebaze, Makerere University

U.S. Partner: Jesse Poland, Kansas State University (Funded by the National Science Foundation)

Dates: December 2017 – November 2018

PROJECT OVERVIEW

Cassava is a very important food security crop in Uganda and in the region and is a major crop grown by small-scale farmers who depend on it for their livelihood. The overarching goal of this project was to improve livelihoods of these small-holder farmers through provision of better tools that offer them actionable information about the health of their crops. This goal can further be broken down to two aims. The first centered around crowd sourcing of crop disease surveillance data from farmers. A total of 200 farmers were provided with smartphones and, using several incentive schemes, were encouraged to collect data about the state of health of their farms and gardens. The data included both images and their geo-coordinates. The principal investigator's hypothesis was that a great deal of data could be collected from all over the country cheaply and that this would be an empowering activity for the farmers. The second aim was to provide farmers with a system that can be used to provide real-time diagnosis of their crops. The mobile phones were equipped with software that can calculate the state of health of a cassava crop by analyzing an image of its leaves. Farmers are therefore able to make the necessary early interventions in their own gardens.

This project drew on a prototype crowd sourcing system that the PI and his team had been testing for more than a year. They distributed phones to 29 people involved in agriculture in the different regions of Uganda and created a mobile phone application that they modified to allow the participants to take pictures of crops and upload them in real time. Data collected consisted of an image of the cassava crop, the GPS coordinates, and a statement of whether the image taken was representative of disease, pests, or an anomaly. Using this system the researchers collected more than 4,800 images from different places in Uganda (http://adsurv.mcrops.org/). Their PEER award allowed them to expand the network to 200 participants in order to generate evidence for a large-scale deployment of a digital system for crop disease surveillance data collection. In particular, they were interested in understanding how accurate the inferences from such data can be, how useful an on-field diagnosis application can be for smallholder farmers, and what incentive mechanisms work.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and his team implemented this project in 12 months to scale-up activities of a previous BMGF funded project that supported the initial outreach and engagement with farmers. This project leveraged the success in that pilot to grow the number of farmers from 25 to 200 using a network of smartphones to report surveillance data to the National Crops Resources Research Institute(NaCRRI), the body in Uganda charged with carrying out surveillance of cassava throughout the country.

The PI engaged several undergraduate and graduate students in the project, enabling them to grow their skills and contribute to its success. Farmers gained knowledge on how to diagnose diseases in cassava and have used the training and knowledge obtained to develop businesses based on providing clean cassava planting materials, thus supporting their livelihoods.

The project provided an unprecedented, large quantity of geo-tagged images of cassava at different health levels that is being used to train better models to predict disease from images. Since the data is geo-tagged, it can also be used for disease spatial analysis. Even after the PEER project ended, the team continued pursuing these avenues and working to put the dataset online for use by the wider community.

The PI also managed to form a partnership between the technical team in Makerere, the Uganda National Farmers Federation (UNFEE), and NaCRRI that is actively looking to further this project to support not only cassava but also other crops. The PEER team has been in talks with other crop teams in NaCRRI who are interested in extending this system to cover cereal crops. From their collaboration with UNFFE and NaCRRI, numerous farmers were trained in disease identification in the field and best practices for mitigating disease.

UGANDA - PROJECT 5-450: MHEALTH FOR TB-TOBACCO: AN APPROACH TO REDUCE TOBACCO USE AMONG TB PATIENTS

PI: Elizeus Rutebemberwa, Makerere University

U.S. Partner: Robert Pack, East Tennessee State University (Funded by the National Institutes of Health)

Dates: February 2017 – January 2021

PROJECT OVERVIEW

Globally, more than 20% of tuberculosis (TB) cases are attributable to smoking, hence the critical need to reduce TB prevalence through smoking cessation. There is sparse information on how to incorporate tobacco control into TB programs in low-and-middle income countries, particularly using mobile information and communications health solutions (mHealth), even though the WHO Global TB program calls for an integrated approach toward TB-tobacco prevention and treatment. Previous studies into the use of mHealth technology for smoking cessation indicate significant potential in successful behavior change. This project aimed to provide policy and program recommendations to the TB program and the tobacco control programs in Uganda by developing and testing mHealth solutions to support TB patients quitting tobacco use and promote adherence to TB treatment.

Researchers measured tobacco quit rates and TB treatment protocol adherence for patients who received integrated tobacco cessation health education in their treatment programs. The project used the mCessation approach using SMS as a solution for providing information, following up with patients, and supporting them to quit tobacco use.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Rutebemberwa and his colleagues selected regional hospitals and other healthcare sites for the study based on their high numbers of TB patients and the availability of medical support for tobacco withdrawal symptoms. Each health facility recommended one health worker in their TB ward to be involved in the study. They were invited to Kampala and trained for a week on the research objectives and their responsibilities in the study. The researchers also undertook a pilot study in Mulago.

Health workers administered questionnaires on paper to identify tobacco users among TB patients and then recruited them to sign up for ongoing SMS messages as part of the program. Every quarter, two supervisors would collect questionnaires, support the health workers in their work, and provide supplies like lab test strips or stationery. There were a total of 80 participants in the control group and 80 in the intervention, spread around the regions.

At the time the PEER grant ended, the PI and his team were still analyzing their results to determine the impact of the intervention. In the meantime, however, the PI received an additional $46,000 grant from Makerere University Research Innovation Fund to continue research on reducing tobacco use. He notes that the PEER grant was helpful in getting this grant because it highlighted an important problem and provided background data documenting that the study site, Moroto District, has high tobacco use rates across all age groups. The work Dr. Rutebemberwa and his team continue to do in consultation with the Ugandan Ministry of Health goes beyond health facilities and looks at tobacco use within communities and schools.

PUBLICATIONS

E. Rutebemberwa, K. Nyamurungi, S. Joshi, Y. Olando, H.M. Mamudu, and R.P. Pack. 2021. Health workers' perceptions on where and how to integrate tobacco use cessation services into tuberculosis treatment; a qualitative exploratory study in Uganda. BMC Public Health *21*(1): 1464. https://doi.org/10.1186/s12889-021-11502-4

H. Mamudu, K. Namusisi, W. Bazeyo, Y. Olando, J. Surabhi, F. Makumbi, R. Pack, and E. Rutebemberwa. 2018. Change in knowledge of tobacco use and secondhand smoke exposure among health workers in Uganda. Tobacco Induced Diseases 2018;16(Suppl 1):A636. https://doi.org/10.18332/tid/84518

UGANDA - PROJECT 5-37: DELIVERING CROP YIELD NOWCASTS AND FORECASTS BY INTEGRATING SATELLITE DATA AND CROP MODELLING IN SUB-SAHARAN AFRICA

PI: Ejiet John Wasige, Makerere University
U.S. Partner: Forrest Melton, California State University Monterey Bay and the NASA Ames Research Center Cooperative for Research in Earth Science and Technology (NASA ARC-CREST)
Dates: December 2016 – December 2020

PROJECT OVERVIEW

Africa nations have significant gaps in their ability to produce and deliver near real-time crop yield information and mainstream these in national and farmer operational decision making. There are currently four "global" agricultural monitoring systems: the Global Information and Early Warning System of the United Nations Food and Agriculture Organization, the Famine Early Warning Systems Network of the U.S. Department of Agriculture Foreign Agricultural Service, the Monitoring Agricultural Resources network of the European Union, and the system of the Institute of Remote Sensing Applications of the Chinese Academy of Sciences. The data they have published inevitably have a long lag time in comparison with "conventional" reporting of crop production. The data are also aggregated at the national or district scale and vary in accuracy and availability. The integration of earth observation (EO) data and crop modeling can overcome technical limitations to quantitative yield estimates, and such an effort is justified by the fact that EO data can be used to quantify crop health status at any given time, while the crop model can describe crop growth every day throughout the season on a pixel basis.

The goal of this project was rapid development of large-scale, real-time crop production mapping tools that will close a significant gap in crop yield data availability and enhance the capacity of African governments to deliver reliable near real-time crop production information for decision makers in agricultural planning and food security management. Members of this project team worked toward that goal while also developing the capacity of agriculture extension workers to bring that kind of information to farmers and assist them in incorporating it into their planning to combat threats to crop production in the case of abnormal weather conditions. Ultimately this should help to enhance reliable access to food in sub-Saharan Africa.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team delivered proof of concept that location specific and near real-time vegetation/ plant health and daily 16-day future weather forecasts can be accessed by smallholder farmers and policy workers for agricultural production planning in Africa. The project achieved four outcomes: (1) Developed integrated earth observation data, complementary field work, and free open-source earth data modeling tools to generate crop/vegetation now-casts and forecasts; (2) Disseminated now-casts and forecasts, (3) Built capacity to deliver data; and (4) Supported policy advocacy to target delivering now-casts and forecasts to smallholder farmers in sub-Saharan Africa. The team operationalized delivering near real-time crop/vegetation health information in Uganda and Zambia, as well as provided free online web services and a phone app to enable delivery of real-time information. The team conducted more than 25 community and national policy dissemination workshops for more than 1,000 field farmers in Uganda and Zambia, 200 agricultural extension workers, and policy makers, as well as training for four graduate students. They continue to scale up to a goal of 2,000,000 stakeholders through Facebook (user ID: cropWISE) and Google Play.

The project team also created an improved ICT policy environment for scaling out real-time agricultural ICT services. Users gained skills and knowledge in digital information access, interpretation, and use. The team enhanced the capacity of agriculture extension workers to deliver land health and weather forecast information to farmers and assist them in incorporating it into their planning to combat threats to crop production in the case of abnormal weather conditions, as well as increase reliable access to food in sub-Saharan Africa. Farmers gained knowledge on how to access and interpret real-time vegetation health data and weather forecast information for decision making on when to plant, harvest, dry, transport, and market their crops. They have used the training and knowledge obtained to select crop varieties to plant and target market prices for income to support food production and their livelihoods.

The project provided a large quantity of satellite imagery real-time vegetation health data for period 2015 to 2019 and a daily 16-day-ahead weather forecast that is being used for agricultural production planning and postharvest handling. Using the Facebook platform (cropWISE), the PEER team created a network for land health and weather forecast data and information sharing. Some of the key stakeholders include the Ministry of Agriculture, Uganda National Farmers Federation (UNFEE), Zambia Agriculture Research Institute (ZARI), Zambia National Farmers Union (ZNFU), National Agricultural Research Organization (NARO), National Emergency Coordination and Operations Centre (NECOC), and the National Crop Resources Research Institute (NaCRRI). After the project ended, the project team continued their discussions with relevant government agencies and nonprofits interested in a large-scale expansion of the impact of the cropWISE app to the farming community.

UGANDA - PROJECT 5-19: A MULTI-SENSOR HYDROLOGIC MODELING FRAMEWORK TO ASSESS THE IMPACTS OF SMALL-SCALE WATER STORAGE PRACTICES TO WATER RESOURCES OVER UGANDA

PI: Jamiat Nanteza, Makerere University
U.S. Partner: Mathew Rodell, NASA Goddard Space Flight Center
Dates: December 2016 – July 2021

PROJECT OVERVIEW

Water availability and accessibility are concerns that water managers strive to address in the face of climate change, population growth, and food insecurity. Water resources are strained during extreme hydrologic events, and as climate variability and extremes increase (Trenberth, 2012), the uncertainty of freshwater availability poses a threat for emerging economies like Uganda. Anecdotal reports from Uganda indicate that shrinking rivers and diminishing groundwater resources (Lwanga, 2015) have become commonplace, both of which indicate declines in groundwater storage. Water harvesting has the potential to mitigate climate impacts in the short-term (Kahinda et al., 2010); however, potential hydrologic alterations from such small-scale water captures and storage are unknown.

This study sought to assess the viability of increasing water harvesting efforts in Uganda by examining associated hydrological impacts that result from the capture and storage of water. Dr. Nanteza and her team applied an integrated modelling framework to exploit multivariate remote sensing data from NASA satellite missions combined with ground-based hydrologic observations to examine the spatial and temporal impacts of water harvesting. This project served as a pilot study for model development and hypothesis testing, thus providing a first step towards generation of a decision-support system for evaluating water use and management scenarios in the face of climate change and development. The research team also addressed broader national development goals, including aiding decision making for development efforts towards irrigation-based agricultural production, as well as livelihoods. Results of the study should help to inform ongoing government efforts (for example, the Karamoja Action Plan for Food Security) aimed at transitioning the Karamoja dry-land communities from pastoralism to crop farming.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the course of the project the team worked to identify and characterize recharge, low flow and groundwater behaviors across temporal and spatial scales with links to land use and climate changes, They used a multi-model ensemble of eight global hydrological models (GHMs) of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b) that are driven by the bias-adjusted output of four global circulation models (GCMs). The team assessed the space-time variability in groundwater recharge and the recharge/precipitation ratio and identified areas potentially at risk to future groundwater shortages over Uganda. In 2022, the team published a paper detailing their findings.

The second objective of the project was to quantify and characterize the spatiotemporal groundwater use and water harvesting across the country with links to socio-economic factors and population dynamics. First, the team aimed to examine the status of groundwater and rainwater harvesting supply systems in Uganda, and second, they worked to determine the current rates of groundwater abstracted and rainwater harvested in Uganda as these would further inform the experimental modelling efforts. The researchers further compared this potential with required tank storage (RTS) capacities based on user population, demand and dry period lengths, to examine whether existing rooftop areas in Uganda and tank storage can sustainably supply water for use during 90-day and 180-day dry periods.

Quantifying the runoff, recharge and groundwater storage alterations resulting from water harvesting operations was the project team's third objective. The study used the Community Land Model (CLM4) to evaluate the hydrologic impacts of increasing water abstraction over Uganda. The model was modified to include rainwater and groundwater harvesting. The study results show that current water harvesting practices have no significant hydrologic impacts. However, scenario-based analysis shows that if water harvesting is increased especially from aquifers it would lead to a decrease (increase) in base flow, water table depth, surface runoff (evaporation, groundwater recharge, soil moisture and infiltration).

The project achieved significant developmental impacts through several initiatives. They trained 105 students and researchers on NASA's satellite and hydrologic models, aiming to enhance research quality in water resource management. Additionally, 80 undergraduates and 22 Master's students were trained on pressure transducers for groundwater monitoring, and 20 students learned the CLM model for hydrologic evaluations. The project generated datasets on water abstraction and rainwater harvesting potential across Uganda, facilitating spatial analysis for water development projects. Collaborations with the Ministry of Water and Environment and local governments enabled local water managers to monitor equipment and utilize data effectively. Digitized datasets on rooftop areas for rainwater harvesting were also created, influencing decisions on future projects. Winning the bid to host the African Union New Partnership for Africa's Development center of excellence in water underscores the project's enduring impact, ensuring continued implementation of its recommendations beyond its conclusion.

PUBLICATION

Jamiat Nanteza, Brian Thomas, Jesse Kisembe, Rhoda Nakabugo, Paul Isolo Mukwaya, and Mathew Rodell. 2022. A Google Earth-GIS based approach to examine the potential of the current rainwater harvesting practices to meet water demands in Mityana district, Uganda. PLOS Water 1(11): e0000045. https://doi.org/10.1371/journal.pwat.0000045

UGANDA - PROJECT 2-253: SUSTAINABLE COFFEE-BANANA AGROFORESTRY SYSTEMS TO ADAPT TO CLIMATE CHANGE, ENHANCE FOOD SECURITY, AND ALLEVIATE POVERTY IN UGANDA

PI: Godfrey H. Kagezi, Coffee Research Center, National Agricultural Organization
U.S. Partner: Ivette Perfecto, University of Michigan (Funded by the National Science Foundation)
Dates: August 2013 – July 2015

PROJECT OVERVIEW

Coffee and bananas are key crops in eradicating extreme poverty and hunger as well as ensuring environmental sustainability in Uganda. However, production of both crops is far below the attainable yields, mainly due to abiotic (soil, water, temperature) and biotic (pests, diseases, weeds) stresses. Modern research has identified integrating shade trees in coffee-banana systems as the entry point for re-establishing productivity of both crops. However, prior to this project these systems had not yet been fully quantified. There were no recommendations on how (or if) to intercrop with regard to optimal planting arrangements; shade management regimes; and best soil, water, and crop management options.

This PEER project explored the best coffee-banana agroforestry combinations to identify the optimal trade-offs in food, income, risks, and environmental sustainability. Specifically, the research characterized existing coffee-banana agroforestry systems; identified biotic and abiotic constraints, including farmers' coping strategies; generated an improved Integrated Crop Management package; developed advocacy and lobby tools that can strengthen the value chain; and developed capacity for research and promote synergies among actors along the value chain. Overall, the project sought to improve agriculture and sustainable environmental management in Uganda, aiding adaptation to climate change. In the long run, this information could be scaled up to other farmers in the Lake Victoria region with similar farming systems.

FINAL SUMMARY OF PROJECT ACTIVITIES

Team members created and conducted diagnostic surveys in five major coffee-producing regions of Uganda to characterize existing coffee-banana agroforestry systems and identify the major biotic and abiotic constraints. In each region, 10 districts were selected at random and in each district, 10 households selected randomly were sampled and data collected on their farms. Results showed diverse cropping systems, including coffee as a mono-crop, banana as a monocrop, coffee-banana intercrop, and coffee-banana-shade trees inter-crop, as well as different kinds of coffee growing.

The PEER researchers combined farmers' knowledge and information on regional tree species to make recommendations for appropriate shade trees for the various coffee growing regions and highlight "bad neighbor" trees for coffee and bananas. Among the biotic constraints, farmers reported weeds, particularly couch grass and annual broad-leaved weeds, as well as pests and diseases; particularly the black coffee twig borer (BCTB) for coffee and banana bacterial wilt (BBW) for bananas. Farmers also reported declining soil fertility, limited moisture, soil erosion, and an assortment of socioeconomic constraints, including lack of capital; limited and unaffordable labor, input, and output markets; and several gender-related issues. Most farmers were also aware of climate change and its effects, particularly, prolonged drought and poor yields in both coffee and bananas. At least 50% of the farmers interviewed reported that they plant trees as an adaptation to climate change. Limited space and lack of seedlings were reported as the major reasons hindering farmers from planting more trees.

The researchers conducted follow up studies in the surveyed regions, collecting samples of major pests and diseases of coffee and banana trees. Regional differences in the prevalence of inspect pests were identified and used to update the existing Integrated Pest Management (IPM) package for the twig borer. Media (print and electronic) and farmer-to-farmer communication approaches were the most important sources of agricultural information for the farmers. However, access and use of agricultural credit facilities is still very low in Uganda.

The team used the project results to generate training materials, posters and manuscripts for the farmers, an effort that was significantly expanded thanks to a PEER Evidence to Action supplement awarded to Dr. Kagezi and his team in January 2018. Those funds supported a training needs assessment, development of a training curriculum, and delivery of training to more than 700 Ugandan farmers. The information gathered in the project was also used to update the coffee management calendars which have been used to train farmers and other stakeholders in Farmer Field Schools across the coffee-banana growing regions. In addition, the project contributed to building and improving the research capacity for Coffee Research Center through training of two Master's-level students and provision of short-term courses to students, research technicians, and other COREC staff. The training curriculum developed under the supplement was selected for incorporation into the coffee training center at the National Coffee Research Institute (NaCORI), Kituza. It will also be used by other institutions involved in the promotion of coffee-related activities, such as the Uganda Coffee Development Authority (UCDA); Café Africa Uganda; the Directorate of Extension services of the Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF); Hanns R. Neumann Stiftung (HRNS); and various Ugandan universities.

Although the PEER project and supplement funding have ended, Dr. Kagezi and his team continue to work on several ongoing efforts building on their PEER research, including two major projects funded directly by USAID.

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Judith Kobusinge, Godfrey H. Kagezi, Abisagi Kasoma, Patrick Kucel, Lilian Nakibuule, Ivette Perfecto, and William W. Wagoire. 2018. Farmers' Knowledge of Pests and Diseases in the Coffee-Banana Agroforestry Systems of Mid-Eastern Uganda. Journal of Agriculture and Environmental Sciences 7(2): 109-119. https://doi.org/10.15640/jns.v7n2a12

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UGANDA - PROJECT H1-61: DEVELOPMENT AND EVALUATION OF STRATEGIES TO FOSTER IMPLEMENTATION OF GUIDELINES FOR DIAGNOSIS OF CHILDHOOD TUBERCULOSIS

PI: Achilles Katamba, Makerere University
U.S. Partner: Adithya Cattamanchi, University of California, San Francisco (Funded by the National Institutes of Health)
Dates: October 2013 – April 2019

PROJECT OVERVIEW

Uganda has an estimated 67,000 annual TB cases but has among the lowest case detection and treatment success rates of the 22 high-burden countries. Moreover, case detection and reporting among children is virtually non-existent.

The recently published "Desk Guide for Diagnosis and Management of TB in Children," developed with USAID funding, is an evidence-based, simple decision aid to improve early and accurate identification of children with TB in resource-constrained settings. However, uptake of the Desk Guide had been limited as of the start date of this PEER project in 2013, and little was known about how best to facilitate implementation in routine practice settings. The goal of this project was therefore to develop and evaluate an intervention to facilitate successful adoption of the Desk Guide at primary health centers in Uganda.

The studies took place at six Kampala City Council Authority clinics, representative of urban primary care centers in sub-Saharan Africa. The team tested the overall hypothesis that a multi-faceted intervention will increase the proportions of children identified as TB suspects, child TB suspects evaluated for TB, and children diagnosed and reported as TB cases.

The research aligned with USAID Uganda's goal of strengthening health systems and improving the delivery of health services, and it sought to provide USAID and the Ugandan government with important information on factors that influence Desk Guide use and strategies to promote its uptake at primary level health facilities.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team worked at six Kampala Capital Authority (KCCA) health facilities across the project period. The intervention included a two-hour Continuing Medical Education (CME) with all clinicians at each health facility, followed by a daily one-hour on-the-job coaching session on how to evaluate children for TB. Pediatricians worked with clinicians for seven weeks at each health facility. The researchers also distributed a printed health care guide on the management of tuberculosis in children, and a step-by-step process for the diagnosis of TB in children, placing them where children were being evaluated in the primary health care clinic.

The PEER team provided support and performance feedback for evaluating children for TB through monthly reports. These reports included the number and proportion of children diagnosed and treated for TB, as well as process indicators like the number and proportion of children screened for TB and number and proportion of children tested for TB if only one symptom was present. Of the 24,566 children enrolled in the study, 47% were fully screened for TB symptoms, 15% were screened positive, and of those 80% initiated treatment. Although there were large gaps in the pathway of diagnosis and treatment, the PEER team found that the TB Desk Manual had been implemented with success at their six study sites around Kampala.

The researchers developed databases of patient record forms for both pre-intervention and post-intervention study periods and conducted a post-intervention assessment of knowledge, attitudes, and self-efficacy of health care workers at the six clinics. The team also published their findings in peer-reviewed journals and received several additional grants for other related work, totaling more than $700,000**.**

PUBLICATIONS

S. Kizito, A. Katamba, C. Marquez, P. Turimumahoro, I. Ayakaka, J.L. Davis, and A. Cattamanchi. 2018. Quality of care in childhood tuberculosis diagnosis at primary care clinics in Kampala, Uganda. The International Journal of Tuberculosis and Lung Disease 22(10): 1196-1202. https://doi.org/10.5588/ijtld.18.0043

Irene Ayakaka, Sara Ackerman, Joseph M. Ggita, Phoebe Kajubi, David Dowdy, Jessica E. Haberer, Elizabeth Fair, Philip Hopewell, Margaret A. Handley, Adithya Cattamanchi, Achilles Katamba, and J. Lucian Davis. 2017. Identifying barriers to and facilitators of tuberculosis contact investigation in Kampala, Uganda: a behavioral approach. Implementation Science 12:33. https://doi.org/10.1186/s13012-017-0561-4

UGANDA - PROJECT H1-54: ASSESSING THE EFFECT OF STRENGTHENING THE REFERRAL OF CHILDREN FROM THE PRIVATE HEALTH SECTOR AND ITS IMPACT ON CHILD SURVIVAL IN UGANDA

PI: Anthony Mbonye, Makerere University
U.S. Partner: Philip Larussa, Columbia University (Funded by the National Institutes of Health)
Dates: February 2014 – July 2017

PROJECT OVERVIEW

Uganda's under-five mortality is high, currently estimated at 90/1000 live births. Poor referral of sick children that seek care from the private sector is one of the contributory factors. The intervention conducted under this project aimed to improve timely referral and uptake of referral advice of children that seek care from private facilities. The private sector in this project included private clinics and registered drug shops. The project was implemented in Mukono District, central Uganda. This region was selected because a recent concluded trial in the district showed that drug shop vendors (DSVs) adhere to diagnostic test results, treat appropriately and refer sick children, although uptake of referral is poor. The main reasons attributed to the observed poor referral were negative attitude towards referral forms from drugs shops by the health workers at referral facilities, perceptions of poor quality of care at referral facilities and costs involved (Hutchinson. 2012).

This project was a follow up to address these factors with the aim to improve uptake of referral. The primary objective of the project was to assess the effect of strengthening the referral system on timely uptake of referral of sick children who seek care in the private sector. The secondary objectives were (1) to assess appropriate case management for malaria, pneumonia, and diarrhea; (2) to explore factors which influence the referral or non-referral of sick children from the private sector; and (3) to assess the cost effectiveness of uptake of referral of sick children who seek care in the private sector. A cluster randomized design was applied to test the intervention. In the intervention arm, village health teams sensitized communities on the importance of referral. Private outlets in both arms were trained to diagnose, treat, and refer children. The intervention had three components: (1) training of village health trainers (VHTs) to do community sensitization and initiate community discussions aimed at identifying community support mechanisms for financial hardship (to be community led and managed); (2) training and supervision of providers in the private sector to diagnose, treat, and refer sick children, and (3) regular meetings between the public and private providers (convened by the district health team) to discuss the referral system. The data generated from this study contributed to a better understanding of factors of importance for strengthening the referral system, including optimal training required, supervision activities, community participation, and the costs involved. The lessons learned are likely to inform programming at a national and district level to improve referral of children from the private sector.

FINAL SUMMARY OF PROJECT ACTIVITIES

A sample of study clusters implemented the intervention with ten randomly allocated to the intervention and ten to the control arm. The primary outcome was the proportion of sick children referred from the private sector were seen at higher level facilities:

- Intervention Arm: Community awareness on referral and training private providers using RDTs/ICCM to treat and refer sick children; supervision and regular meetings between the private and public sector.
- Control Arm: No community awareness on referral (trained private providers using RDTs/ICCM to treat and refer sick children).

The primary outcomes included an increase in appropriate case management for malaria, pneumonia, and diarrhea among children in the private sector, and improved cost-effectiveness of timely and uptake of referral of sick children. The secondary outcomes included the increase in the proportion of sick children seeking care and receiving prompt treatment at private outlets within 24 hours of onset of symptoms; the decrease in time between consultations at private outlets and uptake of referral at health facilities (referral facilities); and understanding the factors which influence the referral or non-referral of sick children from the private sector.

In conclusion, adherence to the mRDT test was better in the intervention arm than the control arms. Overall referrals were very few, with no significant differences between the two arms. The improved case management in the intervention could have affected the referrals in that arm. The researchers also designed protocols and tools to conduct a community survey to assess uptake of referral and costs involved in taking up referral. They conducted 24 qualitative interviews: i) six focus group discussions (FGDS) among care takers who recently had sick children (three among mothers and three for fathers) to assess their views why caretakers take up referral or not; ii) four FGDs among health workers (private and public health workers together) to explore their perceptions about the referral system; iii) eight key informant interviews (KIIs) with village health teams (VHTs) and community leaders (local council leaders) to understand whether the VHTs conducted community sensitization on referral as they were meant to; iv) six FGDs community members (three for women and three for men) to explore whether a financial scheme is acceptable to the population and if they think it can enable uptake of referral. The team published four papers on their work.

PUBLICATIONS

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ZAMBIA

ZAMBIA - PROJECT 8-174: INCREASED AVAILABILITY OF FAST COOKING YELLOW DRY BEANS RICH IN BIOAVAILABLE IRON TO ZAMBIA CONSUMERS AND FARMERS

PI: Kelvin Kamfwa, University of Zambia
U.S. Partner: Karen Cichy, United States Department of Agriculture/ Agricultural Research Service
Dates: December 2019 – April 2023

PROJECT OVERVIEW

Common bean (*Phaseolus vulgaris*) is a major source of protein and iron. Iron deficiency is widespread in Zambia, especially among children and pregnant women, and consuming iron-rich beans could mitigate this issue. Faster cooking beans can also reduce the environmental impact of using charcoal or firewood and lower health risks from prolonged indoor cooking emissions. Despite these benefits, adoption of new bean varieties in Zambia remains low. Participatory Variety Selection (PVS), which involves farmers in selecting crop varieties, can enhance adoption. Yellow beans, though nutritionally superior and faster-cooking than the widely consumed purple "kabulangeti" beans, are not as popular due to lack of awareness and access to improved varieties.

The project aimed to (1) improve Zambians' diets by increasing the availability of fast-cooking yellow beans rich in bioavailable iron and (2) improve bean profitability for Zambian farmers by introducing high-yielding varieties with desirable traits. Researchers provided farmers with high-yielding, fast-cooking yellow dry bean breeding lines from the University of Zambia Bean Breeding Program and the breeding program of U.S. partner Dr. Karen Cichy. Through the PVS process, farmers selected appropriate seed stocks for their local conditions. On-farm field trials and cooking trials were conducted, evaluating adoption potential and real-life cooking times using charcoal and firewood. Farmers ranked the beans based on cooking time, gravy quality, aroma, and flavor.

To raise awareness of yellow beans' benefits, the PEER team organized on-farm field days, inviting farmers, consumers, and representatives from institutions with high bean consumption, such as hospitals, boarding schools, and prisons, to sample the beans. Government and traditional leaders, crucial for promoting yellow bean production and consumption, were also invited.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project developed a high yielding, faster cooking, yellow bean variety (YBC129) with high iron bioavailability. This variety was selected from more than 250 yellow bean breeding lines through farmer participatory variety selection (FPVS). In a cooking trial in October 2021, a total of 20 farmers (10 female and 10 male) used a hotplate to cook a total of nine genotypes (four selected elite lines and five checks). The time it took for the beans to be fully cooked was recorded. After cooking, the farmers taste-tested the four genotypes and the checks. The cooking time for the nine genotypes ranged from 2.10 hours for the selected elite line YBC129 to 3.10 hours (YBC120). Interestingly, the fastest cooking and best-tasting genotype was also the highest yielding line among the four genotypes that farmers selected from the on-farm field trial in 2021. Because farmers selected YBC129 based on its desirable agronomic attributes such as seed yield, seed size and shape, cooking time, and taste, it is the elite line that the project chose to recommend for release as an improved yellow bean variety in Zambia to replace landrace Lusaka on the Zambian market. Dr. Kamfwa submitted this variety to the Seed Control and Certification Institute in Zambia in 2022 for testing, and its release is scheduled for 2024. Once released, this variety is expected to have significant impact on farmers' livelihood because of its higher seed yield than the yellow landraces currently on the Zambian market.

In December 2022, the PEER team distributed seed of YBC129 to 620 smallholder farmers in Northern and Muchinga provinces. These smallholder farmers adopted the variety and will be involved in seed multiplication of YBC129 when it is officially released in Zambia. The seed dissemination activities created awareness about the availability of high yielding, faster cooking, and high iron bioavailability variety developed through FPVS. The use of FPVS in the development of YBC129 and the awareness that has been created about this variety is likely to enhance its adoption by smallholder farmers.

This project has undertaken outreach activities and collaborated with several key stakeholders. The researchers provided YBC129 seed to the NGO Community Technology Development Trust to conduct on-farm trials in Lusaka and Central provinces of Zambia. They also worked with the Zambia Agricultural Research Institute, a government agency, to conduct on-farm trials and disseminate seed of the new yellow bean variety, and they are partnering with the private company Good Nature Agro, which is conducting on-farm trials and identifying smallholder farmers that will be involved in YBC129 seed production.

The team published one paper on their work in 2023. The PI has also received a grant in the amount of £39,353 from the AgriFood Africa Programme of the UK's Global Challenges Research Fund to continue his work on the PEER-supported topic. Dr. Kamfwa will also continue collaborating with his U.S. partner Dr. Karen Cichy on better understanding the genetic basis of faster cooking time of YBC129. YBC129 has been crossed with other genotypes to create breeding populations that will be used in genetic studies for cooking time. Additionally, Dr. Cichy will continue collaborating with the University of Zambia Breeding program to develop faster cooking varieties in other market classes.

PUBLICATION

Kuwabo Kuwabo, Swivia M. Hamabwe, Paul Kachapulula, Karen Cichy, Travis Parker, Chikoti Mukuma, and Kelvin Kamfwa. 2023. Genome-wide association analysis of anthracnose resistance in the Yellow Bean Collection of Common Bean. PLoS ONE 18(11): e0293291.
https://doi.org/10.1371/journal.pone.0293291

ZAMBIA - PROJECT 7-109: APPLICATION OF GIS AND GEOSPATIAL ANALYSIS IN UNDERSTANDING CHARCOAL PRODUCTION, SUPPLY AND DEMAND IN SELECTED SITES OF LUSAKA; CENTRAL, COPPERBELT AND NORTH WESTERN PROVINCES OF ZAMBIA

PI: Stephen Syampungani, Copperbelt University
U.S. Partner: Andrew Hudak, USDA Forest Service
Dates: November 2018 – October 2022

PROJECT OVERVIEW

Charcoal consumption is expected to increase in Zambia in the coming decades, and as a result, charcoal must be integrated into development, energy, land use, and food security strategies. This project undertook a detailed value chain analysis of charcoal with the aim of identifying how to reduce the impact of charcoal production, supply, and demand. The project generated spatial distribution information of above-ground woody biomass suitable for charcoal making, data that are currently lacking but are highly useful for designing improved forest management practices in the country.

This project also sought to evaluate the performance of various charcoal production methods, including traditional methods, with a view to improving them. The researchers hoped to contribute to appropriate government policies required to introduce improved charcoal-production technologies at scale, as well as promote rural development through greening of the charcoal value chain and reduction of demands for charcoal through improved stoves to reduce pressure on Zambia's forests and woodlands.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Syampungani and his team identified and classified tree species in the Miombo woodlands using multispectral drone imagery, combined with a field inventory to obtain training and verification data for a classification algorithm. They also used drone-collected Lidar data in estimating forest structure attributes in the Miombo and undertook field work to collect ground-truth data in 16 plots of a 20 m radius in a site in Mwekera forest. The researchers also enhanced the diffusion of improved charcoal kilns, collecting data from four study sites in Copperbelt and North Western provinces using the software KoBoToolkit on their mobile phones. Key informational interviews and a tree inventory using the Point Centered Quarter Method were also completed.

As a result, the researchers generated useful data for forest management throughout the Miombo ecoregion, which covers nine countries in Southern Africa, and provided improved methods of charcoal production through simple technologies affordable to an ordinary charcoal producer.

The team published several papers related to their PEER project. In addition to the research outputs, the project also supported one Master's and two Ph.D. students. Dr. Syampungani also received a new ongoing grant from the Oliver R. Tambo Africa Research Chairs Initiative Chair of Environment and Development worth US$250,000 to $300,000 annually over the next five years, renewable twice based on performance.

PUBLICATIONS

Jean Moussa Kouroumaa, Concillia Monde, Darius Phiri, and Stephen Syampungani. 2023. Community-centred approach for assessing social sustainability in mining regions: a case study of Chingola district, Zambia. Sustainable Development 31(4): 3102-3127.
https://doi.org/10.1002/sd.2572

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https://doi.org/10.3390/s23042241

Hastings Shamaoma, Paxie W. Chirwa, Abel Ramoelo, Andrew T. Hudak, and Stephen Syampungani. 2022. The application of UASs in forest management and monitoring: challenges and opportunities for use in the Miombo woodland. Forests 2022, 13, 1812. https://doi.org/10.3390/f13111812

Jean Moussa Kouroumaa, Darius Phiri, Andrew T. Hudak, and Stephen Syampungani. 2022. Land use/cover spatiotemporal dynamics, and implications on environmental and bioclimatic factors in Chingola district, Zambia. Geomatics, Natural Hazards, and Risk 13(1): 1898-1942.
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ZAMBIA - PROJECT 7-100: ADOPTION AND SCALE-UP OF CHARCOAL ALTERNATIVES IN ZAMBIA

PI: Francis Yamba, Centre for Energy, Environment and Engineering Zambia
U.S. Partner: Robert Bailis, Stockholm Environment Institute – U.S. Center (Funded by the National Science Foundation)
Dates: November 2018 – February 2022

PROJECT OVERVIEW

Charcoal is a highly complex socio-environmental issue throughout sub-Saharan Africa. Charcoal production and use is frequently associated with climate change, environmental degradation, adverse health outcomes, and poverty. Strategies to mitigate reliance on charcoal as the dominant cooking fuel are urgently needed, particularly in areas where urban populations are growing and inefficient production systems are putting pressure on atmospheric and terrestrial systems. Zambia presents a critical case for understanding the supply and demand dynamics of charcoal and strategies for mitigating associated negative externalities. This project examined the potential of a dual-pronged approach to develop technical and social alternatives to charcoal in Zambia: improved charcoal production and alternative fuels and stoves.

For any alternative stove or fuel to have an impact it must be not only acquired but also used in a way that reduces charcoal use. This study aimed to determine if this reduction occurs and whether it can be sustained and scaled up. By working closely with stove/fuel developers, distributors, and users, this project team identified factors that might be changed to enhance access to clean energy and reduce charcoal consumption. With multiple U.S. partners involved in several different regional collaborations, and primarily in partnership with the Stockholm Environmental Institute's Africa Center, an influential regional think-tank, this research project relied on linkages throughout Southern and East Africa. These ties fostered cooperation and knowledge exchange well beyond Zambia, offering many opportunities to share experiences and lessons through workshops, conferences, and one-on-one meetings with high-level policy makers in Zambia and throughout the region. Other potential impacts are expected through exploration of the market potential for pellet fuels and ethanol. The project further supported enhanced job opportunities by collecting and sharing data about the types of stoves and fuels consumers prefer and their willingness to pay for charcoal alternatives.

FINAL SUMMARY OF PROJECT ACTIVITIES

The final activity on this project took place in February 2022, when members of the co-PI team at the Stockholm Environmental Center (SEI) in Kenya travelled to Zambia to collaborate with the PI Dr. Yamba and researcher Nancy Serenje at the Centre for Energy, Environment, and Engineering Zambia (CEEZ) on a series of activities, including a focus group discussion (FGD) meeting in Choma. The FGD participants included officials from the Provincial Forestry Department and District Forestry Department, members of the local Charcoal Producers Association, and staff from SEI Kenya and CEEEZ. The main aims were to share updates on activities that had taken place since the first visit in 2019 and discuss the impacts of COVID-19 on charcoal production.

A report titled "An assessment of the Charcoal Producers Groups in Choma District and overview of the forecasted demand for charcoal in Zambia" was completed by SEI Kenya in the summer of 2022.

Charcoal is critical for African countries; consequently, exploring and investing in effective ways to monitor, manage, and support sustainable production and trade in wood fuel is valuable. Charcoal producers in Sub-Saharan Africa can be broadly classified into three major groups: independent, seasonal, and employed producers. The role and influence of these producer categories continue to put pressure on the natural ecosystem of the resources in the region, while at the same time loosing revenue streams that could be diverted to other sectors. Hence, it is crucial to conduct research on formalization of these groups and their potential role in reducing the losses faced in financial streams and further pushing the region to face increased risks related to climate change. The report highlights challenges in the charcoal value chain, looks at supporting policy and legal frameworks, presents an assessment of the producer groups, and offers conclusions based on the findings.

Modelling work undertaken and presented in the report shows that charcoal use intensity will remain the same over the next decade under the business-as-usual (BAU) scenario, assuming minimum policy implications. Strict government policy actions are essential to shift cooking patterns, and this is discussed in the sustainable scenario, which has factored in current measures taken by the government in terms of policy giving direction in demand management and production efficiency. This is projected to reduce charcoal demand by 35% against the BAU scenario, from 1.9 million tons to 1.2 million tons of charcoal in 2030, and firewood requirements by 55% against BAU, from 19.5 million tons of wood to 9.7 million tons in 2030. The Choma Charcoal Producers Association is at the forefront of making these efforts a reality, despite the long journey ahead. The lessons learned from the association can be replicated in establishing other similar associations across Zambia to potentially decrease the current losses. Policy must go together with this practice, and this is important for complementing the efforts of the producers who join the producer groups and association overall.

The CEEEZ and SEI Kenya teams have established a good relationship with the Food and Agriculture Organization branch that works with charcoal producers in Zambia. This has also led to associations with the Charcoal Producers Association in Choma, the Zambia Forestry Department, and Cotton Association of Choma. The results and methodologies of the teams' initial studies on the project have been shared with these NGOs and relevant government institutions.

ASIA

AFGHANISTAN

Afghanistan – Project 9-012: Water harvesting at community level for enhanced access to ground water
PI: Fatema Samim, Herat University
U.S. Partner: Christine Lee, NASA Jet Propulsion Laboratory

Afghanistan - Project 5-183: Impact of climate change on runoff from glaciers, snow, and rainfall in the Pamir and Hindu Kush Mountains: a comparison of Amu Darya and Kabul River basins
PI: Fahimeh Salehi, Green Social Research Organization
U.S. Partner: Daniel Fagre, USGS

Afghanistan – Project 5-074: Regionalizationof the Global Integrated Drought Monitoring and Prediction System (GIDMaPS) for Afghanistan
PI: Khadija Jawadi, Environmental Conservation Specialist Organization of Afghanistan
U.S. Partner: Amir AghaKouchak, University of California, Irvine Regionalization of the Global Integrated Drought Monitoring and Prediction System (GIDMaPS) for Afghanistan

Afghanistan – Project 5-033: Determination of Floods magnitude projection, Causes, Vulnerable areas and its Solutions: A cause study of Kabul River basin
PI: Assem Mayar, Organization of Skill Development and Social Services
U.S. Partner: Jonathan Nelson, U.S. Geological Survey

Afghanistan - Project 4-257: Impacts of climate change on transboundary water treaties/sharing: a case study of Kabul River basin, Afghanistan
PI: Fahima Sadeqinezhad, AZMA the Technical Vocational Private Institute, Afghanistan
U.S. Partner: Devendra M. Amatya, USDA Forest Service Center for Forested Wetlands Research

Afghanistan – Project 4-47: Impact of climate change and variability and land use change on Afghanistan's water resources: a case study of Kabul River Basin and Amu Darya River Basins
PI: Sediqa Hassani, Ibn e Sina University
U.S. Partner: Jeff Dozier, University of California, Santa Barbara

BANGLADESH

Bangladesh - Project 9-441: Engaging the private sector in increasing voluntary use of long acting reversible contraceptives and permanent family planning methods in rural areas of Bangladesh
PI: Md. Jasim Uddin, International Centre for Diarrhoeal Disease Research, Bangladesh
U.S. Partner: Sian Curtis, University of North Carolina at Chapel Hill (funded by the United States Agency for International Development)

Bangladesh - Project 9-17: Renewable hydrogen generation with carbon recycling (ReHyCaRe) from biogenic residues of Bangladesh
PI: Kawnish Kirtania, Bangladesh University of Engineering and Technology
U.S. Partner: Mohammad Toufiq Reza, Florida Institute of Technology (funded by the National Science Foundation)

Bangladesh - Project 8-170: Integrated rice advisory system (IRAS) for sustainable productivity in Bangladesh
PI: Niaz Rahman, Bangladesh Rice Research Institute, in partnership with Bangladesh Agricultural University
U.S. Partner: Faisal Hossain, University of Washington (funded by the National Aeronautics and Space Administration)

Bangladesh - Project 6-10: Ecosystem Services in a changing climate; assessing critical services in Bangladesh rice production landscapes

PI: Md Panna Ali, Bangladesh Rice Research Institute (BRRI)
U.S. Partner: Douglas A Landis, Michigan State University (funded by the National Science Foundation)

Bangladesh - Project 6-9: Unmanned Aerial Systems-based Assessment of Tree Cover and Deforestation Dynamics in Bangladesh

PI: A.B.M, Kamal Pasha, Daffodil International University
U.S. Partner: Demetrios Gatziolis, The United States Forest Service

Bangladesh - Project 6-5: Climate change adaptation of rural households in charlands of Bangladesh

PI: Humnath Bhandari, International Rice Research Institute (IRRI)
U.S. Partner: Charles (Chuck) W. Rice, Kansas State University (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Bangladesh - Project 5-424: Community intervention to promote Chlorhexidine for reducing umbilical cord infections in Jamalpur district, Bangladesh

PI: Lutfe Ara, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)
U.S. Partner: Eben Kenah, University of Florida (funded by the National Institutes of Health)

Bangladesh - Project 4-85: Scaling up of satellite-assisted flood forecasting systems in South and Southeast Asian nations

PI: Md. Sohel Masud, Institute of Water Modeling, with co-PI Md. Sazzad Hossain, Flood Forecasting and Warning Center
U.S. Partner: Faisal Hossain, University of Washington (funded by the National Aeronautics and Space Agency)

Bangladesh - Project 3-1: Improving adaptation against coastal vulnerability and enhancing flood forecasting skill in Bangladesh through a satellite data integrative modeling framework in a changing climate

PI: Zahirul Khan, Institute of Water Modeling
U.S. Partner: Faisal Hossain, University of Washington (funded by the National Science Foundation)

Bangladesh - Project 2-524: Field assessment of arsenic-bearing waste treatment options

PI: Ahammadul Kabir, Asia Arsenic Network
U.S. Partner: Lutgarde Raskin, University of Michigan (funded by the National Science Foundation)

Bangladesh and the Philippines - Project 2-4: Validation of salt tolerance determinants in rice (*Oryza sativa L. indica*) landrace Horkuch and its segregating population by 2b-RAD sequencing and RNA-seq analysis under stress

PI: Zeba Seraj, University of Dhaka, with co-PI Abdelbagi Ismail, International Rice Research Institute
U.S. Partner: Thomas Juenger, University of Texas at Austin (funded by the National Science Foundation)

Bangladesh - Project 1-226: Defining the ecology of the Nipah virus outbreaks in Bangladesh: identifying additional potential foodborne and livestock transmission routes

PI: Muhammad Salah Uddin Khan, ICDDR
U.S. Partner: Peter Daszak, EcoHealth Alliance Inc (funded by the National Science Foundation)

Bangladesh - Project 1-97: Toward geohazard assessment in Bangladesh: academic infrastructure and knowledge transfer
PI: Syed Humayun Akhter, Dhaka University
U.S. Partner: Michael Steckler, Columbia University (funded by the National Science Foundation)

Bangladesh - Project H1-125: Evidence-based Knowledge into Practice: Extending a Successful Maternal, Neonatal, and Child Health Program in Matlab into the Government Health System in Bangladesh
PI: Anisur Rahman, International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b)
U.S. Partner: Randall Kuhn, University of Denver (funded by the National Institutes of Health)

BHUTAN

BH-006: Health-related quality of life and psychological well-being among people living with HIV in Bhutan
PI: Nidup Dorji, Faculty of Nursing and Public Health, Khesar Gyalpo Unviersity of Medical Sciences of Bhutan
U.S. Partner: Kaveh Khoshnood, Yale School of Public Health

BH-009: Building a Harmonious Human-Primate Society: A Citizen Science Based Primates Conservation Research in Bhutan.
PI: Kuenzang Dorji, Nature Study Center (Bhutan Primates Conservation Society)
U.S. Partner: Lori Kay Sheeran, Central Washington University

BH-012: Impact of climate change on alpine timberline and its socio-economic impact on highlander in Bhutan
PI: Changa Tshering, Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER)
U.S. Partner: Steven William Running, University of Montana

BH-022: Enhancing food security of smallholder farmers in Bhutan through building capacity in climate-smart agriculture
PI: Rekha Chhetri, College of Natural Resources, Royal University of Bhutan
U.S. Partner: Sarah Halvorson, W.A. Franke College of Forestry and Conservation, University of Montana

BH-025: Understanding of Source Waters and Recharge Mechanism of Mountain Springs and Streams in Radhi and Phongmey Gewogs in Trashigang, Bhutan Himalaya
PI: Tshewang Dendup, Centre for Science & Environmental Research, Sherubtse College, Royal University of Bhutan
U.S. Partner: Fengjing Liu, College of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI, USA

BH-035: Baseline data for freshwater biodiversity conservation in the face of climate change in Punatsangchhu basin in Bhutan
PI: Tshering Dorji, College of Natural Resources, Royal University of Bhutan
U.S. Partner: Paul Frandsen, Brigham Young University

Bhutan - Project 4-187: Monitoring forest cover changes in Bhutan using Landsat data in a cloud-computing environment
PI: Kinley Tshering, Ugyen Wangchuck Institute of Conservation and Environment
U.S. Partner: Kevin Megown, Remote Sensing Applications Center (funded by the United States Department of Agriculture/ Forest Service)

CAMBODIA

Cambodia - Project C-01: Using 4-s technique to analyze rural income in developing countries
PI: Sok Serey, Royal University of Phnom Penh

Cambodia - Project C-02: Irrigation and nutrient management for improving small-holder's Vegetable Production in Battambang
PI: Nareth Nut, Royal University of Agriculture

Cambodia - Project C-03: ICT Uses for Inclusive Cashew Value Chain and Agricultural Inputs in Cambodia
PI: Nget Raby, Royal University of Agriculture

Cambodia - Project C-05: Understand the management and support for the Anlong Svay Protected Area Community
PI: Samnang Nguon, Ecosystem Services and Land Use Research Center, Royal University of Agriculture

Cambodia - Projecy C-07: Diagnostic Investigation of Water Eutrophication in Stung Treng Ramsar Site, Cambodia
PI: Saret Bun, Institute of Technology of Cambodia

Cambodia - Project 7-88: Rapid assessment of the pesticide network and its influence on the use of pesticides in Cambodian agriculture
PI: Vichet Sorn, General Directorate of Agriculture
U.S. Partner: Buyung Hadi, International Rice Research Institute (funded by the United States Agency for International Development)

Cambodia - Project 7-86: Establishing cropland database in Cambodia from remote sensing satellite data
PI: Sanara Hor, Royal University of Agriculture
U.S. Partner: Robert Hijmans, University of California, Davis (funded by the United States Agency for International Development)

Cambodia - Project 7-85: Climate change impact on rice yield and food security in the riverine communities in Cambodia
PI: Serey Sok, Royal University of Phnom Penh
U.S. Partner: Aniruddha Ghosh, University of California, Davis (funded by the United States Agency for International Development)

Cambodia - Project 7-80: GIS based weather, soils, land use and agricultural management database in Cambodia
PI: Nareth Nut, Royal University of Agriculture
U.S. Partner: Gilbert Sigua, Agriculture Research Service Coastal Plains Soil, Water, Plant Research Center (funded by the United States Department of Agriculture/ Agricultural Research Service)

Cambodia - Project 7-79: Increasingthe adoption of nutrient management innovations by Cambodian vegetable farmers
PI: Leangsrun Chea, Royal University of Agriculture
U.S. Partner: Zachary Stewart, Kansas State University (funded by the United States Agency for International Development)

Cambodia - Project 2-395: Biodiversity of Cambodian leaf- and treehoppers: scientific training and education through development of bioindicators and agricultural pest control
PI: Phauk Sophany, Royal University of Phnom Penh
U.S. Partner: Kevin Johnson, Illinois Natural History Survey (funded by the National Science Foundation)

Cambodia - Project H1-15: Newborn Infection Control and Care Initiative for health facilities to accelerate reduction of neonatal mortality (NICCI)
PI: Chivorn Var, National Institute of Public Health (NIPH)
U.S. Partner: Richard Oberhelman, Tulane School of Public Health and Tropical Medicine (funded by the National Institutes of Health)

INDIA

India - Project 9-440: Young wives: An exploratory study of married women below twenty and the socio-cultural determinants of their contraceptive behavior in low resource settings in India
PI: Sudipta Mondal, Project Concern International
U.S. Partner: Cristine Legare, The University of Texas at Austin (funded by the National Science Foundation)

India - Project 8-141: Conversion from intermittent to continuous water supply (24 x 7) through public-private partnership (PPP): Investigating governance and sustenance issues in Karnataka, India
PI: Nayanatara Nayak, Centre for Multi-Disciplinary Development Research, in partnership with Karnatak University, Dharwad
U.S. Partner: Emily Kumpel, Universityof Massachusetts, Amherst (funded by the National Science Foundation)

India - Project 8-79: Collaborative adaptation pathways for agricultural water management in Bhavani basin, India (Co-Adapt)
PI: Geethalakshmi Vellingiri, Tamil Nadu Agricultural University
U.S. Partner: Sridhar Venkataramana, Virginia Polytechnic Institute and State University (funded by the National Aeronautics and Space Administration)

India - Project 8-25: Planning plantations: past learning, toward triple wins in carbon, biodiversity and livelihoods
PI: Rajesh Thadani, Centre for Ecology Development and Research, in partnership with Kumaun University
U.S. Partner: Forrest Fleischman, University of Minnesota (funded by the National Aeronautics and Space Administration)

India - Project 7-360: Off-grid, clean energy cooling for affordable storage of perishables for BOP farmers
PI: Sangeeta Chopra, Indian Council of Agricultural Research-Indian Agricultural Research Institute
U.S. Partner: Norbert Mueller, Michigan State University (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

India - Project 5-550: Development of comprehensive performance evaluation and O&M strategy for Indian solar sector
PI: Dibin Chandran, World Institute of Sustainable Energy
Partner: Deepak Sagi, GE India

India - Project 4-216: The Banni Grasslands in a time of change: ecological and socioeconomic resilience in a coupled human-natural system
PI: Ankila Hiremath, Ashoka Trust for Research in Ecology and the Environment (ATREE)
USDA Forest Service Collaborator: Susan Cordell, Institute of Pacific Islands Forestry

India - Project 3-207: Effects of climate change on cryosphere-river linkages: Insights from seasonal and inter-annual variation of glacial melt discharge in the headwaters of the Ganges River
PI: Indra Sen and co-PI Rajiv Sinha, Indian Institute of Technology--Kanpur
U.S. Partner: Bernhard Peucker-Ehrenbrink, Woods Hole Oceanographic Institution (funded by the National Science Foundation)

India - Project 2-171: Evolution, diversification and biogeography of cicadas (*Insecta: Hemiptera: Cicadidae*) on the Indian Subcontinent
PI: Krushnamegh Kunte, National Center for Biological Sciences
U.S. Partner: Chris Simon, University of Connecticut (funded by the National Science Foundation)

India - Project 2-61: Targeting low-arsenic and low-fluoride groundwater to reduce exposure in rural Punjab, India
PI: Chander Kumar Singh, TERI University; with co-PIs Saumitra Mukherjee, Jawaharlal Nehru University; Umesh Kumar Garg, Adesh Institute of Engineering and Technology; and Manpreet Singh Bhatti, Guru Nanak Dev University
U.S. Partner: Alexander Van Geen, Lamont-Doherty Earth Observatory of Columbia University (funded by the National Science Foundation)

India - Project 1-32: Institutional dynamics of adaptation to climate change and urbanization: analysis of rain-fed agricultural-urban lake systems in Bangalore, India
PI: Harini Nagendra, Ashoka Trust for Research in Ecology and the Environment
U.S. Partner: Tom Evans, Indiana University (funded by the National Science Foundation)

India - Project PP-27: NSF-PIRE collaboration: developing low-carbon cities in India: focus on urban infrastructures, climate risks, and vulnerability
PI: Sachchida Nand Tripathi, Indian Institute of Technology-Kanpur
U.S. Partner: Anu Ramaswami, University of Minnesota (funded by the National Science Foundation)

India - Project PP-26: NSF-PIRE collaboration: developing low-carbon cities in India: field research on water-energy-carbon baselines and low-carbon strategies in Indian cities
PIs: Emani Kumar, ICLEI – Local Governments for Sustainability, and Rakesh Yadav, Resource Optimization Initiative
U.S. Partner: Anu Ramaswami, University of Minnesota (funded by the National Science Foundation)

India - WMSG2-003: Understanding Mycobacterium Tuberculosis Mediated Host Metabolomics In Pulmonary Tuberculosis: Correlation With Disease Severity And Treatment Course
Pi: Senbagavalli Prakashbabu, Jawaharlal Institute Of Postgraduate Medical Education & Research

India – WMSG2-010: "Creating A Hope": A Mixed-Method Approach To Identify Most Acceptable Evidence-Based Psycho-Social Intervention To Improve The Retention In Care Among Indian Youth Diagnosed With Multi-Drug Resistant Tb (Mdr-Tb)
Pi: Gauri Dhumal, Johns Hopkins, Bj Government Medical College, Pune, India

India – WMSG2-001: Assessing Preparedness Of Urban Community Health Workers For Tuberculosis (Tb) Control- An Exploratory Study In Two Cities Of India

Pi: Dr. Shilpa Karvande, Foundation For Medical Research

India – WMSG2-011: "Bridging the Gaps": Understanding the Barriers and Facilitators in the Tuberculosis Prevention Care Cascade for Optimizing Isoniazid Preventive Therapy Uptake among Adults Living with HIV in India, a Mixed-Method Approach, Johns Hopkins, India

PI: Neetal Nevrekar, Byramjee Jeejeebhoy Government Medical College (BJGMC) - Johns Hopkins Clinical Research Site in Pune, India

India – WMSG2-005: Post Tb Sequelae –Metabolic Syndrome And The Utility Of Plasma Biomarkers In Pulmonary And Extrapulmonary Tuberculosis Patients From South India

Pi: Priyadarshini Padaki, St. John's Medical College And Hospital, India

India – WMSG2-004: Sampling with Mask and Reverse Transcriptase (SMaRT)-PCR for diagnosis of pediatric tuberculosis

PI: Ambreen Shaikh, Foundation for Medical Research, India

INDONESIA

Indonesia - COV-159: Improving public acceptance of COVID-19 vaccine in Yogyakarta, Indonesia: an application of community ethic gotong royong and the protector schema

PI: Retna Padmawati, Universitas Gadjah Mada

U.S. Partner: Abram Wagner, University of Michigan (funded by National Institutes of Health)

Indonesia - COV-128: Cost-effectiveness of SARS-CoV-2 Surveillance on Wastewater and Environmental Sampling (SWESP) as an early warning system for community COVID-19 transmission in Indonesia

PI: Indah Kartika Murni, Universitas Gadjah Mada

U.S. Partner: David Boyle, PATH (funded by National Institutes of Health)

Indonesia - Project 8-237: Development of woodidentification system and timber tracking database to support legal trade

PI: Ratih Damayanti, Forestry Research Development and Innovation Agency (FORDA) of the Ministry of Environment and Forestry, Indonesia, in partnership with Bogor Agricultural University

U.S. Partner: Michael Wiemann, U.S. Forest Service, Forest Products Laboratory

Indonesia - Project 8-124: Advancing shark conservation through innovative molecular and multi-stakeholder approaches

PI: Andrianus Sembiring, Yayasan Biodiversitas Indonesia, in partnership with Udayana, Diponegoro, and Nahdlatul Ulama Universities

U.S. Partner: Paul Barber, University of California, Los Angeles (funded by the National Science Foundation)

Indonesia - Project 7-304: Integrated geoscience studies for hazard mitigation at the Agung-Batur Volcanic System, Bali, Indonesia

PI: Sri Widiyantoro, Institut Teknologi Bandung

U.S. Partner: Jacob Lowenstern, USGS Cascades Volcano Observatory

Indonesia - Project 6-446: Delineating stock structure for tuna fish within Sulu Sulawesi Regions
PI: Ida Astarini, Udayana University and BIONESIA
U.S. Partner: Allen Collins, National Systematics Lab of NOAA's Fisheries Service and Smithsonian Institution

Indonesia - Project 6-52: Integrating ISLE in Integrated Science Instruction toImprove Science Teacher's Abilities on STEM Education
PI: Irwandi Irwandi, Syiah Kuala University
U.S. Partner: Eugenia Etkina, Graduate School of Education, Rutgers, The State University of New Jersey (funded by the National Science Foundation)

Indonesia - Project 6-42: Developing Biodiverse Agroforests on Rewetted Peatlands in Indonesia
PI: Sonya Dewi, International Centre for Research in Agroforestry (ICRAF) aka World Agroforestry Centre
U.S. Partner: Randall Kolka, USDA Forest Service Northern Research Station

Indonesia – Project 6-25: Converging climate change adaptation and disaster risk reduction strategies into agglomeration policy for coastal metropolitan planning
PI: Harkunti Pertiwi Rahayu, Institut Teknologi Bandung
U.S. Partner: Louise Comfort, University of Pittsburgh (funded by the National Science Foundation)

Indonesia - Project 5-497: Increasing TB Notification through one STop clinics and Engagement with Private health care providers in Bandung, Indonesia (INSTEP)
PI: Bachti Alisjahbana, TB-HIV Research Center, Universitas Padjadjaran
U.S. Partner: Megan Murray, Harvard Medical School (funded by the National Institutes of Health)

Indonesia - Project 5-429: Science teaching in Indonesian religious schools
PI: Askuri Ibn Chamim, Indonesian Consortium for Religious Studies (ICRS)
U.S. Partner: Joel Kuipers, George Washington University (funded by the National Science Foundation)

Indonesia - Project 5-408: Implementing a combination of rapid diagnostic tests, biomarkers and standard of care procedures for the diagnosis of pneumonia in pediatric patients to improve clinical management in Indonesia
PI: Herman Kosasih, INA RESPOND
U.S. Partner: Clifford Lane, US-NIAID (funded by the National Institutes of Health)

Indonesia - Project 5-395: Incorporating climate change induced sea level rise information into coastal cities' preparedness toward coastal hazards
PI: Syamsidik, Tsunami and Disaster Mitigation Research Center (TDMRC), Syiah Kuala University
U.S. Partner: Louise K. Comfort, University of Pittsburgh (funded by the National Science Foundation)

Indonesia - Project 5-215: Enhancing research capacity through a biotechnology-driven investigation of novel gram-negative bacteria from Indonesian sponges
PI: Ocky Radjasa, Diponegoro University
U.S. Partner: Phillip Crews, University of California Santa Cruz (funded by the National Institutes of Health)

Indonesia - Project 5-125: Strengthening resilience to extreme weather related events in Indonesia through improving the predictability of drought risk within Drought Cycle Management Model
PI: Heri Kuswanto, Institut Teknologi Sepuluh Nopember (ITS)
U.S. Partner: Justin Sheffield, Princeton University (funded by the National Science Foundation)

Indonesia - Project 4-393: Integrated watershed management for enhancing local livelihoods and biodiversity conservation in Indonesia

PI: Ani Adiwinata Nawir, CIFOR (Center for International Forestry Research) (formerly Terence Sunderland, through December 2017)

U.S. Partner: Jefferson Fox, East-West Center (funded by the National Aeronautics and Space Agency)

Indonesia - Project 4-309: A better understanding of future seismic and tsunami hazards due to the Mentawai Seismic Gap, West Sumatra, Indonesia through dense geodetic networks and capacity building efforts

PI: Ashar Muda Lubis, Bengkulu University

U.S. Partner: Louise Comfort, University of Pittsburgh (funded by the National Science Foundation)

Indonesia - Project 4-260: One fits all: developing decapods biodiversity research for education, conservation, and research benefits

PI: Ambariyanto, Indonesian Biodiversity Research and Diponegoro University

U.S. Partner: Christopher Meyer, Smithsonian National Museum of Natural History (funded by the National Science Foundation)

Indonesia - Project 4-146: Developing a bioeconomy in Indonesia: identification of novel microorganisms and microbial enzymes from Indonesian peatland and buffaloes to improve bioconversion of oil palm residues

PI: Amadeus Pribowo and co-PI Irnayuli Sitepu, Indonesia International Institute for Life Sciences

U.S. Partner: Kyria Boundy-Mills, University of California, Davis (funded by the National Science Foundation)

Indonesia - Project 4-125: Developing science and learning research capacity of Bengkulu University in ex situ conservation of Sumatran freshwater and terrestrial turtles

PI: Aceng Ruyani, Bengkulu University

U.S. Partner: Catherine Matthews, University of North Carolina, Greensboro (funded by the National Science Foundation)

Indonesia - Project 4-29: Implementation of a randomization-based curriculum for introductory statistics at UPH and across Indonesia

PI: Kie Van Ivanky Saputra, Universitas Pelita Harapan

U.S. Partner: Nathan Tintle, Dordt University (funded by the National Science Foundation)

Indonesia - Project 4-12: Coral vulnerability assessment to temperature stress (bleaching) and ocean acidification in the Spermonde Archipelago: conservation strategies for climate resilience

PI: Nita Rukminasari, Universitas Hasanuddin

U.S. Partner: Brian Hopkinson, University of Georgia (funded by the National Science Foundation)

Indonesia - Project 3-212: Study of climate change and air quality impact from short-lived climate forcers (SLCFs) reduction in Indonesia

PI: Asep Sofyan with co-PI Ayu Purwarianti, Institut Teknologi Bandung

U.S. Partner: Gregory R. Carmichael, University of Iowa (funded by the National Science Foundation)

Indonesia - Project 3-195: Sustainable conversion of oil palm lignocellulosic waste into pentanol using metabolically engineered microbes

PI: Fransiskus X. Ivan, Surya University, with co-PI Yalun Arifin (former PI, now at Curtin University, Malaysia)

U.S. Partner: Brian Pfleger, University of Wisconsin, Madison (funded by the National Science Foundation)

Indonesia - Project 3-148: Strengthening research and teaching capacity of Brawijaya University in monitoring and exploring of volcanoes (pilot study: Ijen volcano complex, East Java)
PI: Sukir Maryanto, Brawijaya University
U.S. Partner: James Foster, University of Hawaii (funded by the National Science Foundation)

Indonesia - Project 3-147: Tsunami waves impacts on coastal morphological changes based on sediment transport numerical simulations
PI: Syamsidik, Tsunami and Disaster Mitigation Research Center, Syiah Kuala University
U.S. Partner: Philip L-F. Liu, Cornell University (funded by the National Science Foundation)

Indonesia - Project 3-103: Integrated local emergency response policy improvement and capacity building for advance-early warning system in the face of near-field tsunami risk
PI: Harkunti Pertiwi Rahayu, Institut Teknologi Bandung
U.S. Partner: Louise K. Comfort, University of Pittsburgh (funded by the National Science Foundation)

Indonesia - Project 3-82: Sediment transport evaluation on the Bengawan Solo River (downstream and estuary) to minimize sedimentation and flood combining effect on nearby infrastructure
PI: Ria Asih Aryani Soemitro, Institut Teknologi Sepuluh Nopember
U.S. Partner: Gangfeng Ma, Old Dominion University (funded by the National Science Foundation)

Indonesia - Project 3-40: Diversification and inventory of the threatened lowland herpetofauna of Java and Sumatra
PI: Nia Kurniawan, Brawijaya University
U.S. Partner: Eric Nelson Smith, University of Texas at Arlington (funded by the National Science Foundation)

Indonesia - Project 3-21: CLEAN project: converting municipal solid waste leachate into energy
PI: Wiratni Budhijanto, Universitas Gadjah Mada
U.S. Partner: Largus T. Angenent, Cornell University (funded by the National Science Foundation)

Indonesia - Project 2-457: Citizen science solutions for national biodiversity data needs: developing a plant checklist for West Kalimantan, Indonesia
PI: I Made Wiryana, Universitas Gunadarma
U.S. Partner: Campbell Webb, Arnold Arboretum of Harvard University (funded by the National Science Foundation)

Indonesia - Project 2-409: Tree isotope records of past rainfall variability in the Indonesian maritime region
PI: Sri Yudawati Cahyarini with co-PI Intan Suci Nurhati, Indonesian Institute of Science (Lembaga Ilmu Pengetahuan Indonesia)
U.S. Partner: Mike Evans, University of Maryland (funded by the National Science Foundation)

Indonesia - Project 2-324: Connecting science and management through biodiversity research and collaboration
PI: Made Pharmawati, Universitas Udayana
U.S. Partners: Forest Rohwer, San Diego State University, and Paul H. Barber, University of California, Los Angeles (funded by the National Science Foundation)

Indonesia - Project 2-319: Combating seagrass decline: developing a restoration manual for Indonesia and the Coral Triangle

PI: Rohani Ambo-Rappe, Universitas Hasanuddin

U.S. Partners: John J. Stachowicz and Susan L. Williams, University of California, Davis (funded by the National Science Foundation)

Indonesia - Project 2-232: Exploring the dynamic of extreme weather events in Indonesia using large scale meteorological pattern as the forecast guidance (pilot study: Indramayu, West Java)

PI: Heri Kuswanto, Institut Teknologi Sepuluh Nopember

U.S. Partner: Richard Grotjahn, University of California, Davis (funded by the National Science Foundation)

Indonesia - Project 2-42: Improving process-skills of STEM undergraduate students in Indonesia through Problem-Based Learning(PBL): faculty member development, student assessment, and curriculum adjustment

PI: Kamarza Mulia, Universitas Indonesia

U.S. Partner: Lisa Hunter, University of California, Santa Cruz (funded by the National Science Foundation)

Indonesia - Project 1-235: Coral healthsurveys in COREMAP: building resilience in climate-impacted coral reefs of Indonesia

PI: Jamaluddin Jompa, Universitas Hasanuddin

U.S. Partner: C. Drew Harvell, Cornell University (funded by the National Science Foundation)

Indonesia - Project 1-208: Assessing degradation of tropical peat domes and dissolved organic carbon (DOC) export from the Belait, Mempawah, and Lower Kapuas rivers in Borneo

PI: Gusti Z. Anshari, Universitas Tanjungpura

U.S. Partner: Charles F. Harvey, Massachusetts Institute of Technology (funded by the National Science Foundation)

Indonesia - Project 1-205: Marine biodiversity of Raja Ampat Islands: the ARMS, morphology, and genetic approaches for inventorying and monitoring patterns of marine biodiversity

PI: Abdul-Hamid Toha, State University of Papua

U.S. Partner: Kent Carpenter, Old Dominion University (funded by the National Science Foundation)

Indonesia - Project 1-152: Enhancements of research for adaptation of wetlands in Indonesia to projected impacts of sea level rise

PI: Frida Sidik, Institute for Marine Research and Observation, Ministry of Marine Affairs and Fisheries

U.S. Partner: Ilka Feller, Smithsonian Institution

Indonesia - Project 1-102: Building Indonesian research capacity throughgenetic assessment of commercial fish species

PI: I Gusti Ngurah Kade Mahardika, Universitas Udayana

U.S. Partner: Kent Carpenter, Old Dominion University (funded by the National Science Foundation)

Indonesia - Project 1-90: Strengthening research and teaching capacity of the Andalas University in climate change and natural resources management

PI: Rudi Febriamansyah, Andalas University

U.S. Partner: Brendan Buckley, Lamont-Doherty Earth Observatory, Columbia University (funded by the National Science Foundation)

Indonesia - Project 1-21: IncorporatingBali's subak heritage into primary and secondary education: curriculum development, teacher training, and action research

PI: Sang Putu Kaler Surata, Mahasaraswati University
U.S. Partner: John Stephen Lansing, University of Arizona Tucson (funded by the National Science Foundation)

Indonesia – Project H2-3: Effects of air pollution in early life on infant and maternal health

PI: Nikmah Salamia Idris, University of Indonesia - Cipto Mangunkusumo National General Hospital
U.S. Partner: Kerstin Klipstein-Grobusch, University Medical Center Utrecht (funded by the National Institutes of Health)

Indonesia – Project H2-4:Development of a referral system using kangaroo mother care for low birth weight babies

PI: Hadi Pratomo, Faculty of Public Health, Universitas Indonesia
U.S. Partner: Abdullah Baqui, Johns Hopkins University Bloomberg School of Public Health (funded by the National Institutes of Health)

Indonesia – Project H2-2: Improving hospital care for breastfeeding support in Indonesia

PI: Francisca Handy Agung, Center for Health Research, Universitas Indonesia
U.S. Partner: Valerie Flaherman, University of California, San Francisco School of Medicine(fundedby the National Institutes of Health)

Indonesia – Project H2-1: Impact of reduced in-home secondhand smoke exposure on low birthweight prevalence and neonate health

PI: Yayi Suryo Prabandari, Center for Health Policyand Management, Faculty of Medicine, Gadjah Mada University
U.S. Partner: Donald Bailey, Research Triangle Institute (RTI) International (funded by the National Institutes of Health)

Indonesia Project H1-163: Epidemiologic and genotypic analysis of active M. tuberculosis cases in Indonesia: Understanding the acquisition and transmission of drug-resistant tuberculosis

PI: Andani Eka Putra, Andalas University
U.S. Partner: Megan Murray, Harvard Medical School (funded by the National Institutes of Health)

Indonesia Project H1-158: Intensified antibiotic treatment plus low dose aspirin for tuberculous meningitis: a randomized clinical trial

PI: Rovina Ruslami, Universitas Padjadjaran
U.S. Partner: H. Clifford Lane, National Institute of Allergyand Infectious Diseases (NIAID) (funded by the National Institutes of Health)

Indonesia Project H1-115: Development of an antigen-capture immunoassay for the rapid diagnosis of acute leptospirosis

PI: Farida Handayani, Ministry of Health, Republic of Indonesia
U.S. Partner: David AuCoin, University of Nevada, Reno (funded by the National Institutes of Health)

Indonesia Project H1-89: Implementation of PharmaCheck to assure the quality of IMCI drugs in Indonesia

PI: Iwan Ariawan, Universitas Indonesia
U.S. Partner: Muhammad Zaman, Boston University (funded by the National Institutes of Health)

Indonesia Project H1-16: Mosquito-borne arboviral surveys in Indonesia with a focus on Dengue vectors
PI: Isra Wahid, Universitas Hasanuddin
U.S. Partner: David Severson, University of Notre Dame (funded by the National Institutes of Health)

Indonesia – Project WMSG2-008: Association Between Burden of Medicine and Therapy Adherence Among Multi-Drug Resistant Tuberculosis Patients in West Java, Indonesia
PI: Melisa Barliana, Universitas Padjadjaran

Indonesia – Project WMSG2-009: Spinal Tuberculosis In Indonesia: Five-Year Epidemiology, Risk Factors And Quality Of Life Outcomes
Pi: Astri Ferdiana, Department Of Public Health Faculty Of Medicine, University of Mataram and Gadjah Mada University, Indonesia

Indonesia – Project WMSG2-006: The effectiveness of The Mobile Nursing Centre and determinants for TB care and prevention using telehealth and telenursing approach to reduce stigma of TB and COVID-19 in West Java Indonesia
Dr. Neti Juniarti, Universitas Padjadjaran, Indonesia

Indonesia – Project WMSG2-007: Parents' knowledge, attitude, and health seeking behavior towards childhood TB during the COVID-19 pandemic
PI: Dr. Windy Rakhmawati, Universitas Padjadjaran, Indonesia

Indonesia - Project WMSG2-002: Strengthening community to recognize and prevent tuberculosis and diabetes mellitus (SCREEN TB-DM) among informal workers
PI: Dr. Vitri Widyaningsih**,** Universitas Sebelas Maret, Indonesia

KAZAKHSTAN

Kazakhstan - Project 9-472: The evaluation of challenges of youth in Kazakhstan and piloting innovative solutions
PI: Alima Ibrasheva, Nazarbayev University Graduate School of Education
U.S. Partner: James Cox, Georgia State University (funded by the National Science Foundation)

Kazakhstan - Project 9-38: The effects of excessive water use and agricultural intensification on aral sea shrinkage: SES dynamics within the Syr Darya River Basin
PI: Maira Kussainova, Kazakh National Agrarian University
U.S. Partners: Ranjeet John, University of South Dakota, and Jiquan Chen, Michigan State University (funded by the National Aeronautics and Space Administration)

Kazakhstan – Project 5-236: Satellite enhanced snowmelt flood and drought predictions for the Kabul River basin with surface and groundwater modeling
PI: Mohammad Najaf (deceased), Kabul Polytechnic University, with co-PIs Jay Sagin, Nazarbayev University (Kazakhstan), and Muhammad Abid, COMSATS, (Pakistan)
U.S. Partner: Jennifer Jacobs, University of New Hampshire

KYRGYZSTAN

Kyrgyzstan - Project 5-519: Integratedwater resources management and strategic environmental assessment of Kabul and Amudarya Rivers
PI: Zheenbek Kulenbekov, American University of Central Asia
U.S. Partner: Forrest Melton, California State University Monterey Bay, and the NASA Ames Research Center Cooperative for Research in Earth Science and Technology (NASA ARC-CREST)

Kyrgyzstan - Project 4-454: Water resources response on glacier dynamics in Central Asia transboundary river basins
PI: Tamara Tuzova, Institute of Water Problems and Hydro Power of the National Academy of Sciences of Kyrgyzstan (funded by the National Science Foundation)
U.S. Partner: David Watkins, Michigan Technological University (funded by the National Science Foundation)

MALDIVES

Maldives - Project 4-463: Can drought and flood hazard be skillfully assessed at fine spatial resolutions from combining constrained streams of observed, remotely sensed, and model predicted data in Sri Lanka and the Maldives?
PI: Piyasena Wickramagamage, Foundation for Environment, Climate, and Technology
U.S. Partner: Randall Koster, NASA Goddard Space Flight Center

MONGOLIA

Mongolia - Project 2-296: Building research and teaching capacity to aid climate change and natural resources management at the National University of Mongolia
PI: Baatarbileg Nachin, National University of Mongolia
U.S. Partner: Amy Hessl, West Virginia University (funded by the National Science Foundation)

Mongolia - Project 1-98: Impacts of climate change on freshwater and fisheries resources of the Lake Hovsgol watershed
PI: Bud Mendsaikhan, Mongol Ecology Center
U.S. Partner: Olaf Jensen, Rutgers University (funded by the National Science Foundation)

Mongolia - Project 1-16: Determining sources of health impacts of particulate matter in Ulaanbaatar City to aid and assess current air pollution mitigation efforts
PI: Sereeter Lodoysamba, National University of Mongolia
U.S. Partner: Christa Hasenkopf, University of Colorado (funded by the National Science Foundation)

NEPAL

Nepal - Project 6-182: Mapping of pesticide residue and (oo)cysts on vegetable and fruits using low-cost field based assays
PI: Basant Giri, Kathmandu Institute of Applied Sciences
U.S. Partner: Toni Barstis, Saint Mary's College (funded by the National Science Foundation)

Nepal - Project 5-576: Understanding the phenomenon of open mapping: creating open-source map data as a critical information infrastructure for disaster preparedness and development
PI: Nama Budhathoki, Kathmandu Living Labs
U.S. Partner: Kenneth Anderson, University of Colorado Boulder (funded by the National Science Foundation)

Nepal - Project 5-185: JaibikMap: Nepal's biodiversity and climate change tool for the future
PI: Menaka Panta, International Union for Conservation of Nature - Nepal
U.S. Partner: Walter Jetz, Yale University (funded by the National Science Foundation)

Nepal - Project 5-17: Cluster-controlled implementation science trial of integrated maternal newborn child healthcare delivery in group settings
PI: Pushpa Chaudhari, Nepal Ministry of Health and Possible (formerly known as Nyaya Health)
U.S. Partner: Duncan Maru, Brigham and Women's Hospital (funded by the National Institutes of Health)

Nepal - Project 1-183: Establishing a collaborative assessment of the impacts of climate change on the hydrological regime of the Langtang River Basin, central Nepal
PI: Rijan Bhakta Kayastha, Kathmandu University
U.S. Partner: Mark W. Williams, University of Colorado (funded by the National Science Foundation)

Nepal - Project H1-32: Investigation of the effectiveness of national clean cookstoves program in Nepal in reducing Acute Respiratory Tract Infection in ≤ 5 children
PI: Sharat Verma, National Tuberculosis Center
U.S. Partner: Kirk Smith, University of California, Berkeley (funded by the National Institutes of Health)

PAKISTAN

Pakistan - Project 7-226: Enhancing reproductive health services use by married adolescent girls - role of women volunteers
PI: Tasleem Akhtar, NUR Center for Research and Policy
U.S. Partner: Adnan A. Hyder, Milken Institute School of Public Health, George Washington University (funded by the National Institutes of Health)

Pakistan – Project 5-85: Using water resources systems analysis to guide transboundary Kabul River water partnership
PI: Hina Lotia, Leadership for Environment and Development Pakistan
U.S. Partner: Julie Kiang, and Jerad Bales, United States Geological Survey

Pakistan - Project 4-323: Understanding our joint water-climate change challenge and exploring policy options for cooperation on the Afghan-Pak transboundary Kabul River Basin
PI: Hina Lotia, Leadership for Environment and Development Pakistan
U.S. Partners: Amir AghaKouchak, University of California, Irvine, and Konstantinos M. Andreadis, Jet Propulsion Laboratory (funded by the National Aeronautics and Space Agency)

Pakistan - Project 4-255: Enhanced Engagement in Research on the Kabul River Basin (EKaRB)
PI: Muhammad Azeem Ali Shah, International Water Management Institute
U.S. Partner: Lauren Hay, United States Geological Survey

PHILIPPINES

Philippines - Project 9-379: Assessment and comparison of recovery of biodiversity and carbon sequestration in Philippine mangroves among natural, replanted and naturally-recolonized mangrove stands
PI: Severino Salmo III, University of the Philippines Diliman - Institute of Biology
U.S. Partner: Richard MacKenzie, United States Department of Agriculture/Forest Service

Philippines - Project 7-128: Baselining persistent and emerging organic pollutant levels in environmental and engineered systems (PEOPLES) for healthy Philippines

PI: Caroline Jaraula, Marine Science Institute, University of the Philippines
U.S. Partner: Diana Aga, University at Buffalo (funded by the National Science Foundation)

Philippines - Project 5-173: Using contact tracing to assess barriers to diagnosis and treatment and develop an educational campaign surrounding childhood tuberculosis in the Northern Philippines

PI: Flordeliza Bassiag, Isabela State University
U.S. Partner: Tania Thomas, University of Virginia (funded by the National Institutes of Health)

Philippines - Project 3-236: Early detection of volcano flank failure using InSAR

PI: Alfredo Mahar Francisco Lagmay, University of the Philippines, National Institute of Geological Sciences
U.S. Partner: Falk Amelung, University of Miami (funded by the National Science Foundation)

Philippines - Project 3-226: "A Glass of the Sea:" an immersive, interactive, visual exhibition on the apex of the Earth's marine life

PI: Maria Isabel Garcia, The Mind Museum (of the Bonifacio Art Foundation, Inc.)
U.S. Partner: Terrence Gosliner, California Academy of Sciences (funded by the National Science Foundation)

Philippines - Project 3-191: Enhancement of Philippines' research capability in understanding the role of mangrove ecosystem health in the adaptation and mitigation against natural disasters

PI: Severino Salmo III, Ateneo de Manila University
U.S. Partner: Ilka Feller, Smithsonian Environmental Research Center, Smithsonian Institution

Philippines - Project 3-163: Lake Taal: Sustaining native biodiversity in the face of aquaculture, climate change, and non-native species

PI: Rey Donne Papa, University of Santo Tomas
U.S. Partner: Terrence Gosliner, California Academy of Sciences (funded by the National Science Foundation)

Philippines - Project 1-177: Enhancing marine natural resource and biodiversity management in the Philippines by extending population connectivity research

PI: Maria Carmen Ablan Lagman, De La Salle University
U.S. Partner: Kent Carpenter, Old Dominion University (funded by the National Science Foundation)

Philippines - Project 1-34: Pathways for indigenous knowledge engagement on marine biodiversity conservation

PI: Marivic G. Pajaro, Haribon Foundation for the Conservation of Natural Resources
U.S. Partner: Douglas Medin, Northwestern University (funded by the National Science Foundation)

Philippines – Project H2-7: Effect of a smoking cessation intervention program for families of children diagnosed with TB

PI: Benjamin Sablan, Philippine Ambulatory Pediatric Association
U.S. Partner: Jonathon Winickoff, Massachusetts General Hospital and Harvard Medical School (funded by the National Institutes of Health)

Philippines – Project H2-6: Diagnosis, treatment and management of pediatric tuberculosis in health emergencies and disasters

PI: Salvacion Gatchalian, University of Philippines, College of Medicine, Philippine General Hospital
U.S. Partner: Kristy Murray, Baylor College of Medicine (funded by the National Institutes of Health)

Philippines – Project H2-5: Enhancing childhood tuberculosis identification and treatment in the Philippines
PI: Anna Ma. Lena Lopez, Institute of Child Health and Human Development, University of the Philippines Manila--National Institutes of Health
U.S. Partner: Karin Nielsen, David Geffen UCLA School of Medicine (funded by the National Institutes of Health)

SRI LANKA

Sri Lanka - Project 7-201: Developing dengue risk predictions from environmental, entomological, and societal information to aid public health management in Sri Lanka
PI: Pahalagedera Hewayalage Dona Kusumawathie, Tropical Climate Guarantee
U.S. Partner: Aravinda de Silva, University of North Carolina Chapel Hill (funded by the National Institutes of Health)

Sri Lanka and the Maldives - Project 3-152: Developing monitoring tools for managing drought risk and addressing the riddle of increased drought tendency amidst the wetter climate change projections for Sri Lanka and the Maldives
PI: Lareef Zubair, Foundation for Environment, Climate and Technology, with Co-PI Mizna Mohamed, Maldives National University
U.S. Partner: Bradfield Lyon, International Research Institute for Climate and Society, Lamont-Doherty Earth Institute at Columbia University (funded by the National Science Foundation)

Sri Lanka and India - Project 2-475: Fecal sludge and urine reuse in agriculture – opportunities for addressing phosphorus needs in India
PI: Pay Drechsel, International Water Management Institute, with co-PI Vijayaraghavan M. Chariar, Indian Institute of Technology Delhi
U.S. Partner: James Elser, Arizona State University (funded by the National Science Foundation)

Sri Lanka - Project 1-194: Intra-seasonal climate predictions for Sri Lanka and Maldives for water resources management
PI: Lareef Zubair, Foundation for Environment, Climate and Technology, Mahaweli Authority of Sri Lanka
Co-PI: Piyasena Wickramagamage, University of Peradeniya
U.S. Partner: Adam H. Sobel, Columbia University (funded by the National Science Foundation)

TAJIKISTAN

Tajikistan - Project 5-140: Interstate water resource risk management: towards a sustainable future for the Pyanj River basin
PI: Rano Eshankulova, Institute of Water Problems, Hydropower, and Ecology, Academy of Sciences of the Republic of Tajikistan
U.S. Partner: Mark Williams, University of Colorado Boulder (funded by the National Science Foundation)

Tajikistan - Project 4-356: Risk management and assessment of water resources of the Amu Darya River Basin under conditions of climate change and construction of large reservoirs
PI: Inom Normatov, Institute of Water Problems, Hydropower, and Ecology, Academy of Sciences of the Republic of Tajikistan
U.S. Partner: Mary Brodzik, University of Colorado Boulder (funded by the National Aeronautics and Space Agency)

THAILAND

Thailand and Cambodia - Project 6-436: Connecting climate change, hydrology & fisheries for energy and food security in Lower Mekong Basin
PI: Vilas Nitivattananon, Asian Institute of Technology; with co-PIs Sangam Shrestha, AIT; Thanapon Piman, Stockholm Environmental Institute; and Chheng Phen, Inland Fisheries Research and Development Institute
U.S. Partner: John Sabo, Arizona State University (funded by the National Science Foundation)

Thailand and Burma - Project 2-473: Analysis of historical forest carbon changes in Burma and Thailand and the contribution of climate variability and extreme weather events
PI: Amnat Chidthaisong, The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, with co-PI Khin Lay Swe, Yezin Agriculture University
U.S. Partners: Merryl Alber and Monique Y. LeClerc, University of Georgia (funded by the National Science Foundation)

Thailand, Laos, and Vietnam - Project 2-93: Biodiversity and conservation in the Lower Mekong: empowering female herpetologists through capacity building and regional networking
PI: Anchalee Aowphol, Kasetsart University, with co-PIs Niane Sivongxay, Wildlife Conservation Society and National University of Laos; and Huy Duc Hoang, University of Science, Ho Chi Minh City
U.S. Partner: Bryan L. Stuart, North Carolina Museum of Natural Sciences (funded by the National Science Foundation)

Thailand, Indonesia, and Vietnam - Project 1-243: Assessment of impacts of the emission reduction measures of short-lived climate forcers on air quality and climate in Southeast Asia
PI: Nguyen Thi Kim Oanh, Asian Institute of Technology
Co-PIs: Hoang Xuan Co, Hanoi University of Sciences Vietnam National University; Asep Sofyan, Institute of Technology Bandung; and Nguyen Tri Quang Hung, Nong Lam University
U.S. Partner: Philip Hopke, Clarkson University (funded by the National Science Foundation)

UZBEKISTAN

Uzbekistan - Project 6-310: Reducing water pollution and carbon emissions from irrigated areas by improving irrigation management and rural livelihoods: case studies from energy intensive pump irrigated areas of Sogd Province, Tajikistan and Kashkadarya Province, Uzbekistan
PI: Oyture Anarbekov, International Water Management Institute - Central Asia Office
U.S. Partner: James Ayars, United States Department of Agriculture Agricultural Research Service

Uzbekistan - Project 5-523: Implications of climate change, land use and adaptation interventions on water resources and agricultural production in Transboundary Amu Darya river basin
PI: Zafar Gafurov, International Water Management Institute (IWMI)
U.S. Partner: John Bolten, NASA Goddard Space Flight Center

Uzbekistan - Project 5-323: Provision of science based evidence on climate induced water quality challenges in Amu Darya basin
PI: Iskandar Abdullaev, Regional Environmental Center for Central Asia (CAREC)
U.S. Partner: Antarpreet Jutla, West Virginia University (funded by the National Aeronautics and Space Agency)

Uzbekistan - Project 4-407: Use of non-conventional agricultural water resources to strengthen water and food security in the transboundary watersheds of the Amu Darya River Basin (UNCAWR)
PI: Kristina Toderich, International Center for Biosaline Agriculture
U.S. Partner: Robert Nowak, University of Nevada, Reno (funded by the United States Department of Agriculture/ Agricultural Research Service)

Uzbekistan - Project 4-112: Transboundary water management adaptation in the Amu Darya Basin to climate change uncertainties
PI: Viktor Dukhovniy, Scientific-Information Center of Interstate Commission for Water Coordinationof Central Asia
U.S. Partner: Benjamin F. Zaitchik, Johns Hopkins University (funded by the National Science Foundation)

Uzbekistan - Project 4-97: Mitigating the competition for water in the Amu Darya River Basin, Central Asia, by improving water use efficiency
PI: Kakhramon Djumaboev, International Water Management Institute
U.S. Partner: James Ayars, USDA-ARS Water Management Unit

Uzbekistan - Project 1-41: Utilizationof low quality water for halophytic forage and renewable energy production
PI: Kristina Toderich, International Center for Biosaline Agriculture
U.S. Partner: Laurel Saito, University of Nevada (funded by the National Science Foundation)

VIETNAM

Vietnam - COV-139: Understanding the importance of ecosystem services and medicinal plants during and after the COVID-19 crisis in Vietnam
PI: Tuyen Nghiem, Vietnam National University—Central Institute for Natural Resources and Environmental Studies
U.S. Partner: Pamela McElwee, Rutgers, The State University of New Jersey (funded by National Science Foundation)

Vietnam - Project 9-554: Developing a framework for the identificationof soil limiting factors for bioremediation of dioxin compounds in contaminated soils of Vietnam
PI: Nguyen Khoi Nghia, Can Tho University
U.S. Partner: M. Scott Demyan, The Ohio State University (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Vietnam - Project 9-553: Biochar facilitated bioremediation: A green solution for dioxin/furan pollution
PI: Dang Thuong Huyen, University of Technology, Vietnam National University-Ho Chi Minh City
U.S. Partner: Karl Rockne, University of Illinois at Chicago (funded by the National Institutes of Health)

Vietnam - Project 9-551: Nanoassisted bioremediation of diffused dioxins in soil and sediment
PI: Nguyen Thi Kim Oanh, Asian Institute of Technology (AIT) Center in Vietnam and AIT Thailand
U.S. Partner: Dana Barr, Emory University (funded by the National Institutes of Health)

Vietnam - Project 8-14: Improved management of water and sediment yield in 3S basin – upper part of Mekong River Basin
PI: Duong Bui, National Center for Water Resources Planning and Investigation, in partnership with the National University of Civil Engineering
U.S. Partner: Venkataraman Lakshmi, University of Virginia (funded by the National Aeronautics and Space Administration)

Vietnam - Project 8-6: Sustainable groundwater management under socioeconomic and climate change in Mekong Delta, Vietnam

PI: Chau Nguyen Xuan Quang, Vietnam National University - Ho Chi Minh City, with co-PI Sangam Shrestha, Asian Institute of Technology

U.S. Partner: John Sabo, Arizona State University (funded by the National Science Foundation)

Vietnam - Project 8-3: Identifying conditions for successful landscape-scale conservation policy implementation in Vietnam

PI: Pham Thu Thuy, Center for International Forestry Research, in partnership with the Vietnam National University of Forestry

U.S. Partner: Darla Munroe, The Ohio State University (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Vietnam, Cambodia, Laos, Thailand, and Myanmar - Project 6-435: Riverscape genetics to inform natural history of exploited fishes in the Lower Mekong River Basin

PI: Dang Thuy Binh, Institute for Biotechnology and Environment, Nha Trang University; with co-PIs Chheng Phen, Inland Fisheries Research and Development Institute; Latsamy Phounvisouk, Living Aquatic Resources Research Center; Chaiwut Grudpan, Ubon Ratchathani University; and Mie Mie Kyaw, University of Mandalay

U.S. Partner: Jeffrey Williams, Smithsonian Institution

Vietnam - Project 6-220: Field-scale applicationof vetiver grass to mitigate dioxin contaminated soil at Bien Hoa Airbase

PI: Ngo Thi Thuy Huong, Vietnam Research Centre on Karst and Geoheritage of the Vietnam Institute of Geosciences and Mineral Resources

U.S. Partner: James Landmeyer, United States Geological Survey

Vietnam - Project 5-666: An assessment of smoking and access to care as risk factors for gender-differences in TB rates: a substudy of the Vietnam NTP TB prevalence survey 2016-2018

PI: Nguyen Van Hung, Vietnam National Tuberculosis Program

U.S. Partner: Payam Nahid, University of California, San Francisco (funded by the National Institutes of Health)

Vietnam - Project 5-618: Study on coral reef resilience in comparative areas in South Vietnam for marine biodiversity conservation in a changing world

PI: Tuan Si Vo, Institute of Oceanography

U.S. Partner: Mark Eakin, NOAA Coral Reef Watch

Vietnam - Project 5-257: GIS and remote sensing application for assessment of land degradation in the Lower Mekong River Basin

PI: Quyet Vu, Soils and Fertilizers Research Institute

U.S. Partners: John Bolten, NASA Goddard Space Flight Center, and Venkat Lakshmi, University of Virginia

Vietnam - Project 5-253: Using mult i data for biodiversity conservation at Dak Nong Province in the Central Highlands of Vietnam

PI: Nguyen Thi Thanh Huong, Tay Nguyen University

U.S. Partner: Volker Radeloff, University of Wisconsin–Madison (funded by the National Aeronautics and Space Agency)

Vietnam - Project 4-189: Application of geodetic, satellite remote sensing, and physical modeling tools for the management of operational groundwater resources in the Red River Delta, Vietnam

PI: Nguyen Duc Luong, Institute of Environmental Science and Engineering, National University of Civil Engineering
U.S. Partner: Faisal Hossain, University of Washington (funded by the National Aeronautics and Space Agency)

Vietnam - Project 3-190: Water governance of minority communities in the Mekong Delta

PI: Nguyen Van Kien, Research Centre for Rural Development, An Giang University
U.S. Partners: Carol Xiaohui Song and Venkatesh Merwade, Purdue University (funded by the National Science Foundation)

Vietnam, Cambodia, and Laos - Project 3-149: Biodiversity conservation in Indochina: Integrating research and training to enhance wildlife trade management

PI: Minh Le, Central Institute for Natural Resources and Environmental Studies of Vietnam National University (VNU-CRES), with co-PIs Seak Sophat, Royal University of Phnom Penh, and Sengdeuane Wayakone, National University of Laos
U.S. Partner: Mary Blair, The American Museum of Natural History (funded by the National Science Foundation)

Vietnam, Cambodia, and Laos - Project 3-100: Building a Mekong River genetic biodiversity research network

PI: Vu Ngoc Ut, Can Tho University, with co-PIs Dang Thuy Binh, Nha Trang University; Chheng Phen, Inland Fisheries Research and Development Institute; So Nam, Mekong River Commission; Latsamy Phounvisouk, Living Aquatic Resources Research Centre
U.S. Partner: Kent Carpenter, Old Dominion University (funded by the National Science Foundation)

Vietnam - Project 2-544: Evaluating the sustainability of ground water resources: academic and scientific gaps

PI: Pham T.K. Trang, Hanoi University of Science
U.S. Partner: Benjamin Carlos Bostick and Alexander Van Geen, Columbia University (funded by the National Science Foundation)

Vietnam - Project 2-496: Technical development and field-testing of a self-contained, inexpensive wave energy converter device

PI: Tho H. Nguyen, Tan Tao University
U.S. Partner: Brian Bingham, University of Hawaii (funded by the National Science Foundation)

Vietnam - Project 2-7: Conservationgenetics for improved biodiversity and resource management in a changing Mekong Delta

PI: Dang Thuy Binh, Nha Trang University
U.S. Partner: Kent E. Carpenter, Old Dominion University (funded by the National Science Foundation)

Vietnam - Project 1-319: Research and capacity building on REDD+, livelihoods, and vulnerability in Vietnam: developing tools for social analysis of development planning

PI: Le Thi Van Hue, Central Institute for Natural Resources and Environmental Studies of Vietnam National University (VNU-CRES)
Co-PIs: Nguyen Viet Dung, PanNature--Center for People and Nature Reconciliation; and Tran Huu Nghi, Tropenbos International Vietnam
U.S. Partner: Pamela McElwee, Rutgers University (funded by the National Science Foundation)

AFGHANISTAN

AFGHANISTAN – PROJECT 9-012: WATER HARVESTING AT COMMUNITY LEVEL FOR ENHANCED ACCESS TO GROUND WATER

PI: Fatema Samim, Herat University
U.S. Partner: Christine Lee, Nasa Jet Propulsion Laboratory

PROJECT OVERVIEW:

One of the main challenges facing society when striving for urban sustainability is that of water supply, a resource that is decreasing in both quantity and quality in Afghanistan. Increasing water demand for both domestic and agricultural uses has put enormous pressure on groundwater resources. Due to this rising demand coupled with a series of droughts, the groundwater tables in multiple regions of Afghanistan have declined to the extent that about 60-70 percent of traditional groundwater irrigation systems (karezes) have dried up. This over-exploitation of water resources has caused devastating impacts on drinking water supplies for urban and rural populations. To address sustainability concerns, appropriate government policies are needed to effectively manage and monitor groundwater development and use. The project aimed to focus on the use of rainwater harvesting as a technique for groundwater recharge to capture and store water during rainy periods so it could be used for drinking, irrigation, and other purposes in the dry seasons.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project did not start due to the government transition during the first week of project activities.

AFGHANISTAN - PROJECT 5-183: IMPACT OF CLIMATE CHANGE ON RUNOFF FROM GLACIERS, SNOW, AND RAINFALL IN THE PAMIR AND HINDU KUSH MOUNTAINS: A COMPARISON OF AMU DARYA AND KABUL RIVER BASINS

PI: Fahimeh Salehi, Green Social Research Organization
U.S. Partner: Daniel Fagre, USGS
Dates: December 2016 - December 2018

PROJECT OVERVIEW

The main objective of this project was to assess the role of glaciers, snow, and rainfall in the total stream flow of the Kabul and Amu Darya river basins. These rivers are transboundary waters, with Afghanistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan sharing the Amu Darya, and Afghanistan and Pakistan sharing the Kabul River Basin. Therefore, this project was intended to inform these countries in the face of climate change and economic growth. While the Amu Darya is believed to be heavily glacier-fed, the Kabul River Basin is believed to be heavily snow-fed as a result of climate change. This is an obvious challenge in the winter, as Afghanistan may face flooding, avalanches, flash floods, and the formation of glacier lakes and moraine lakes. In contrast, in summer the country experiences water scarcity. This PEER team focused on these challenges and analyzed the variation of river flows and climate change on sources of water in Afghanistan. Through this project, Afghan and American researchers worked together to share knowledge, experience, and information. Knowing that a primary goal of USAID/Afghanistan is to reduce extreme poverty, the researchers aimed to promote economic growth by optimizing river flow management, helping to predict future climate-related disasters, and presenting alternatives for disaster mitigation and preparedness among the transboundary riparian countries. Information about transboundary water issues remains limited even at the university level, and this project was anticipated to provide an opportunity for researchers, university faculty members, the engineering community, and policy makers to share knowledge and utilize the new technologies.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project contributed to capacity building for junior researchers, resulting in the production of six articles in local languages supervised by the PI and team members. Training received from US partners and professionals enabled the creation of valuable maps and data, influencing decision-making and prompting institutional reforms and climate change adaptation measures. A total of 100 men and 25 women benefited from the project's training efforts.

The research identified glaciers as prominent indicators of global change in Afghanistan, highlighting their melting due to rising temperatures. This phenomenon has caused both floods and droughts, affecting the Kabul River Basin (KRB) and Amu Darya River Basins. The project developed models tracking climate impacts on these basins, which predominantly rely on water from melting glaciers, snow packs, and icecaps in the Hindu-Kush, Himalayan, and Pamir ranges. Diminished water discharge has negatively impacted local livelihoods, creating future water resource challenges for economic development and environmental sustainability. The GSRO Yearbook web platform was launched in 2018 to disseminate project findings, with an updated version planned for 2019.

Through the project, a national-level conference convened stakeholders and decision-makers, resulting in policy notes derived from project findings and official data. Additionally, the team also presented their research at various conferences and workshops to enhance dissemination and discussion of their findings.

AFGHANISTAN – PROJECT 5-074: REGIONALIZATION OF THE GLOBAL INTEGRATED DROUGHT MONITORING AND PREDICTION SYSTEM (GIDMAPS) FOR AFGHANISTAN

PI: Khadija Jawadi, Environmental Conservation Specialist Organization of Afghanistan
U.S. Partner: Amir Aghakouchak, University of California, Irvine Regionalization of the Global Integrated Drought Monitoring and Prediction System (GIDMaPS) for Afghanistan
Dates: January 2017 - July 2019

PROJECT OVERVIEW

In the past decades, Afghanistan has encountered several droughts that inflicted terrible damage on groundwater, surface water resources, agricultural sectors, forests, and pastures. Extreme droughts were expected to occur more frequently in the coming decades, which could cause major economic losses and social and environmental disasters. The overall objective of this research was to develop, validate, and implement a drought monitoring system for the Amu Darya and Kabul Basins in Afghanistan. The researchers worked to provide reliable information that could be used towards drought mitigation, risk management, and planning strategies. Regionalization of this model for the Afghanistan basins aimed to promote better monitoring and prediction of droughts and enhance decision-making and risk reduction efforts.

This research built upon the successful development and implementation of previous UNESCO drought monitoring systems and enhanced risk management and drought mitigation by providing consistent and continuous drought information. The system provided drought monitoring information based on multiple indicators and data sources, including satellite observations and local ground-based information. Providing multi-model, multi-index, seasonal drought prediction information for Afghanistan was an integral part of the implementation. The use of a single index to indicate the diversity and complexity of drought conditions and impacts was one of the major limitations to drought monitoring. For this reason, the system developed and tested by this team provided drought information based on multiple univariate drought indicators and one multivariate drought index.

FINAL SUMMARY OF PROJECT ACTIVITIES

The Government of Islamic Republic of Afghanistan (GoIRA) committed to adopting Integrated Water Resource Management (IWRM) by establishing River-Basin Agencies (RBAs) in the country's five major river basins. This initiative aimed to integrate water resource planning and involve users and societal institutions in decision-making processes for equitable water distribution, environmental protection, and sustainable development. Adequate and reliable water availability information is crucial for these efforts.

Throughout the project, a data gathering team collected data for the Global Integrated Drought Monitoring and Prediction System (GIDMaPS) project. They gathered local ground-based data such as precipitation, soil moisture, and temperature from the Kabul and Amu Darya river basins spanning a 10-year period. Data on land-cover, land-use, GIS maps, and soil from these basins were obtained from the Ministry of Agriculture, Irrigation, and Livestock (MAIL). Meetings with MAIL officials and the Ministry of Energy and Water (MEW) provided additional local data including precipitation, temperature, evaporation, and wind data.

The team plans to evaluate satellite imagery and remote sensing data from sources including MERRA-Land, NLDAS, GLDAS, PERSIANN, TMPA, and the Global Precipitation Climatology Project (GPCP). They will continue gathering on-site data from meteorological stations, focusing on precipitation, temperature, and soil moisture. This comprehensive data will be integrated into a database and used to calibrate their models for effective drought monitoring and climate change impact prediction in the two river basins.

AFGHANISTAN – PROJECT 5-033: DETERMINATION OF FLOODS MAGNITUDE PROJECTION, CAUSES, VULNERABLE AREAS AND ITS SOLUTIONS: A CAUSE STUDY OF KABUL RIVER BASIN

PI: Assem Mayar, Organization of Skill Development and Social Services
U.S. Partner: Jonathan Nelson, U.S. Geological Survey
Dates: September 2017 - November 2019

PROJECT OVERVIEW

Floods have been one of the most destructive natural disasters on Earth, and the frequency of flood events has rapidly increased worldwide. Various models for quantifying flood discharge have been developed, but they require significant data inputs, which are mostly unavailable or inaccurately represented, especially in developing countries. Thus, this project addressed the challenge of flood modeling.

This study combined applied and scientific research and was divided into two components. In the applied component, the research team worked to identify flood magnitude trends, causes, and vulnerable locations, proposing reasonable solutions for these issues in the Kabul River Basin. The second component focused on the scientific challenge of hydrologic modeling, involving the development of a novel and simplified approach for flood flow computation using lumped hydrologic models. The U.S. partner, Dr. Nelson, cooperated on this effort and integrated it into a model (iRIC) being developed with support from the U.S. Geological Survey.

The analyses resulting from this project were intended to provide a solid foundation for scientific and engineering modeling of Afghan river basins. The study generated datasets crucial for water-related projects and programs in Afghanistan, particularly those related to transboundary water resource management.

This work supported USAID goals of building capacity in research and integrating it with policy in Afghanistan. Led by Afghan scientists in an academic environment, this study marked one of the first efforts in hydrologic and hydraulic engineering. Students from public and private Afghan universities participated, expanding their scientific and engineering knowledge and modeling skills. Throughout project implementation, several training courses, workshops, and conferences were conducted for Afghan university students and government water sector employees, who also had opportunities for internships on the project. The internship program exposed participants to basic research skills, methodologies, emerging challenges in the water sector, and techniques for proposal writing and securing funding. Recommendations were shared with public and private university authorities to aid in curriculum development.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the project implementation period, the team successfully achieved most of its goals. The project activities started with data collection, sorting, and organizing in appropriate formats. This consisted of hydrologic data, satellite images, and raw GIS data from national and international organizations. Next, data quality control was implemented to filter irrelevant recording data and statistical analyses were used find flood peak and frequency projection for the study area.

Afterward, the project team worked on data preparation for the Kabul River Basin floodplain delineation in the GIS interface. As a first result, it was identified that existing river networks were not appropriate for flood simulation and only usable for general management purposes. Thus, the team first delineated the river center lines using high-resolution satellite images. Later, the river profiles were prepared according to 5-meter topographic information and the team conducted simulations, calibration, and post-processing of the floodplain in the study area. Planned and additional scenarios were tested to acquire a corrected version of flood vulnerable areas. The generated floodplain was calibrated using online high-resolution images and the recorded discharges. The developed high-resolution results of the river network and floodplain for the study area were then shared with the public through the Afghanistan Spatial Data Center's (ASDC) online geo-portal.

In order to approach policymakers, the PI published the results of investigations as columns on the mainstream media websites. The articles were widely read, republished, and used in the digital reports. The PI also participated in TV and radio discussions about the floods and water management in Afghanistan.

Capacity building activities were also an integral aspect of this project. In total, nine seminars and three workshops were organized, covering 598 participants. The seminars covered research methodology and introduced funding opportunities, while the workshops focused on the introduction and application of new technologies for predicting natural disasters such as for floods (Global Flood Awareness System and Global Flood Monitoring System), extreme climatic events (Global Forecast System and European Centre for Medium-Range Weather Forecasts systems), dust (Barcelona Dust Forecast Center) and drought (Global Drought Observatory). The workshops also covered skills development for flood simulations using HEC-SSP, GIS, and HEC-RAS software. Additionally, 14 B.Sc. students were trained for three months’ internship period.

In the future, the team plans to continue their research work and attract additional financial support from the international community to tackle water-related problems and promote research in Afghanistan.

AFGHANISTAN - PROJECT 4-257: IMPACTS OF CLIMATE CHANGE ON TRANSBOUNDARY WATER TREATIES/SHARING: A CASE STUDY OF KABUL RIVER BASIN, AFGHANISTAN

Pi: Fahima Sadeqinezhad, AZMA the Technical Vocational Private Institute
U.S. Partner: Devendra M. Amatya, USDA Forest Service Center for Forested Wetlands Research
Dates: December 2015 - September 2020

PROJECT OVERVIEW

One of the biggest challenges to mankind in the twenty-first century is climate change. The escalation in the frequency and severity of natural disasters and extreme climate phenomena has been widely discussed worldwide. Responding to climate change requires joint global actions for both mitigation and adaptation. This project explored the impacts of climate change on transboundary flows to quantify the required environmental flows for healthy ecosystems, hydropower exports, and irrigated agriculture for the Kabul River basin. The Indicators of Hydrologic Alteration (IHA) method, considering Range of Variability Analysis (RVA), was used to estimate environmental flow requirements (EFR). Since maintaining natural flow variability is crucial for preserving native riverine biota and river ecosystem integrity, the RVA results were used as a reference for evaluating EFR. Maintaining environmental flows of a river means reducing the water demand of one or more sectors to allocate for other ecological requirements, including the biota. Finally, alternative mitigation measures were suggested to reduce the impacts of allocating environmental flows on irrigation and hydroelectric demands. A dry year conservation zone was developed to reduce irrigation shortages caused by environmental flow consideration. Additionally, this study was intended to demonstrate how a sustainable water-sharing agreement could be achieved by linking transboundary flows to hydropower exports, irrigated agriculture, and environmental flow demands.

Besides its scientific objectives regarding water resource management, this PEER project was also designed to help strengthen the relationship between Afghanistan and Pakistan by reducing the potential for conflict between the two countries on water treaties or resource sharing.

FINAL SUMMARY OF PROJECT ACTIVITIES

The Kabul River Basin (KRB) exhibits an unusual riparian circumstance in that Afghanistan and Pakistan are both down and upstream of one another, deterring each from arguing for absolute sovereignty over water on their territory, as this traditional upstream position would then function to their detriment in the downstream position. This characteristic of the KRB is an opportunity for the riparian states to negotiate and cooperate. Nonetheless, distrust and capacity weaknesses have created a complex situation in the basin in terms of mutual utilization.

The findings of this project reveal that the countries will not reach a state of cooperation over the water resources of the basin unless the distrust and capacity weakness challenges are overcome. Furthermore, the project-by-project approach to negotiations are deadlocked in the basin and, therefore, it is required to shift from such a traditional approach towards enlargement of the basket of benefits. The emphasis should be on benefit sharing rather than physical water sharing.

Another important finding of this project is that Afghanistan has shown tangible political efforts and willingness to alleviate the ongoing disputes and improve mutual cooperation. This project has formulated a step-by-step conflict transformation process framework, which may transform the existing conflicts to sustainable cooperation. The framework is formulated in a manner to move the topic of talks from rights to benefits. This framework can be widely used as a decision-making tool for potentially resolving both technical as well as political issues.

Finally, the role of the international community as facilitators and mediators for the transformation process is vital. In the absence of donor and international support, there may not be a willingness to successfully implement the formulated framework of transformation. This was seen throughout the project as the project team struggled to secure accurate data across borders. It is highly recommended that the needs on both sides of the basin be identified and analyzed for benefit sharing and enlarging the basket of benefits.

In addition to the overall frameworks, the project team was able to conduct numerous trainings and workshops on water management. Starting in 2016, more than 1000 students from private and government universities from Herat and Kabul were trained in different software related to water management and climate change. Furthermore, over 100 participants comprised of office staff, lecturers, and professors from the Hari-Rud Murghab river basin Herat office and the Herat University Civil Engineering Department were trained. This was completed through over 35 workshops, seminars and training courses organized by AZMA Vocational Technical Institute for students, government staff in the Ministry of Energy and Water and university professors.

AFGHANISTAN – PROJECT 4-47: IMPACT OF CLIMATE CHANGE AND VARIABILITY AND LAND USE CHANGE ON AFGHANISTAN'S WATER RESOURCES: A CASE STUDY OF KABUL RIVER BASIN AND AMU DARYA RIVER BASINS

PI: Sediqa Hassani, Ibn e Sina University
U.S. Partner: Jeff Dozier, University of California, Santa Barbara
Project Dates: December 2015 - December 2017

PROJECT OVERVIEW

The record of surface measurements of Afghanistan's climate and hydrology has numerous gaps, owing to the country's historical political instability, especially since the 1970s. This research addresses for the first time Afghanistan's challenges in transforming to an integrated approach for managing its water resources.

The study had two main objectives. First, the research team worked on recovering the gap of observed climate data to create a dataset combining historical climate and hydrologic data from Afghan stations and information from the Climate Research Unit. Second, to translate the meaning of these data to the country's mountainous regions, where surface data had been sparse even during the best of times, the researchers compared their reconstructions of surface measurements with remotely sensed data of snow cover and snow water equivalent derived by their U.S. partner covering the period from 2000 to the present. The resulting analyses provided a base for scientific and engineering modeling on Afghanistan river basins. As there were limited studies on Afghanistan water resources conducted by international organizations, the created dataset was used in engineering models to examine the current and future status of climatic parameters and water availability in Afghanistan. The study provided datasets for Afghanistan water-related projects and programs, particularly in transboundary water resource management, and also engineering information regarding the quantity of Afghanistan water resource for use in decision and policy making.

The team's objectives were to improve Afghanistan's ability to analyze, synthesize, and present information essential for planning and decision making. In this context, assessment of seasonal snow resources relative to historical trends and extremes was the primary need in the country's mountains, with their austere infrastructure, sparse gauging, accessibility challenges, and emerging or enduring insecurity related to water resources that included both droughts and floods. These issues required that remotely sensed data provided much of the information necessary to analyze the snow cover and predict seasonal and paroxysmal runoff. This work supported USAID goals of building capacity in research and its integration with policy in Afghanistan. This study was one of the first in hydrologic engineering that was led by Afghan scientists in an academic environment. Students from two Afghan universities actively participated, and their participation expanded their scientific and engineering knowledge and engineering modeling skills.

SUMMARY OF RECENT ACTIVITIES

The research project successfully achieved its primary objectives. Firstly, it has filled historical gaps in meteorological data from 1960 to 2012, including the period of 1978-2003, for monthly temperature and precipitation records at 18 meteorological stations across the Amu Darya and Kabul River Basins. Data from the Climatic Research Unit (CRU) of the University of East Anglia has supplemented this effort and been shared with Afghanistan's Ministry of Energy and Water and Ministry of Agriculture, Irrigation, and Livestock. Additionally, research units have been established at two universities to foster research on current social, economic, and environmental issues, equipped with ArcGIS and Excel software for spatial and statistical analysis.

Furthermore, stream gauge data from 12 stations between 1965 and 1978 has been collected from the Water Resources Department of the Ministry of Energy and Water. Despite disruptions during periods of social unrest and war, efforts have been made to improve data collection since 2010, although the quality of current gauge stations is still being enhanced.

The project has also promoted a culture of knowledge sharing between data providers and researchers in Afghanistan, supported by a PEER research grant. This initiative addresses challenges such as data scarcity and limited sharing, aiming to enrich climate and water-related information. It has resulted in publications addressing environmental challenges and has built research capacity within universities, fostering collaboration with governmental and private entities to enhance the resilience of water and agriculture infrastructure to climate variability. Overall, the project emphasizes teamwork among diverse stakeholders to improve decision-making and management of natural resources.

BANGLADESH

BANGLADESH - PROJECT 9-441: ENGAGING THE PRIVATE SECTOR IN INCREASING VOLUNTARY USE OF LONG-ACTING REVERSIBLE CONTRACEPTIVES AND PERMANENT FAMILY PLANNING METHODS IN RURAL AREAS OF BANGLADESH

PI: MD. Jasim Uddin, International Centre for Diarrhoeal Disease Research, Bangladesh
U.S. Partner: Sian Curtis, University of North Carolina at Chapel Hill (Funded by the United States Agency for International Development)
Dates: June 2021 - May 2024

PROJECT OVERVIEW

This PEER project aimed to reduce an unmet need for family planning (FP) services and increase the use of effective contraception among postpartum women in rural Bangladesh through engaging the private clinics at the upazila (sub-district) level. The researchers tested various interventions related to pregnant women and evaluated their effectiveness after 36 months. The private clinics received various types of FP supplies from the local upazila Family Planning Office of the Ministry of Health and Family Welfare (MoHFW) as per a recently introduced policy, and a team consisting of doctors from local public and private facilities and Upazila and District level managers of MoHFW, representatives from the Directorate General of Family Planning (DGFP), and study investigators were involved monitoring the study activities at the private clinics. The researchers sought to develop a mechanism to engage private sector providers to accelerate access to postpartum family planning services which can be scaled up in other areas of Bangladesh.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project team enrolled 2,360 women from four private clinics in Baraigram and Gurudaspur upazilas of Natore district. Private clinic staff were involved in training on technical and ethical issues involved. The intervention included counseling pregnant women at the clinic on antenatal care (ANC), safe delivery, and postpartum family planning (PP-FP), as well as developing and sending SMS messages to enrolled pregnant women to promote ANC, institutional delivery, and PP-FP after delivery.

The women enrolled received multiple follow-up surveys after delivery. The researchers also collected qualitative data during the reporting period to gather insights into the challenges associated with implementing the interventions, with the goal of refining the strategies used. The team also conducted ten key informant Interviews with service providers of private clinics and MOHFW officials and five in-depth interviews with project counselors and record keepers. Throughout the project, the PEER team organized a monthly review meeting with officials from MOHFW and private clinic providers and met with a variety of stakeholders. To ensure data quality, the team contacted a randomly selected group of 883 out of 2360 recently delivered women (RDW) by phone in intervention and comparison areas, successfully completing 391 interviews to check for any inconsistencies.

The PEER team's findings included increased use of long-acting reversible contraception (LARC) and permanent methods (PM) among postpartum women in rural Bangladesh. Dedicated counseling during ANC had a significant contribution in increasing LARC/PM use after delivery. The findings showed that a significantly higher proportion of women in the intervention area had at least two or three ANC visits, and 17% of women had 4+ ANC visits which is more than 3 times higher than in the comparison area (5%). Facility delivery was significantly higher in the intervention area, and c-section delivery was significantly lower.

The findings also showed a significantly higher proportion of women in the intervention area used PP-FP compared to those of the comparison area within the three days of facility delivery. Overall contraceptive use among the recent delivered women (RDW) within the 5 months of delivery was significantly higher in the intervention area, and the proportion of women accepting LARC or PM within 5 months of delivery was also significantly higher. All the women who accepted LARC/PM reported that counseling was the key factor in their motivation. Use of behavior change communication materials and SMS communications were mentioned by 68.9% and 56.1% RDWs respectively as motivating factors.

The PEER team has made several recommendations to private clinics and health workers as a result of this project, and the PI received a new grant of $321,541 from the Vaccine Alliance for a different project.

BANGLADESH - PROJECT 9-17: RENEWABLE HYDROGEN GENERATION WITH CARBON RECYCLING (REHYCARE) FROM BIOGENIC RESIDUES OF BANGLADESH

PI: Kawnish Kirtania, Bangladesh University of Engineering and Technology
U.S. Partner: Mohammad Toufiq Reza, Florida Institute of Technology (Funded by the National Science Foundation)
Dates: April 2021 - March 2024

PROJECT OVERVIEW

Bangladesh is expected to see a surge in energy demand in the upcoming years. While the country's fossil fuel reserve has already been depleted, Bangladesh produces an enormous amount of biogenic residue that could be harnessed for hydrogen (H2) production. In order to distribute clean energy at a lower cost throughout the country, researchers believe low-risk, ready-to-deploy modular H2 generation systems hold the key to success for Bangladesh.

This PEER project proposes studying a novel process using biogenic residues for renewable H2 generation on the modular scale. This concept has been developed by three leading universities of Bangladesh (Bangladesh University of Engineering and Technology, Bangladesh Agricultural University, and Dhaka University) collaborating with partners at the Florida Institute of Technology. By converting an environmental liability (biogenic residues) into clean energy (H2), this project could aid in attaining energy security for Bangladesh. The project sought to undertake unique research and development activities focused on Bangladesh and its H2 generation potential. The ReHyCaRe concept uses anaerobic digestion on biogenic residues available to produce biogas, which will be cleaned and further upgraded to H2 with a low-cost catalyst. The project aimed to identify specific biogenic residues and their biochemical methane potentials and perform co-digestion of mixed biogenic residues to explore synergistic effects on biogas production.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers undertook a life cycle assessment study on the ReHyCaRe concept (biogenic residues for green hydrogen production), which suggested a climate change reduction of 69% compared to the current practices of landfilling of biogenic wastes. The acidification potential could also be reduced by 98% and eutrophication could be reduced by 60%. A life cycle assessment for anaerobic mono-digestion and co-digestion showed that co-digestion can reduce the climate change impact by 61% compared to mono-digestion for cow manure with food waste. For poultry manure (with food waste), co-digestion resulted in 50.4% climate change impact reduction. This part of the study also revealed that proper management of digestate plays an important role on climate change impact during biogas production can be performed by hydrothermal carbonization (HTC) to produce solid biofertilizer, based on data provided by the U.S. partner.

The PEER team also conducted a scoping study on mono-digestion all available biogenic wastes in Bangladesh in an effort to select the feedstocks for existing plants for co-digestion that would maximize the conversion to biogas. The team studied co-digestion of poultry droppings with corn cobs, rice straw, rice husks, and municipal solid waste, along with studies on anaerobic co-digestion of cow dung with some of these wastes to find the optimum mixing ratios for the highest methane yield. They also tested biogas cleaning in the lab with promising results. An optimum ratio of waste iron and activated carbon (75:25) as absorbent managed to reduce the hydrogen sulfide concentration in biogas to 3 ppm. Use of activated carbon showed efficiency in CO2 removal from biogas as well.

They also demonstrated hydrogen generation using the catalytic dry reforming reactor (CADRE) in the lab and a techno-economic analysis on the hydrogen generation from biogenic waste showed a potential selling price of $8/kg with a payback period of 7 years.

This project led to an increase in capacity through procurement of a biogas reactor (BAU-CSTR) and CADRE for each institution in the PEER team and established a strong multi-university collaboration. The project trained about 25 energy professionals from three Bangladeshi universities, of whom 76% are female. PEER team members also organized eight energy seminars to disseminate knowledge to experts in the field. The team received two additional grants worth more than $35,000 for related and other work and presented widely on their findings, including at the International Conclave on Materials, Energy, and Climate and International Conference on Mechanical, Industrial, and Materials Engineering.

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BANGLADESH - PROJECT 8-170: INTEGRATED RICE ADVISORY SYSTEM (IRAS) FOR SUSTAINABLE PRODUCTIVITY IN BANGLADESH

PI: Niaz Rahman, Bangladesh Rice Research Institute, in Partnership with Bangladesh Agricultural University

U.S. Partner: Faisal Hossain, University of Washington (Funded by the National Aeronautics and Space Administration)

Dates: November 2019 - January 2022

PROJECT OVERVIEW

One of the major components of increasing rice yield is efficient crop management, but in Bangladesh, weather variability is a crucial hindrance to ensuring better management. This PEER project is built upon ongoing research on forecast-based rice crop management at the Agromet and Crop Modeling Lab of Bangladesh Rice Research Institute. With mentorship from his U.S. partner Dr. Faisal Hossain and his group at the University of Washington, Dr. Rahman and his team sought to develop an integrated framework for agro-meteorological advisory services for rice crops in Bangladesh. To this end, the PI and his colleagues developed a Web-based platform, “Integrated Rice Advisory System (IRAS),” to provide extension workers and rice farmers with agro-meteorological advisories for effective decision-making.

With almost 16.5 million farmers in Bangladesh, the team's target is to provide weather-based advisory to all interested farmers once a week on a regional basis. The researchers mapped the sensitivity of rice crops in specific areas to certain weather conditions to understand how the weather in general will influence the growth of rice. The team then used the open-source Weather Research and Forecast (WRF) model for generating location-specific weather forecasts and automated it within the IRAS.

The project also helped validate BRRI’s previous research on forecast-based rice crop management with the participation of volunteer farmers from four districts. Farmers and extension workers in the target locations were trained to utilize the advisories generated through IRAS and apply them during the rice season at pilot fields. The U.S. partner provided valuable R&D support and technical guidance on systems integration for IRAS.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team developed IRAS as a web-based platform that generates location-specific weather forecasts, capable of consolidating advisories with input from researchers for different locations and considers growth stages of rice varieties. The platform has been developed only for rice crops and combines expertise from Bangladesh Meteorological Department, the Bangladesh Rice Research Institute, and the Department of Agricultural Extension. The platform automatically runs the Weather and Research Forecasting (WRF) model every day, generates location-specific weather forecasts, and visualizes its graphical and tabular results, generating advisories that are emailed to extension officials and farmers.

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The researchers also conducted field experiments in several locations during the 2019-2020 and 2020-2021 Boro rice season using popular and high-yielding rice varieties. Farmers' land was used for both forecast-based management and traditional management. The team shared its location-specific advisories, and the farmers implemented those advisories for day-to-day farm decision-making under the supervision of the BRRI regional stations and extension workers. The researchers collected a wide variety of data on the crops grown, including grain yield, weight, maturity date, and plant height, as well as climate data like temperature, rainfall, etc.

The team members made frequent field visits during the experiment and conducted five training workshops for farmers. The project involved strong collaboration with government agencies like the Bangladesh Meteorological Department (BMD), the Flash Flood Warning Center (FFWC), the Department of Agricultural Extension (DAE), and the international NGO Regional Integrated Multi Hazard and Early Warning System (RIMES).

The team's study showed positive and significant improvements on yield and grain weight for forecast-based management crops. Different rice varieties had different yield improvements, but generally a 7-10% increase was observed. The team theorized that this might be attributed to the function of the application of fertilizer to the field and optimal irrigation use based on the forecast model. Their research also found that implementing weather forecasting-based management could lower production costs by 15% and increase total income by more than 30%.

PUBLICATION

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BANGLADESH - PROJECT 6-10: ECOSYSTEM SERVICES IN A CHANGING CLIMATE; ASSESSING CRITICAL SERVICES IN BANGLADESH RICE PRODUCTION LANDSCAPES

PI: Md Panna Ali, Bangladesh Rice Research Institute (BRRI)
U.S. Partner: Douglas A Landis, Michigan State University (Funded by the National Science Foundation)
Dates: December 2017 - October 2021

PROJECT OVERVIEW

Rice contributes more than 80% of the total food supply in Bangladesh, including 76% of daily caloric intake and 66% of total protein requirements. The coastal region, covering 20% of the country and over 30% of cultivable land, contributes 16% of total rice production and is the most vulnerable to climate change. Due to increasingly variable rainfall reducing freshwater flows, about 53% of coastal areas face salinity intrusions that restrict crop production, resulting in rice productivity being 70% lower than the national average.

In this project, the team quantified the potential impacts of changing conditions on ecosystem services by determining the impact of climate variability on carbon sequestration, pest suppression, water supply, and rice production. They used spatially explicit models to project future patterns of terrestrial ecosystems and their services. This collaborative research effort focused on developing models to estimate the impacts of changing conditions on ecosystem services in Bangladesh. The study analyzed environmental impacts on crop production systems and suggested coping strategies and adaptation options to improve coastal agriculture, enhance agricultural production, and improve livelihoods for the vulnerable farming community.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the project, the PEER team investigated the effect of climate change on rice yield in Bangladesh. To create an adaptation plan, they explored nearly 50 years of rice yield data, examining yield changes and drivers of anomalies. At the national and regional levels, the PI reported clear yield increases over time for Aus, Aman, and Boro rice in all regions, attributed to improved genetics (e.g., disease resistance) and new agronomic practices (e.g., better access to fertilizer).

The team also worked on predicting carbon stock in soil at coastal areas of Bangladesh using multilayer perceptron (MLP). The findings indicated that bulk density, soil organic carbon, and carbon stock in soil are associated with salinity. The model showed strong predictive power, revealing that higher salinity levels significantly decreased soil carbon stock in rice production landscapes.

The PEER team studied the climate change adaptation perceptions of smallholder rice farmers in vulnerable areas. Over 80% of farmers identified salinity and freshwater scarcity as main issues, with 95% noting the rice plant's reproductive stages as most sensitive to salinity. Most farmers adapted by early transplanting and applying irrigation during later stages of crop growth. The project's experimental plots showed similar results, suggesting that addressing salinity and involving farmers' perceptions in policy formulation can secure rice production and contribute to Sustainable Development Goals.

The project also investigated the effect of landscape composition and configuration on natural enemies, herbivore suppression, and rice yield at multiple spatial scales in two rice-producing regions. Landscape heterogeneity effects on pest abundance were observed at all scales and were most pronounced at the 1000 m scale for all natural enemies combined and at smaller scales for ladybird beetles (500 m) and spiders (200 m). Ladybird beetles were positively influenced by rainfall, roads, and fallow land, while spiders were influenced by rice phenology. Natural enemies also responded to rice landscape configuration, declining with increasing patch cohesion and aggregation but increasing with edge density. These findings suggest that finer-grained rice landscapes are better suited to pest suppression.

At the conclusion of the project, the PEER team reported that landscape diversity is crucial for maintaining ecosystem services in agricultural production. This study indicates that landscape diversity shapes species diversity in rice fields, providing guidelines for conservation of arthropod diversity to maximize ecosystem services in crop production.

For assessing climate change adaptation, sixty farmers' fields were selected for field trials in Satkhira and Khulna districts. Rice seedlings were transplanted in 60 plots at three different dates. The project identified early transplanting of rice in saline soil before January as the best option to avoid salinity at the crop's vulnerable stage, enhancing yield in coastal areas. Sixty rice growers were trained in climate-susceptible areas and the impact of climate change on ecosystem services. These trainings in Cox's Bazar improved farmers' knowledge on climate change and sustainable rice production in saline areas. The project team demonstrated the performance of BRRI-released rice varieties over local varieties in 60 farmers' fields, proving that high-yielding varieties can increase food production, improve food security, farm income, and livelihood resilience.

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BANGLADESH - PROJECT 6-009: UNMANNED AERIAL SYSTEMS-BASED ASSESSMENT OF TREE COVER AND DEFORESTATION DYNAMICS IN BANGLADESH

PI: A.B.M, Kamal Pasha, Daffodil International University
U.S. Partner: Demetrios Gatziolis, the United States Forest Service
Dates: December 2017 - June 2022

PROJECT OVERVIEW

The main advantages of photogrammetry based on unmanned aerial vehicles (UAVs, or drones) compared to traditional aircraft imaging campaigns are low cost and flexibility. They can also be deployed at easily customizable above-canopy altitude, camera orientation, trajectory, and speed. They are thus ideal for imaging small areas of forests, such as over individual tree stands, management units, or inventory plots. Most developing countries do not yet have the capacity or knowledge base to support modern forest inventories and typically depend on satellite imagery and applications developed elsewhere to meet their needs, including the obligation to report on the status of their forests if they participate in international initiatives for reducing emissions from deforestation and forest degradation (REDD). The advent of novel, inexpensive technologies, including UAVs, and the development of affordable software capable of performing complex photogrammetric tasks hold promising potential into assisting the assessment of forest resources in developing countries and facilitating their verifiable participation in efforts to mitigate the effects of deforestation and forest degradation.

In this project, the PI Dr. Pasha and his team devised and optimized a fully automated UAV-based image acquisition protocol compatible with generating comprehensive, high-density, precisely geo-referenced point clouds representing forest canopies for areas in selected locations in the Sal and Sundarbans forests. The researchers generated canopy surface and canopy height rasters for each selected inventory plot and its surroundings, as well as estimates of canopy cover for each subplot, and compared them to those obtained by inventory personnel during field visits.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team played a key role in getting the drone use law in Bangladesh passed, thus facilitating the advancement of drone technology in environmental monitoring. In order to have the permit to access the hard to reach areas for implementation of the project using drones, and in efforts of capacity building, the team worked closely with the Bangladesh Forest Department (BFT) staff to make it happen. With the help of the U.S. partner, the team trained the Bangladesh Forest Department (BFD) staff how to use drones and their software, and provided comprehensive free training to the BFD personnel.

The team undertook extensive field trips to various forest plots, including Tambulbunia, Horintana, Shapla, Kokilmoni, Dubla, Harbaria, Jhapshi, Nondobala, Moraposhur, and Hiron Point, gathering the largest and most precise sets of drone data over the Sundarbans. They observed unexpected findings in tree composition and variation, and processed the raw data in partnership with BFD. They shared data analysis methods with BFD staff and helped develop and train a drone patrol team for the Sundarbans, including a newly commissioned drone for patrolling the forest. Dr. Pasha and colleagues relied on BFD's commitment to provide access to the Department’s central remote sensing lab for data processing and analysis.

The team involved young students and researchers in actual research efforts, setting a trend for research action and methodology in Bangladesh. They developed new course curriculums, which significantly improved the learning outcomes of students at Daffodil International University (DIU). The project also contributed to student training through research trips and hands-on training in field data collection protocols. Curriculum modules for forestry, GIS, and remote-sensing courses were updated at their university. Two research team members joined the USAID Research Technical Assistance Center (RTAC) initiative and subsequently gained acceptances to PhD programs in U.S. universities.

A major achievement was leading the effort to create the largest dataset of drone data on the Sundarbans. This dataset has been pivotal in bridging the gap between policymakers and the research community in Bangladesh.

To get the drone law passed regulating the use of the drones, the team interacted with several government agencies including the Bangladesh Forest Department, the Education Ministry (GoB), the University Grants Commission (GoB), the Directorate General of Forces Intelligence, National Security Intelligence, Special Branch (Bangladesh Police), the Air Force Intelligence Unit, the Defense Ministry of Bangladesh, and the Civil Aviation Authority of Bangladesh.

In the implementation of the project goal, the team collaborated with various organizations and institutions, including the Bangladesh Forest Department, FAO, SilvaCarbon, CIMMYT, the Education Ministry (GoB), the University Grants Commission (GoB), the Directorate General of Forces Intelligence, National Security Intelligence, Special Branch (Bangladesh Police), the Air Force Intelligence Unit, the Defense Ministry of Bangladesh, and the Civil Aviation Authority of Bangladesh. The fruits of their efforts are now being enjoyed by thousands of researchers and administrators who are using drones in research, infrastructural development projects, and even in the entertainment industry. The team is proud and happy to see their work and collaborations being utilized by many.

The project contributed to the broader context of climate change adaptation by enhancing conservation practices for the Sundarbans, the world's largest mangrove forest. This initiative has played a crucial role in improving the conservation efforts in the region.

Team feedback: "*The setup we have made is hard-earned. We now are able to operate in both the national and international spheres and have a proven ability to work in one of the most remote and challenging places on earth. We have great expectations for the future of this team. In the future, DIU, USFS, and BFD will continue producing quality research and addressing the reduction of risks induced by climate change*.

BANGLADESH - PROJECT 6-5: CLIMATE CHANGE ADAPTATION OF RURAL HOUSEHOLDS IN CHARLANDS OF BANGLADESH

PI: Humnath Bhandari, International Rice Research Institute (Irri)
U.S. Partner: Charles (Chuck) W. Rice, Kansas State University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: March 2018 - April 2022

PROJECT OVERVIEW

The charlands in Bangladesh are riverine land masses formed over time through the deposition of sand, silt, and clay carried by the country's four major rivers (Padma, Meghna, Jamuna, and Brahmaputra) and their more than 500 tributaries. More than 8 million people live in the charlands, facing high rates of poverty and food insecurity. Agriculture in these areas is characterized by rainfed cultivation, low nutrient levels in the soil, traditional crop varieties, conventional management practices, poor access to agricultural technologies and services, and low cropping system diversification. The charlands are highly susceptible to climatic stresses, including floods, drought, salinity, river and coastal erosion, and tropical cyclones, leading to annual losses for local farmers. Climate change will exacerbate these problems, making charland livelihoods increasingly precarious. The adoption of climate-smart agriculture could significantly reduce negative effects and build resilience, but not every option is suitable for every location.

This PEER project aimed to understand charland characteristics and residents' livelihoods, assess households' vulnerability and adaptation to changing conditions, and promote climate-smart agricultural technologies. Dr. Bhandari and his colleagues focused on two study sites: Ganai Char in Kaunia Upazila, Rangpur District, representing the northern region, and Shaula Char in Bauphal Upazila, Patuakhali District, representing the coastal region.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project team began with ten focus group discussions to collect information such as biophysical and socioeconomic profiles, climate and environmental factors, and livelihoods in the two study areas. They followed this up with a survey of 306 households in the Rangpur and Patuakhali districts and used the survey data for their economic analysis of the major cropping systems in the charlands. Survey results found households facing food insecurity during two periods of the year. Large gender differences in farm and non-farming decision making were also noted, and the survey confirmed farmers' perceptions of increasing temperatures and changing rainfall patterns. Farmers reported high vulnerability of agriculture to climatic risks, with up to 100% crop losses in some years for pulses and groundnuts. The survey found a range of adaptations, including changing planting and harvest times, changing input use, switching to alternate crops, using short duration varieties, increasing homestead farming, and keeping land fallow.

The researchers also conducted several field experiments in different cropping seasons in the two study sites. They tested, evaluated, and scaled up 34 new or improved crops, varieties, and/or cropping systems in an 87-hectare area involving 512 farm households. They also organized farmers' field days and demonstrations around these strategies to promote awareness.

The results of researchers' economic analysis of different cropping systems show that Aman-Onion-Groundnut and Aman-Early Potato-Onion are the most economically viable cropping systems for the northern charlands, while Aman-Mungbean-Fallow and Aman-Groundnut-Fallow are the most economically viable for the southern charlands. Based on their field experiments, the researchers recommended improved rice varieties and suitable non-rice crops like sweet and bitter gourd, among others, as well as adding solar irrigation, temporary ponds, and dibbling cultivation methods to help farmers' resilience to climate change.

As a result, more than 500 farmers in six villages are now using improved varieties of rice, groundnut, potato, mustard, mungbean, and others. The use of improved varieties and management practices increased yield and profitability of crops up to 150%. In the northern charlands (Rangpur District), the cultivation of improved groundnut varieties gave a 60% higher average yield and increased employment and income for farmers, especially for women in postharvest activities. Likewise, the cultivation of flood-tolerant rice varieties significantly reduced rice production losses from flooding. The PEER researchers also tested an improved rice-based cropping system (Aman Rce-Potato-Groundnut), which led to a 55% higher crop equivalent yield and 70% higher gross margin as compared to farmers' previous practices.

In the southern charlands (Patuakhali District), the cultivation of suitable cash crops such as mungbean, sunflower, watermelon, potato, and others produced up to a 150% higher gross margin per hectare as compared to farmers' previous practices. The introduction of improved rice varieties allowed farmers to cultivate rice in the fallow areas and reduced production losses during flooding seasons.

Due to the demonstrated shorter cultivation duration, higher yield, and better adaptation to local agro-climatic conditions, the Department of Agricultural Extension and NGOs are scaling up these new crops and varieties in the charlands. The PEER project team trained more than 160 farmers (120 men and 40 women) and 20 agricultural extension workers on the new improved agricultural technologies and practices. As part of this project, six Master's students were also supported in conducting their thesis research, and three members of the project participated in the International Rice Congress 2018 held in Singapore. The team organized a results sharing workshop attended by many researchers, extension workers, policymakers, planners, and others.

The PI and team also won four additional grants for related work from the CGIAR COVID-19 Hub, Asian Development Bank and J-PAL/MIT, for a total of $350,000. Their first two publications appeared in 2023, with others reported to be in process at the time of their final report.

PUBLICATIONS

Rahman, M. N., Azim, S. A., Jannat, F. A., Rony, M. R. H., Ahmad, B., & Sarkar, M. A. R. (2023). Quantification of rainfall, temperature, and reference evapotranspiration trend and their interrelationship in sub-climatic zones of Bangladesh. Heliyon, 9, e19559. https://doi.org/10.1016/j.heliyon.2023.e19559

Al Mamun, M. A., Nihad, S. A. I., Sarkar, M. A. R., Sarker, M. R., Skalicka, J., & Skalicky, M. (2023). Spatio-temporal variability of climatic variables and its impacts on rice yield in Bangladesh. Frontiers in Sustainable Food Systems, 7, 1290055. https://doi.org/10.3389/fsufs.2023.1290055

BANGLADESH - PROJECT 5-424: COMMUNITY INTERVENTION TO PROMOTE CHLORHEXIDINE FOR REDUCING UMBILICAL CORD INFECTIONS IN JAMALPUR DISTRICT, BANGLADESH

PI: Lutfe Ara, International Centre For Diarrhoeal Disease Research, Bangladesh (Icddr,B)

U.S. Partner: Eben Kenah, University of Florida (Funded by the National Institutes of Health)

Dates: March 2017 - October 2019

PROJECT OVERVIEW

Neonatal mortality is one of the major challenges facing most of the low- and middle-income countries like Bangladesh, where neonatal sepsis is the third leading cause of these deaths. The effectiveness of applying 7.1% chlorhexidine digluconate (delivering 4% chlorhexidine) on the umbilical cord stump to prevent umbilical cord sepsis and neonatal death has been proven through community-based clinical trials in Bangladesh, Nepal, and Pakistan. In Bangladesh, however, chlorhexidine is not widely used in the rural areas, and no community intervention has been implemented to train and motivate pregnant mothers, their family members, community members, and traditional birth attendants (TBAs) to use chlorhexidine for neonatal umbilical cord care.

The PEER project team conducted an 18-month study in Jamalpur, Bangladesh, to assess the effectiveness of a community intervention. This project built awareness among pregnant mothers, their family members, other community members, TBAs, and pharmacy personnel on umbilical cord infections and the effectiveness of using chlorhexidine to prevent sepsis. These interventions will eventually help in achieving development goals for child health by reducing under-five mortality.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Lutfe Ara and her group conducted a baseline study of chlorhexidine use; rate of umbilical cord sepsis; and knowledge, attitudes, and practices of the respondents in both an intervention group and a control group. The PEER team then implemented a Social and Behavioral Change Communication (SBCC) intervention in the intervention group. Field research assistants undertook more than 22,000 door-to-door meetings with mothers, grandmothers, family members, and community members to raise awareness on umbilical cord care and cord infection, discussing the advantages and the proper use of 7.1% chlorhexidine for umbilical cord care among pregnant women. The research team also organized three town hall meetings and 30 community meetings to further knowledge sharing, inviting community leaders, school administrators, and journalists.

Following the SBCC intervention, the intervention group exhibited a significant increase in chlorhexidine use—1.1% to 57.8%—and recorded a reduction—8.02% to 1.6%—in the rate of umbilical cord infection. The PEER team visited pharmacists to share information about chlorhexidine and to ensure a regular supply of the drug in the area. About 150 TBAs as well as family members of pregnant mothers were trained on the advantages and the proper use of chlorhexidine through the intervention. The PI and her colleagues shared results with the director of primary health care under the Directorate General of Health Services of Bangladesh, who expressed interest in incorporating SBCC into the Bangladesh National Guideline to promote the use of chlorhexidine throughout Bangladesh.

PUBLICATIONS

Lutfe Ara, Md Al Amin, Waseq Billah, Shohel Mahmud, Riyasad Iqbal, Taranum Rahman, Md Ehsanul Haque Tamal, and Eben Kenah. 2021. Effectiveness of social and behavioral change communication intervention to promote the use of 7.1% chlorhexidine for umbilical cord care in hard-to-reach rural Bangladesh: A mixed method study. Journal of Global Health 11: 04006. https://doi.org/10.7189/jogh.11.04006

BANGLADESH - PROJECT 4-85: SCALING UP OF SATELLITE-ASSISTED FLOOD FORECASTING SYSTEMS IN SOUTH AND SOUTHEAST ASIAN NATIONS

PI: Md. Sohel Masud, Institute of Water Modeling, With Co-Pi Md. Sazzad Hossain, Flood Forecasting and Warning Center
U.S. Partner: Faisal Hossain, University of Washington (Funded by the National Aeronautics and Space Agency)
Dates: January 2016 - June 2018

PROJECT OVERVIEW

South and southeast Asian countries are frequently hit by floods, causing loss of lives and property damage. Almost every year in the recent past, a flood has struck in regional countries such as Bangladesh, India, Nepal, or Pakistan. Flood management practices currently available in most of these countries are structural or non-structural. Structural solutions like embankments and other related structures require huge amounts of resources and time. Other non-structural means of flood management include early warning and proactive preparation. In Bangladesh, flood forecasting and warning services (FFWS) have been practiced and have proven effective. FFWS have provided effective flood warnings, disseminated by e-mail, text messages, fax, and a dedicated website operated by the Flood Forecasting and Warning Center (FFWC) under the Bangladesh Water Development Board (BWDB). When the Center began in 1972, it could only provide flood warnings a few hours in advance, but by 2014, thanks to NASA satellite data from JASON-2, warnings could be issued up to 8 days in advance. Without data from JASON-2, these warnings could be issued only 3-5 days in advance of an impending flood.

Because flooding is a shared problem for countries in the same basin or climate, a shared vision to manage floods together by sharing experience and training was essential for a better and more flood-safe world. In this project, stakeholder agencies with flood management responsibilities in their countries learned about FFWC operations for flood warning generation and dissemination. The U.S. Government-supported partner led a special training and outreach session on the value of multi-satellite platforms to improve river modeling, hydrologic modeling, and flood forecasting in situations where ground data were limited or missing entirely. Through this training, the agencies learned about ways to build a tailored system for beneficiaries in their own countries. They were able to decide collaboratively how satellite data could be implemented for their water resource management.

FINAL SUMMARY OF PROJECT ACTIVITIES

The FFWC, under the BWDB of the Ministry of Water Resources of the Government of Bangladesh, in coordination with the Institute of Water Modelling (IWM), a trustee under the Ministry, successfully organized regional training workshops in two consecutive years as part of this now-completed project. The workshops were held July 24-28, 2016, and July 9-13, 2017. U.S. partner Dr. Faisal Hossain of the University of Washington transferred crucial knowledge and know-how regarding the satellite-assisted flood forecasting system to the Bangladeshi PEER team, who subsequently shared it with other flood management agencies of the South Asian region that sent participants to the workshops. Participating agencies included the Department of Hydrology and Meteorology (Hydro-Met) of Vietnam, the Department of Hydrology and Meteorology (Hydro-Met) of Nepal, the Institute of Environmental

Science and Engineering (IESE) of Vietnam; the Royal Irrigation Department of Thailand, the Department of Meteorology and Hydrology of Myanmar, the Lao National Mekong Committee Secretariat of Laos, the Asian Disaster Preparedness Center of Thailand, and several local Bangladeshi agencies such as the Bangladesh Meteorological Department, Department of Disaster Management, the Institute of Water and Flood Management, and the Local Government Engineering Department. To facilitate effective training for the participants, PEER funds supported some infrastructural improvements at the FFWC facilities. Human capacity development was also supported through tailored training in the United States on state-of-the-art satellite technologies for flood forecasting. One staff member from IWM visited Dr. Hossain and his team at the University of Washington for two weeks in April 2017, and three professionals from BWDB visited UW for two weeks in November 2017. To close out the project, the PI and his colleagues implemented a follow-up training program at BWDB from May 29, through June 28, 2018. This training activity allowed the staff trained at UW to share their new skills and knowledge on satellite-based flood forecasting with a larger group of BWDB professionals.

The training and technology transfer activities supported under this project have also facilitated an important new forecasting and data sharing platform. The Flood Forecasting and Warning Center (FFWC) of BWDB is now providing an 8-day lead-time flood forecast based on satellite technology at selected locations in Bangladesh. The site can be accessed at www.ffwc.gov.bd/index.php/hydrograph/gfs-based-forecast. The new flashflood system for the northeast region is online now at depts.washington.edu/saswe/flashflood and is being tested by FFWC and the Bangladesh Water Development Board. Researchers and technical staff of the relevant stakeholder agencies will continue their efforts to make further improvements in the sites and the overall flood forecasting capacity of Bangladesh. The PI also reports that he hopes to build on the new linkages created with other national agencies in the region to explore further opportunities for joint collaborative research on flood management within the Ganges-Brahmaputra-Meghna and Mekong Basin countries.

BANGLADESH - PROJECT 3-1: IMPROVING ADAPTATION AGAINST COASTAL VULNERABILITY AND ENHANCING FLOOD FORECASTING SKILL IN BANGLADESH THROUGH A SATELLITE DATA INTEGRATIVE MODELING FRAMEWORK IN A CHANGING CLIMATE

PI: Zahirul Khan, Institute of Water Modeling

U.S. Partner: Faisal Hossain, University of Washington (Funded by the National Science Foundation)

Dates: October 2014 - November 2017

PROJECT OVERVIEW

The two most sensitive geophysical processes that exacerbate coastal vulnerability in Bangladesh are sea level rise and land motion (uplift/subsidence). Incomplete knowledge of current and projected patterns of these factors is a key hurdle to converting scientific understanding into actionable knowledge. Improved understanding of these patterns is critical for enhancing long-term adaptation policies against coastal vulnerability in Bangladesh. Additionally, understanding the intra-seasonal dynamics of sea level in the estuarine regions is vital for better forecasting the recession phase of upstream flood waves draining into the Bay of Bengal. To address these gaps, this project implemented a satellite data-based integrative modeling framework in collaboration with the NSF Belmont-G8 project awarded to the University of Washington (UW). The project built on a long-standing capacity-building agenda for Bangladesh established by UW and the Institute of Water Modeling (IWM) since 2006. Under the leadership of PI Zahirul Haque Khan of IWM's Division of Coast, Ports and Estuary (CPE), the project studied sea level rise and land motion in coastal Bangladesh at select sites by combining satellite geodetic data with in-situ GPS/tidal measurements. The integration of satellite data (gravimetry, altimetry, and interferometry) was the first of its kind in Bangladesh, revealing accurate snapshots of current rates of sea level rise and land uplift/subsidence in coastal regions. Improved monitoring of downstream boundary conditions on water levels with water level sensors in the Meghna estuary enhanced flood forecasting skill from 8-day to 12-14-day lead times.

The involvement of IWM-Bangladesh as the lead institute in this NSF-USAID PEER initiative was crucial due to the existential threat of sea level rise to Bangladesh. The NSF-Belmont Forum 13-nation consortium, of which UW was a collaborating U.S. institute, did not include Bangladesh as a participating nation. The participation of IWM in the NSF BAND-AID project had previously been in-kind only, despite the critical role of IWM in addressing this existential issue for Bangladesh. Through human resource training of key IWM-CPE staff by Belmont G-8 institutions, IWM was intended to become an independent user and trainer of emerging satellite technology for cost-effective monitoring of sea level rise and land motion for the Government of Bangladesh. Improved intra-seasonal monitoring of water levels in the Meghna river estuary extended flood forecasting warnings to 12-14 days, enhancing proactive flood disaster management and agricultural planning. This project aimed to position IWM and Bangladesh as a regional training hub for satellite technology in hazards assessment and mitigation, significantly reducing future training costs for USAID.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the final year of this project, which was completed as of November 30, 2017, Dr. Khan and his colleagues worked to build on the results of the cyclone-induced storm surge hazard assessment and exposure analysis they had completed earlier in the project for nineteen severe cyclones. In particular, they completed a dedicated storm surge model for the 1991 cyclone that hit the Chittagong coast with a maximum wind speed of 225 kph during high tide. The simulation results highlighted the maximum surge height along the Chittagong coast and nearby islands and predicted the levels of increased surge heights that could be expected in 2050, given anticipated climate change effects. Sandwip Island could be especially hard hit by inundation. The team also applied an innovation in their mathematical model in order to assess the effectiveness of mangroves as a coastal barrier during cyclones. The model allowed them to test out the potential effects of planting mangroves in bands of various widths (50 to 1000m) along the shores of Sandwip Island and seeing how such plantings could affect the surge height at various points on the island. The results have shown differing impacts based on the width of the mangrove bands, bathymetry, and other geographic conditions. The team has concluded that reducing surge height even by a few centimeters in key spots could save thousands of lives, as well as property. Therefore, mangrove afforestation can play a vital role in coastal areas of Bangladesh as a barrier against cyclone-induced storm surge. Although the project has ended, the PI and his team will continue to work on publishing their results, upgrading their models, and further applying them in efforts to predict and mitigate future storm surges. The researchers are well positioned to make an impact, thanks to their close collaboration with crucial government agencies, including the Bangladesh Water Development Board, the Bangladesh Meteorological Department, and Water Resources Planning Organization, and the Survey of Bangladesh.

BANGLADESH - PROJECT 2-524: FIELD ASSESSMENT OF ARSENIC-BEARING WASTE TREATMENT OPTIONS

PI: Ahammadul Kabir, Asia Arsenic Network

U.S. Partner: Lutgarde Raskin, University of Michigan (Funded by the National Science Foundation)

Date: August 2013 – February 2016

PROJECT OVERVIEW

Water quality and supply issues in South Asia, particularly arsenic-contaminated groundwater and microbially contaminated surface water, are expected to worsen with climate change. Arsenic removal systems are essential for providing safe drinking water but generate arsenic-bearing wastes that can re-release arsenic into the environment. This project focused on managing arsenic-bearing waste to facilitate greater implementation of arsenic removal systems. Collaborating with researchers at the University of Michigan (UM) and consultants at Carollo Engineers, Dr. Kabir and his team evaluated field-scale arsenic-bearing waste management options. They analyzed arsenic wastes from two types of arsenic removal systems, evaluated alternative waste disposal options, and quantified the arsenic-transforming potential of microbial communities in disposal environments.

Mitigating arsenic contamination in drinking water in Bangladesh could improve millions of lives by reducing morbidity and mortality. This project provided region-specific recommendations for managing arsenic-bearing waste, enhancing the implementation of arsenic removal systems, and increasing the capacity of the Asia Arsenic Network (AAN) to provide clean drinking water. The study aimed to inform decisions on managing arsenic solids produced during water treatment to prevent recontamination. AAN's outreach experience was leveraged to communicate findings with local plant operators, community members, and policymakers. Training visits to UM were intended to boost AAN's research capabilities and water quality monitoring, with lab equipment upgrades enhancing the organization's ability to test for multiple pollutants, including arsenic and microbial contaminants.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project concluded in 2016 and received an Evidence to Action supplement in the following year to better disseminate results. In 2018, Dr. Kabir and his team distributed about 300 copies of an operations and maintenance (O&M) manual they created for arsenic iron removal plants and SIDKO plants. Recipients included plant caretakers, local government institution members, water workers, NGO staff, students, and water user committee representatives. The publication was well-received and expected to improve knowledge and practices related to O&M for arsenic removal technologies. The remaining 200 copies of the guidelines will be distributed in the coming quarter.

The project team also conducted train-the-trainers (TOT) sessions for water professionals and workers from various organizations. The objectives were to increase participants' knowledge of timely operations and maintenance, regular monitoring, arsenic content of water and sludge, the impact of sludge disposal, and minor fault repair procedures in the arsenic removal systems. Training methods included lectures, interactive presentations, and practical demonstrations. Three of the five planned TOT events were completed in the first quarter of the year, serving 62 participants (45 male and 17 female), with the remaining events scheduled for the coming quarter.

A significant aspect of the project involved orientation sessions for officials from local government institutions (LGI). The Union Parishad (UP), an LGI at the grassroots level in Bangladesh, significantly impacts various aspects of community life. UPs can raise awareness about the impacts of disposing of high-arsenic sludge and monitor arsenic removal systems and plant caretakers' actions regarding regular operations and maintenance. The PI and his team selected UPs as the third-party monitor for project outcomes. They oriented UP chairmen, secretaries, and male and female members on the importance of proper disposal of arsenic-bearing sludge, periodic and regular maintenance of treatment systems, and monitoring of removal technologies. Five orientation events were conducted during the first quarter of 2018, covering 71 participants (56 male, 15 female). Following the sessions, UP members enthusiastically began monitoring the maintenance of the arsenic removal systems.

Practical training for the arsenic plant caretakers themselves was another key element of this project. The training aimed to increase knowledge about the importance of arsenic-safe drinking water, O&M for arsenic removal technologies, regular backwashing, maintenance recordkeeping, and impacts of arsenic-bearing sludge disposal. Interactive presentations, discussions, and practical demonstrations were included in the training. Each system involved in the project had one male and one female caretaker participate. The theoretical part of the training was held in selected UP complexes, while the practical part was conducted at the nearest arsenic removal plant. The hands-on elements were particularly helpful for understanding O&M concepts and backwashing procedures. In the last quarter of 2017, six training events covering 56 caretakers were conducted. The remaining four events were conducted in the first quarter of 2018, covering 24 participants (12 male, 12 female). During the training, some participants mentioned difficulties in opening gate valves for system backwashing. AAN project staff found damages to some gate valves that could not be easily repaired. With PEER funds, the team covered the cost of extensive repairs to 16 plant gate valves and additional general repairs such as plastering and changing pipes and elbows.

This multifaceted demonstration project also strengthened collaboration between the Department of Public Health Engineering (DPHE), local NGOs, and companies that sell and install arsenic iron removal and SIDKO arsenic removal plants. Dr. Kabir reported that stakeholders were enthusiastic about the results and committed to regular backwashing and maintenance from the installation to reduce future environmental contamination risks. The involvement of LGIs in the orientation program created new prospects for motivating caretakers to perform regular backwashing. According to LGIs, most organizations providing arsenic removal technologies are reluctant to conduct training for caretakers and lack monitoring mechanisms. LGIs now demand that the activities carried out in this project be extended to other locations. They have committed to motivating caretakers for regular backwashing to improve water quality and reduce arsenic content in the sludge. The TOT sessions provided to water workers and professionals will ensure proper operations, maintenance, and regular backwashing of arsenic removal technologies in the project area.

The researchers conducted two additional TOT events in 2018 for water workers and professionals, monitored the arsenic content of sludge from 40 plants with the new backwashing procedures, and held a district-level consultation workshop on sludge disposal.

BANGLADESH AND THE PHILIPPINES - PROJECT 2 - 004: VALIDATION OF SALT TOLERANCE DETERMINANTS IN RICE (ORYZA SATIVA L. INDICA) LANDRACE HORKUCH AND ITS SEGREGATING POPULATION BY 2B-RAD SEQUENCING AND RNA-SEQ ANALYSIS UNDER STRESS

PI: Zeba Seraj, University of Dhaka, With Co-Pi Abdelbagi Ismail, International Rice Research Institute

U.S. Partner: Thomas Juenger, University of Texas at Austin (Funded by the National Science Foundation)

Dates: August 2013 - May 2016

PROJECT OVERVIEW

Bangladesh is the world's fourth-largest rice-producing country and is an enriched germplasm reservoir with 6,500 varieties of wild accessions, landraces, and modern varieties. Salt-tolerant rice landraces are of particular interest as donors of salt tolerance traits. The Bangladesh Rice Research Institute has released six slightly to moderately tolerant modern rice varieties, but for various reasons most have not be widely adopted by farmers. In view of the predicted increase in salinity levels in Bangladesh, more tolerant varieties are needed. Horkuch is a rice landrace popular with some farmers in the southwestern coastal areas in Satkhira, but it has low yields. Farmers in this area cannot grow modern high-yielding varieties due to salinity in the soil. Horkuch has been identified as salt tolerant at the seedling stage, and subsequently its yield-related traits under stress were also found to be superior. In order to determine exactly which genes from Horkuch could be integrated most productively into existing rice varieties, intensive study of the Horkuch landrace is essential.
As part of this project, next-generation sequencing (NGS) methods were used to map a population of several hundred individual plants in weeks rather than the usual months or years required. The ultimate goal was to develop a list of candidate genes to be targeted for introgression into popular but sensitive varieties of rice to make them more salt tolerant.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project aimed to identify, characterize, and validate the salt-tolerant determinants in the rice landrace Horkuch, popular among farmers in the southwestern coastal areas of Bangladesh, particularly Satkhira. This region is north of the Sundarbans and is known for its salinity stress. Using a reciprocal population derived from the tolerant Horkuch and sensitive IR29, the study aimed to locate genetic loci associated with salinity tolerance and sensitivity. Next-generation sequencing (NGS) tools were applied to identify loci, their linked markers, and genes related to salinity tolerance. By the project's completion in May 2016, several key focus areas were addressed.

The team discovered QTLs linked to tolerance by combining phenotype and genotype data (RAD genotyping) in both seedling and reproductive stages. A linkage map was produced, and QTLs were identified under stress at both stages. Several progenies in the F5 stage with multiple QTLs, including combinations from both stages, were identified. These plants will be further validated and incorporated into breeding programs in Bangladesh.

The researchers observed differential expression of genes in Horkuch, IR29, and their reciprocal populations (RNA-Seq) under salt stress in different tissues and stages. They identified notable differences in stress responses between tolerant and sensitive progenies. Combining expression and genotyping data, preliminary analysis revealed that under salt stress, most trans-eQTL hotspots were linked to genes involved in photosynthesis. Further analysis is ongoing.

The team completed whole-genome resequencing and transcriptome analysis of Horkuch and IR29, annotating over 70% of both genomes. These data, aligned with QTL and eQTL findings, are expected to provide insights into Horkuch's salt tolerance mechanisms.

Dr. Seraj and her team completed at least seven papers expected to be submitted for publication in the summer of 2016. Additionally, Dr. Seraj received two grants to continue the work initiated with PEER funds. The first, from the Third World Academy of Sciences, supports a project on drought and salinity-tolerant transcription factors. The second, from the Bangladesh Academy of Sciences and USDA, funds a three-year project on developing high-yielding, abiotic stress-tolerant rice. Summarizing the results and impacts, Dr. Seraj emphasized the excellent mentorship from the U.S. partner, which elevated the lab's standard of work. The team aims to publish seven research articles in prestigious international journals, significantly boosting Dhaka University's reputation. The findings are expected to propose a mechanism for Horkuch's salt tolerance, enhancing salinity tolerance breeding programs. The output is anticipated to lead to breeding programs incorporating multiple salt tolerance QTLs in single progenies, potentially producing greater tolerance levels.

Dr. Seraj notes that the mentorship of the U.S. partner has been excellent and has led to a standard of work previously unreachable by the lab before PEER. The team hopes to publish seven research articles in prestigious international journals from this PEER grant, bringing a tremendous boost to the reputation of Dhaka University. By the time all the papers are published, they will hopefully be able to propose a mechanism for salt tolerance of the traditional landrace Horkuch, increasing knowledge and enhancing salinity tolerance breeding programs. The output of this work is expected to lead to salt tolerance breeding programs incorporating multiple salt tolerance QTLs in single progenies, potentially producing greater tolerance levels.

PUBLICATIONS

Haque, T., Elias, S.M., Razzaque, S. et al. 2022. Salt tolerance QTLs of an endemic rice landrace, Horkuch at seedling and reproductive stages. Sci Rep 12, 17306 (2022). https://doi.org/10.1038/s41598-022-21737-9

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BANGLADESH - PROJECT 1-226: DEFINING THE ECOLOGY OF THE NIPAH VIRUS OUTBREAKS IN BANGLADESH: IDENTIFYING ADDITIONAL POTENTIAL FOODBORNE AND LIVESTOCK TRANSMISSION ROUTES

PI: Muhammad Salah Uddin Khan, Icddr
U.S. Partner: Peter Daszak, Ecohealth Alliance Inc (Funded by the National Science Foundation)
Dates: June 2012 - March 2016

PROJECT OVERVIEW

Nipah virus (NiV) is an emerging zoonotic virus (a virus transmitted to humans from animals) that causes high mortality in humans. In addition to human-to-human transmission, epidemiological studies have identified another possible transmission pathway, namely from fruit bats of the Pteropodidae family to humans when people drink contaminated date palm sap. Human NiV cases in Bangladesh have been found to be seasonal, coinciding with the date palm harvesting season (November to March), and consumption of date palm wine appears to serve as a major portal for infection due to contamination of palm sap from contact with urine or saliva from infected fruit bats.

In addition to foodborne transmission pathways, animals other than bats may play a role in transmission. The project team has previously studied livestock during outbreak investigations, and during the PEER grant, they sought to test the hypothesis that multiple species of animals (including dogs, cats, cattle, goats, horses, and pigs) may acquire and spread Nipah infection during an outbreak. The Bangladeshi and U.S. researchers developed sampling strategies and analytical approaches to assess the risk of infection via livestock and food-borne routes.

This project involved screening domestic, peri-domestic, and feral animals in a NiV outbreak to look for evidence of NiV infection. Furthermore, the researchers investigated bats' date palm sap drinking behavior year-round, in the locations where harvesters collect and ferment date palm sap for wine production. Beyond its research aspects, this project provided training in NiV surveillance, field sampling techniques, biosafety practices, and outbreak response for veterinarians under the Bangladeshi Department of Livestock Services, Ministry of Agriculture, and the Forestry Department.

FINAL SUMMARY OF PROJECT ACTIVITIES

Throughout the project, the team was able to collect a total of 1016 tree nights of observation, recording a total of 42,456 bats. The team also collected serum samples from 400 domestic (cattle, goat, horse) and 360 peri-domestic animals (rats, house shrews, cats, and dogs) from the Faridpur and Naogaon regions. Researchers were able to conduct an outbreak investigation at six different Nipah outbreak sites (Natore, Guibandha, Nauga, Rajshahi, Faridpur, Madaripur) and sampled bat roosts from those sites. All recordings and samples were reconciled to determine the seasonality of bats' feeding behavior in relation to the seasonality of Nipah virus transmission to humans in Bangladesh.

Researchers found in their study of bat date palm sap feeding behavior that Pteropus bats visited date palm trees more frequently during the spring and winter, perhaps due to lack of other available food. Feeding behavior could be one reason why the risk of Nipah infection to people has been concentrated in the winter season, even when fermented sap is consumed year-round. The researchers suggested that sap harvesters should regularly use skirts to prevent bats from contaminating the date palm sap to prevent Nipah virus and other bat associated zoonoses. They have published their findings in major international journals, with these research outputs continuing even several years after the PEER project ended.

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BANGLADESH - PROJECT 1-097: TOWARD GEOHAZARD ASSESSMENT IN BANGLADESH: ACADEMIC INFRASTRUCTURE AND KNOWLEDGE TRANSFER

PI: Syed Humayun Akhter, Dhaka University
U.S. Partner: Michael Steckler, Columbia University (Funded by the National Science Foundation)
Dates: May 2012 - May 2016

PROJECT OVERVIEW

Situated at the junction of three tectonic plates and overlying the world's largest delta, Bangladesh is one of the most natural disaster-prone countries in the world. This rapidly developing nation is undergoing rampant urbanization and has a population of more than 169 million (2021), almost half the population of the United States crowded into an area the size of Iowa. The country faces frequent water-related natural disasters, including widespread seasonal floods, recurrent tropical cyclones with large storm surges, river erosion and channel avulsions, permanent land loss from sea level rise, and natural groundwater arsenic. These have overshadowed the severe hazard from rare but devastating earthquakes.

To address seismic and other natural hazards, this project focused on creating a sediment sample and data storage facility and transferring knowledge to the local geoscience and engineering communities through training courses. The goal was to increase local capacity to evaluate and mitigate hazards, while also contributing valuable data and insights to the U.S. partner's ongoing National Science Foundation (NSF)-supported research.

At the time the project began, there was no place to archive sediment samples in Bangladesh. Encouraged by the success of the small seismology training facility previously established under a PEER pilot program grant, this project renovated, furnished, and equipped space donated by Dhaka University into a fully functioning center. The first contributions were expected to be samples from the more than 250 wells being drilled as part of the U.S. partner's NSF-funded project. The sample repository will be open to all Bangladeshi researchers to store samples and analyze results regarding a multitude of hazards, including earthquakes, sea level rise, land subsidence, arsenic contamination, and river avulsions.

The project workplan also involved several training workshops in Bangladesh on earthquake geology, seismic processing and interpretation, and seismic hazard mapping and its role in disaster risk. This will help establish a new line of research in Bangladesh to help trainees begin a coordinated countrywide effort to recover the geologic record of earthquakes in Bangladesh and create a new generation of students able to apply earthquake geology techniques. Through creation of the new center and the associated training activities, the project should also help to bring up-to-date knowledge to geoscientists, engineers, and government administrators in Bangladesh in order to integrate these disparate groups and facilitate resilience against seismic hazard threats.

FINAL SUMMARY OF PROJECT ACTIVITIES:

Thanks to PEER funding, the PEER project team purchased a laser particle size analyzer and a handheld X-ray fluorescent (XRF) analyzer. Students and teachers were given initial training on these tools by engineers from their respective companies. Graduate students used both tools for their research.

The researchers completed their renovation of the lab, receiving and organizing sediment samples from the U.S. partner's BanglaPIRE project and from other organizations. With the help of the U.S. partner, the team also purchased and installed a server to develop a database of sediment samples archived in the repository. The team received more than 15,000 sediment samples from 419 bore holes drilled along 19 transects across deltas in Bangladesh, building a first-of-its-kind archive in the country.

The grantees successfully organized three training workshops and two seminars. In the first 10-day training course, 20 participants learned about seismic data interpretation using professional software. The workshop included two days of learning about theoretical aspects of seismic reflection data processing and interpretation, and eight days of hand-on training. The second training course, on the topic Earthquake Geology and Paleoseismology, involved lectures, lab work, and a day of fieldwork at the coastal belt of Teknaf. The participants learned how to identify historical earthquakes from landforms and neotectonics, demonstrating in the field the systematic procedures for collecting field data and sampling for dating earthquake events. During a third training on XRF and Laser Particle Size Analyzer Instrument Operation and Data Interpretation, participants learned the operation and use of XRF spectometers and laser particle size analyzers through lectures and hands-on training. Students used sediment samples from the project's sample repository for analyses.

A variety of researchers and visitors from different organizations have shown interest in the new soil samples and the PI's work. The Bangladesh Water Development Board (BWDB) has given sediment samples to the repository. After hearing about the Multichannel Seismic Processing and Interpretation training program, officials from an international oil company provided stipends to two Master's students to work with their seismic reflection data using the Kingdom Suite software. The PI also presented at the American Geophysical Union Fall Meeting in 2015.

PUBLICATION

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BANGLADESH - PROJECT H1-125: EVIDENCE-BASED KNOWLEDGE INTO PRACTICE: EXTENDING A SUCCESSFUL MATERNAL, NEONATAL, AND CHILD HEALTH PROGRAM IN MATLAB INTO THE GOVERNMENT HEALTH SYSTEM IN BANGLADESH

PI: Anisur Rahman, International Centre For Diarrhoeal Disease Research, Bangladesh (Icddr,B)

U.S. Partner: Randall Kuhn, University of Denver (Funded by the National Institutes of Health)

Dates: October 2013 - December 2017

PROJECT OVERVIEW

Despite widespread poverty and malnutrition, progress towards achieving the MDGs for child (MDG 4) and maternal (MDG 5) health in Bangladesh is encouraging. However, maintaining the pace of mortality reduction is challenging. Neonatal deaths contribute about 43% of under-five mortality, and the reduction pace is slow compared to post-neonatal and childhood mortality. In the rural Matlab Upazila of Bangladesh, icddr,b has maintained a health and demographic surveillance system (HDSS), operated a field hospital, and tested intensive in-home outreach and service delivery strategies on maternal and child health. In 2007, icddr,b introduced a successful integrated Maternal, Neonatal, and Child Health (MNCH) model into its existing intensive treatment area, achieving a 36% reduction in perinatal mortality within a short time.

The Maternal, Neonatal, and Child Health Extension (MNCH-Ext) Project aimed to extend these services to the remaining parts of Matlab, where the population receives care from government health facilities similar to the rest of the country. The overall goal was to implement evidence-based maternal and neonatal interventions through a functional and responsive primary health care service delivery system to improve perinatal health in Matlab. The study interventions focused on strengthening the primary health care system by addressing health system building blocks, such as improving governance, human resources (training and quality improvement), ensuring supplies, enhancing the health delivery system, improving information systems, and working with the community to create demand for uptake of interventions.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project began with a series of health facility surveys and gap analysis that took place in November - December 2015. The team conducted a series of focus group discussions (FGDs) and in-depth interviews (IDIs) to understand the gaps related to the existing services. The participants included in the discussions and interviews were selected from community and facility level health workers with the aim to understand the: (i) existing gaps in the availability of evidence-based maternal and neonatal interventions; (ii) to identify the challenges for offering high-quality MNH interventions at community and facility levels; (iii) to determine the needs for introducing the high impact MNH interventions which are not existing in the current system; and (iv) to identify the gaps in documentation and reporting of data. The team conducted 7 FGDs (71 participated) and 12 IDIs.

The gap analyses highlighted the need to: a) Implement appropriate methodology to determine accurate number of pregnancies within the study population; b) Work with opinion leaders within the government sector to encourage the idea that government sector can achieve high outcomes without additional resources. c) Have a clear check-list (and goals) of antenatal and post-natal care counseling and services available to all staff across the continuum of care; d) Establish accountability and reporting mechanisms based on this shared understanding; e) Determine if patient tracking /communication across different facilities is possible; f) Determine if/how to address lack of transportation for hospital referrals; g) Determine how to account for availability or lack thereof of C-section delivery at UHC.

Subsequently, a study was established to implement community and facility-based interventions. The community intervention was accomplished by engaging village health workers- Family Welfare Assistants (FWAs) and Health Assistants (HA) from the Director General of Family Planning (DGFP) and the Director General of Health Services (DGHS), respectively and covered the following interventions: Pregnancy identification; Pregnancy Home Visits (PHV) 1 and 2: PHV1 took place during 12-14 weeks of gestation, and the PHV2 visits during 32-34 weeks of gestation. During the visits health workers assessed the pregnant women's wellbeing and counseled on birth preparedness and maternal and neonatal danger signs. Postpartum Home Visits (PPHV) took place in 0-3 days of delivery and a second took place after 7 days. During these visits, the health workers also assessed the well-being of mothers and their babies and provided appropriate management of sick mothers and baby, if needed; Distribution of delivery kits including the delivery mat to early diagnoses of post-partum hemorrhage; Distribution of misoprostol to be used during delivery; Distribution of health cards; and training FWAs and FHs from the intervention area on pregnancy identification and home visits.

The team also conducted interventions at the facility level, including:

- Facilitated 24-hour emergency obstetric care by training two doctors on anesthesiology and two for obstetrics.
- Trained medical officers and nurses from two sub-district level hospitals and from a tertiary level hospital on EmONC.
- Kangaroo mother training and establishment of KMC unity in the sub-district level facility.
- Helping Baby's Breath training to all staff in the sub-district level hospitals.
- Training on ANC, PNC and normal delivery to health care providers from community clinics and Family Welfare centers.

Additionally, the project collected information related to the evaluation of the study through baseline and end-line surveys. They surveyed to understand the pregnancy outcome listings and the current pattern of health care seeking behavior. This was needed to understand the distribution of stillbirth and neonatal mortality, and the pattern of antenatal and delivery care among the women in the study areas. With the end-line survey, the team performed the data collection similar to the baseline survey to compare the study outcomes.

The intention-to-treat analyses showed significant improvement in increasing the ANC coverage due to intervention. However, no association was observed in perinatal mortality rates.

BHUTAN

BH-006: HEALTH-RELATED QUALITY OF LIFE AND PSYCHOLOGICAL WELL-BEING AMONG PEOPLE LIVING WITH HIV IN BHUTAN

PI: Nidup Dorji, Faculty of Nursing and Public Health, Khesar Gyalpo Unviersity of Medical Sciences of Bhutan
U.S. Partner: Kaveh Khoshnood, Yale School of Public Health
Dates: April 2022 - June 2023

PROJECT OVERVIEW

Only an estimated 55.5% of people living with HIV (PLHIV) in Bhutan are diagnosed, one of the lowest diagnosis rates in the world. Government and civil society stakeholders hypothesize that high stigma and poor quality of life impede the ability of Bhutanese PLHIV to move through the HIV cascade of care (CoC). However, little is known about how PLHIV in Bhutan experience stigma and discrimination and how these factors influence quality of life through the CoC. Studies support the benefits of psychosocial interventions to improve quality of life and HIV CoC outcomes, and support and respect gained from family and friends is known to buffer negative psychological states. A key principle of public health intervention design and implementation science is that psychological interventions must be tailored to the needs of the target population, which is least known about PLHIV in Bhutan.

As formal research on HIV in Bhutan is virtually non-existent, this PEER project sought to build a robust research culture focusing specifically on the HIV epidemic in the country. It aimed to inform policymakers, healthcare providers, counselors, family members, relatives, and the general population about the experiences of PLHIV and the influence of these experiences on their QoL and HIV management. Findings from this research were intended to enable policymakers, healthcare providers, and PLHIV to come together to curb the HIV epidemic, promote quality of life, and mitigate the negative consequences associated with HIV. Financial and technical assistance from PEER and the partners from Yale University helped build a robust research culture and generate scientific evidence to create locally tailored interventions to address the determinants of HIV incidence and lack of uptake of care.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team interviewed 455 people living with HIV, about half male and half female, across multiple study sites throughout Bhutan. The PI Nidup Dorji, co-PI Wangchuk, and their colleagues conducted preliminary data management and analysis. They also trained 45 volunteer counseling and testing focal persons and Health Information Service Center counselors as research assistants (RAs), including training on data management and analysis. Five of the RAs from Thimphu, Phuntsholing, Gelephu, Zhemgang, and Samdrupjongkhar, where the maximum numbers of PLHIV were interviewed, were invited to take part in the final project workshop and were crucial in helping clean the data, checking on double entries and authenticating missing information.

The researchers' findings included that a majority of PLHIV interviewed were low-income and almost 90% of participants reported adherence to antiretroviral therapy and had their viral load suppressed. More than 80% of participants reported mid-level stigma but 70% reported their quality of life to be good or very good. Participants who reported their general health conditions as good to excellent and perceived themselves to be in better health compared to a year ago reported better quality of life and wellbeing. Those who perceived a mid or high level of stigma and experienced some form of discrimination scored low quality of life and wellbeing. Adverse childhood experiences such as sexual and/or emotional abuse, living with violence in a household, parental separation or divorce, and bullying were significantly related with quality of life and wellbeing. A dose-response relationship also was found between cumulative adverse childhood experiences and quality of life.

In April 2023, Dr. Dorji and Mr. Wangchuk traveled to the Yale School of Public Health to discuss findings, conduct advanced statistical analyses with their U.S. partner Dr. Kaveh Khoshnood and other counterparts, and plan for the dissemination of the findings. Dr. Khoshnood also visited Bhutan in May 2023, conducting a workshop on strengthening research collaborations, identifying funding opportunities, and pursuing networking and innovations. The workshop was attended by the teaching faculty and final year students at the School of Nursing and Public Health of the University of Medical Sciences of Bhutan.

The PEER team disseminated their findings to various healthcare centers in eastern and east central Bhutan. A total of 52 VCT focal persons, including medical doctors and nurses from regional hospitals, attended two dissemination workshops. The Minister of Health of Bhutan and officials of the ministry's National AIDS Control Program are aware of the study and the team's findings, which should be useful in informing policies for better care delivery to PLHIV. The study is particularly important, as it was the first ever undertaken directly involving PLHIV since the detection of the first HIV case in Bhutan in the early 1990s.

BH-009: BUILDING A HARMONIOUS HUMAN-PRIMATE SOCIETY: A CITIZEN SCIENCE BASED PRIMATES CONSERVATION RESEARCH IN BHUTAN

PI: Kuenzang Dorji, Nature Study Center (Bhutan Primates Conservation Society)
U.S. Partner: Lori Kay Sheeran, Central Washington University
Dates: April 2022 - June 2023

PROJECT OVERVIEW

Most of the Bhutanese population (80%) depend on farming, but they are challenged by the small size of each farm holding, climate change, and crop depredation by wildlife. Primates (mostly Bhutan's three macaque species) destroy crops across the country, with an overall damage extent greater than all deer species combined, in part because macaques' generalist diet allows them to eat all crop varieties. Annually, farmers lose 20-30% of their crops to wildlife, affecting peoples' food security and the country's overall agricultural system. The impact is more severe for women, who are often responsible for running farms while men are employed as carpenters or construction workers. This PEER project aimed to improve Bhutan's agriculture and food security sectors by gathering data on the understudied area of human-monkey interactions, as the country's seven primate species are increasingly encroaching on farms, as farmers shift their cultivation of cash crops. This project sought to mitigate negative impacts of interspecies contact, create educational outreach on primates' ecological role in Bhutan, and produce the baseline data needed for conservation actions on behalf of primate species poorly known to science.

The researchers mapped human-primate association hotspots for Bhutan's primates, piloted deterrents to monkeys damaging crops, initiated planting of crops to enhance farmers' incomes and to provide a buffer between the forest and farms, and installed signs to reduce fatal accidents with wildlife on roads. The PEER project also built primate conservation research capacity in university students and involved residents through educational outreach developed in partnership with community leaders—primarily women as non-formal educators and heads of households and monks as spiritual leaders. The project was based in rural communities where there is scarce access to educational opportunities, and the researchers relied on the expertise of local foresters, who are based in regions over the long term and therefore are aware of the wildlife issues local people face. The project also built-up professional capacity of foresters through educational programs.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team supported primate-focused research conducted by five Bhutanese undergraduate students enrolled at the Royal University of Bhutan College of Natural Resources. The students completed projects focused on ecology, human interactions, distribution, and predation pressures of golden langurs and Assamese macaques. The students collaborated with team members to write up their results or continue research and undertook training in primate survey protocols and research ethics prior to collecting field data.

The PEER team trained 38 foresters in primate survey methodologies before embarking on a week-long field expedition to collect socioecological data. The training enabled the foresters to coordinate and assist, as well as collect field data using online data collection apps. Foresters from Bumthang, Dagana, Sarpang, Tsirang, and Zhemgang forest divisions, as well as Jigme Singye Wangchuck National Park, Royal Manas National Park, and Phibso Wildlife Sanctuary, participated and strengthened collaborations with eight forestry field offices. The researchers and foresters took on a variety of education outreach activities in communities living with monkeys, including sharing basic information about golden langur ecology and wildlife identification in ten rural schools in regions with low adult literacy rates, reaching 600 students across a wide range of ages. The PEER team also met monks in these areas and received feedback from them on community-level information.

With the assistance of local forestry staff, the team worked with approximately 200 farmers in Trongsa and Zhemgang districts, focusing on women whose farms were adjacent to forests and who had previously reported issues with crop damage. Forestry staff interviewed farmers to learn more about their views of problematic wildlife and recommended farm sites to deploy wildlife deterrent devices. Two types of deterrents were tried. Both use electricity and rely on vocalization files on a thumb drive hooked to a speaker. Approximately 100 farmers, particularly women as household heads, were able to harvest 80-90% of their produce from the farm thanks to the team's interventions. Local foresters know places on the highway where wildlife and car collisions occur. Based on the foresters' survey and knowledge, the team installed signs to alert drivers to the possible presence of golden langurs and other wildlife.

Perhaps the most significant outcome of this project is research-based documentation and mapping of human-primate negative interaction hotspots and the resulting practical research findings. The researchers' model showed that Zhemgang District is one of the primate hotspots in Bhutan. The national tourism flagship program highlights Zhemgang as a tourist hub due to its high floristic and faunal diversity. Stakeholder and other consultative meetings with the PEER team helped shift mindsets, identifying the important role monkeys play in the ecosystem and in potential income generation through ecotourism. Like other local celebrations, residents have proposed organizing a monkey festival to promote these animals' importance and conservation.

The U.S. partner Dr. Lori Sheeran and her graduate student Ms. Kelsie Strong visited the PEER team during the project period, validating data on primates and recorded more than 500 individual primates in various habitat types in 12 days. In addition, they met with field foresters, school children, women's groups, and a student research fellow from the College of Natural Resources.

The PEER project team was awarded two additional grants for their work, including a $63,000 grant from the Ocean Park Conservation Foundation Hong Kong.

BH-012: IMPACT OF CLIMATE CHANGE ON ALPINE TIMBERLINE AND ITS SOCIO-ECONOMIC IMPACT ON HIGHLANDER IN BHUTAN

PI: Changa Tshering, Ugyen Wangchuck Institute for Conservation and Environmental Research
U.S. Partner: Steven William Running, University of Montana
Dates: April 2022 - March 2024

PROJECT OVERVIEW

Timberline is one of the most conspicuous boundaries between forest and alpine. In Bhutan, this region is considered more vulnerable to climate change due to amplified warming and the presence of marginalized communities. The existing research from these areas has mainly focused on glacier melts, snow cover dynamics, glacier lake flood, and field monitoring of alpine vegetation. Very few empirical studies have been conducted to assess how timberline has advanced or retreated in response to climate warming in Bhutan, due to challenging and inaccessible topography and lack of professional capacity. Increasing availability of satellite data and cloud computing platforms offers new opportunities to monitor timberline dynamics more consistently, reliably, frequently, and with fewer resources. The Google Earth Engine, a web-based platform, provides access to an entire archive of Landsat data and high computing speed to process data without the need to download the satellite data. In addition, its capability to apply standard and uniform change detection algorithms to Landsat data over multiple years ensures the consistent and reliable comparison of forest cover change over decades.

The main goal of this PEER project was to compare the forest cover from 1980 sequentially, by decade, with the current forest cover. Dr. Changa Tshering and his group sought to quantify and monitor the shift in alpine timberline in the Bhutan Himalaya. The project provided crucial evidence on the timberline's response to climate change and assessed its threats to some of the highly endemic and endangered alpine biodiversity. In addition, the project included a socioeconomic research component aimed at understanding how the vegetation shift has forced changes in the livelihoods of alpine nomadic herders.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers analyzed satellite image data to determine tree line ecotone shift over a period of decades. Fifteen project staff were trained on the use of Google Earth Engine to study landscape dynamics. The PEER team also undertook biophysical field data collection from the Merak and Sakteng regions of Eastern Bhutan. This collection was designed to validate satellite image analysis findings.

In addition to collecting vegetation data, the field team also carried out tree coring and collected tree ring data from these regions to understand tree stand establishment in the research sites. Around 20 unemployed youths from the area were recruited as field data collectors for one month and were trained in ecological survey methods and dendrochronological coring.

In the complementary social science component of the project, the PI led socioeconomic survey training for 14 youths in Merak and Sakteng, and with their help, he and his colleagues completed a survey of 228 households in that locality. While in the area, the researchers also carried out some additional drone mapping of their sample area. In Laya, they trained 10 youths and surveyed 160 households even though their visit coincided with a four-day heavy snowstorm.

The PI visited his U.S. partner in Montana during the project period to carry out satellite data processing and analysis. The PEER project provided support to purchase equipment like drones and GPS for conducting field surveys, improving the infrastructure for future efforts. The team continues working to draft papers on their work even now that the project has ended.

BH-022: ENHANCING FOOD SECURITY OF SMALLHOLDER FARMERS IN BHUTAN THROUGH BUILDING CAPACITY IN CLIMATE-SMART AGRICULTURE

PI: Rekha Chhetri, College of Natural Resources, Royal University of Bhutan
U.S. Partner: Sarah Halvorson, W.A. Franke College of Forestry and Conservation, University of Montana
Dates: April 2022 - June 2023

PROJECT OVERVIEW

Despite contributing little to its cause, climate change impacts are being increasingly felt in Bhutan, particularly in the agriculture sector. The impact could worsen if the future climate scenarios of the Himalayas projected by various climate models are to come true. The current climate variability has reduced crop production and threatened food security, which was further amplified during the COVID-19 pandemic. To address the impacts of worsening climate scenarios on food systems, the Government of Bhutan is urging the adoption of smart agricultural practices so that food security would not be compromised. However, Bhutan has not been able to achieve much so far due to limited funds, expertise, and research.

This PEER project on climate-smart agriculture (CSA) researched indicators of smallholder farmers' vulnerability to climate change, farmers' perceptions on challenges and benefits of CSA practices in the project areas and farmers' willingness and preference to adopt CSA technologies. The project also included capacity building through training and supply of basic materials to stakeholders to implement the CSA technologies and practices, strengthening smallholder farmers' capacity to respond to climate change impacts. The team sought to generate data to make informed policy decisions on CSA and location-specific CSA tools and practices. Targeted farmers were encouraged to share their skills and knowledge with other interested farmers to broaden community participation.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team surveyed 248 randomly selected farmers from Chhimoong, Chongshing, and Yurung Gewogs in Pemagatshel District in Eastern Bhutan. The researchers' findings highlighted the importance of small-scale animal husbandry, specifically certain cattle breeds, and cultivation of less common cereal crops. Typical non-farm winter activities in the study area were weaving, wage labor, and brewing Ara (local alcohol). The top five challenges identified by farmers included pests and diseases, conflicts with wildlife, a lack of irrigation water, labor shortages, and post-harvest losses. Farmers also reported an increase in windstorms, hailstorms, and crop losses. Farmers had adopted or were willing to adopt CSA practices like seed saving, using farmyard manure, planting a mix of crops, improving crop varieties, and integrating livestock on the farms. Most farmers relied on extension personnel for agricultural information and had limited access to most of the technologies and training related to CSA. The PEER team's resource mapping study helped them identify the gaps in enhancing the livelihood of resource-poor farmers in a sustainable manner.

The PEER team undertook an intervention with farmers through field visits to agriculture research centers and other farmers' fields, where they were exposed to new technologies in agriculture, and had hands-on skill development activities led by both researchers and progressive farmers who have already adopted some of the practices and technologies. To help the farmers implement the skills and knowledge they gained, the PEER project supplied them with various equipment, including a diesel engine for cornflake production, a stainless-steel combined rice milling machine, water tanks, and irrigation piping.

The U.S. partner Dr. Sarah Halvorson visited the PI Dr. Rekha Chhetri and her team in Bhutan to discuss future collaborations, visit farmers undertaking CSA practices, and conduct short training courses on Research Design and Fundamentals of Proposal Writing. During her visit, the team visited farmers who had taken part in the intervention, including two locations where Dr. Chhetri and her colleagues had previously installed ultraviolet-resistant water tanks to collect rainwater along with pipe and drip irrigation kits. The team also observed farmers implementing the CSA practice of intercropping legumes with potatoes, which they learned during their project-sponsored farmers' field visit, as well as making their own organic fertilizers by composting leaf litter and other farm wastes, including cow urine and biomass.

As a result of their joint project monitoring exercise, the team saw the project plans were successfully implemented or were in the process of implementation as per the plan. All farm equipment and inputs required by the farmers in the project areas for implementation of the project activities had safely reached their recipients, and the beneficiary farmers and local agriculture extension officials were all happy and grateful for the generous support. The project was only designed for one year, which could be deemed too short to show bigger impact, particularly in the agriculture sector. However, this was not the case with the current project, as Dr. Chhetri notes that she and her colleagues could already see farmers implementing the new lessons they had learned. In addition, the farm machines and materials that were supplied could contribute to addressing the challenges of food security in the years to come. The project team, while deeply happy with the success of the project, will continue seeking additional funds and projects to build on this initiative. They see a huge potential to up-scale the activities and continue to improve the livelihood of Bhutanese farmers in the face of changing climate.

In June 2023, the PEER team published a book about their project, which may be downloaded through the link below.

PUBLICATION

Tashi Dendup, Sonam Tashi, Rekha Chhetri, Ugyen Yangchen, and Sarah J. Halvorson. 2023. Smallholder Farming and Climate-Smart Agriculture: A View from Pemagatshel Districtv. ISBN : 978-99936-994-6-0

BH-025: UNDERSTANDING OF SOURCE WATERS AND RECHARGE MECHANISM OF MOUNTAIN SPRINGS AND STREAMS IN RADHI AND PHONGMEY GEWOGS IN TRASHIGANG, BHUTAN HIMALAYA

PI: Tshewang Dendup, Centre for Science & Environmental Research, Sherubtse College, Royal University of Bhutan

U.S. Partner: Fengjing Liu, College of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI

Dates: April 2022 - June 2023

PROJECT OVERVIEW

Mountain springs and streams are primary source water for millions of people in rural communities of the Himalayas for their drinking, domestic, and agricultural needs. Climate change, population increase, and economic development are mounting pressures on available water resources from springs and small streams in the region. A Bhutanese government report has indicated that flows in about 35% of springs in the country are declining, while 2% of them have completely diminished. Although Bhutan has high per capita water use capacity, most rivers and streams are inaccessible. Therefore, it is imperative to gain insights into spring and small stream generation, which is otherwise poorly understood in the region.

This PEER project sought to provide crucial information on sources and recharge mechanisms of perennial springs and streams used by local communities, with the aim of developing better water resources management and evaluation of climate change impacts on the livelihoods of these communities. The researchers combined field sampling from springs, streams, rainwater, snowmelt, and soil water with mathematical modeling using stable isotopes and geochemical tracers. The information from this study was anticipated to support informed decision-making for springshed management plans and help understand the long-term impact of climate change on the fate of mountain springs and small streams.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project focused on two tributary catchments, the streams Yude Ri and Dungju Ri, within the Gamri watershed in Eastern Bhutan. The researchers conducted a field survey to map the hydrology and select sample sites. They collected a total of 454 water samples monthly from various sources, including main streams, tributary streams, springs, natural ponds, rainwater, and soil water, providing essential data for understanding water dynamics in spring flows. They also measured water level and stream discharge from August 2022 through January 2023 and identified variations in streamflow, with the highest flow during the monsoon season and receding flow in the post-monsoon period.

The team's geochemical analysis of water samples revealed significant variations in solute concentrations among different water sources, with precipitation showing lower solute concentrations compared to spring water and soil water. The researchers used End-Member Mixing Analysis (EMMA) to determine the contributions of various water sources to spring flows. They found that direct precipitation (snowmelt and rainfall), soil water, and groundwater were the primary sources of spring flows and quantified their contributions to spring flow for all springs.

The project made substantial contributions to education by offering comprehensive training opportunities. Participants like Mr. Sonam Tobgay and Ms. Namgay Dema, assistant lecturers in Chemistry at Sherubtse College, were involved from the project's inception and received specialized training in various fieldwork techniques and analytical methods. Forest officers and laboratory assistants also underwent training, while third-year Chemistry BSc students at Sherubtse College benefitted from supplemental training, enriching their undergraduate program. The project's impact extended to the design and construction of essential equipment for collecting soil water and groundwater. These custom-designed tools proved instrumental in practical learning experiences for first-year BSc in Environmental Science students and found potential utility in Forestry and Agriculture programs (e.g. soil nutrient analysis of the cropland or forest) within the Royal University of Bhutan. Additionally, the acquisition of research equipment, including a portable flowmeter and cold storage refrigerator, ensured long-term benefits. International partnerships were also strengthened. The PI Tshewang Dendup and co-PI Dendup Tshering visited their U.S. partner Fengjing Liu in Michigan to collaborate on data analysis, modeling, and planning for report writing in April 2023, and in June Dr. Liu paid them a visit in Bhutan, during which he assisted with a training workshop and took part in field site visits.

Tshewang Dendup and his colleagues presented their preliminary findings presented virtually at the Assembly of the American Geophysical Union in December 2022, as well as through other workshops. The PI joined Water Research Bhutan (WRB), an informal scientific society focusing on the promotion of research and management of water in Bhutan. WRB publishes a monthly technical article in one of the newspapers in Bhutan, on issues related to freshwater and associated ecosystems, biodiversity, and hydrogeology, and the PI contributed two articles that closely align with the PEER project.

The Trashigang Forest Division Office, which collaborated on the PEER effort, is piloting a project as part of an initiative to revive drying water sources in Bhutan. The team shared their findings and provided basic training to foresters on methods for determining groundwater sources or origins using geochemical and isotopic tracer techniques, which appears to be effective for such a study in complex mountain terrain. Although the PEER project ended on June 30, 2023, its impacts continued to be felt afterwards. The PI was invited to participate in the national consultative meeting on "Managing Cryosphere and Water Risks in Bhutan," held August 9-10 in Bhutan. The event was organized by the National Centre for Hydrology and Meteorology (NCHM), Bhutan in collaboration with the International Centre for Integrated Mountain Development (ICIMOD) based in Nepal. The PEER team is well positioned to explore the scope for cooperation with these and other national and international organizations in the areas of cryosphere analysis, disaster risk reduction, and water resource management, and they also hope to continue collaborating with Dr. Liu as well.

BH-035: BASELINE DATA FOR FRESHWATER BIODIVERSITY CONSERVATION IN THE FACE OF CLIMATE CHANGE IN PUNATSANGCHHU BASIN IN BHUTAN

PI: Tshering Dorji, College of Natural Resources, Royal University of Bhutan
U.S. Partner: Paul Frandsen, Brigham Young University
Dates: April 2022 - June 2023

PROJECT OVERVIEW

Climate change is impacting freshwater biodiversity through higher water temperatures. The impact can vary over altitude and between streams affected by human disturbance (e.g. agriculture). Conservation plans for freshwater biodiversity require baseline data like water temperature and air temperature, water quality parameters, and biodiversity distribution data. Macroinvertebrates (a ubiquitous and diverse group) are used as model indicators for biodiversity. These indicator organisms are most useful when identified to species, frequently done with the help of DNA barcoding.

In Bhutan, there had previously been no baseline data available on seasonal water or air temperature along riparian zones and no comprehensive data on macroinvertebrate diversity along altitudinal gradients. This PEER project therefore aimed to collect and analyze data on species-level macroinvertebrate diversity within the Punatsangchhu Basin from both undisturbed (forested) and disturbed (agricultural) streams along an altitudinal gradient of 3500 meters above sea level (MASL) in the Bhutan Himalaya. The team built a DNA barcode database of macroinvertebrate specimens, the first of its kind in the Eastern Himalaya, and a macroinvertebrate reference collection in the laboratory of the College of Natural Resources, the only institute in Bhutan where conservationists and environmentalists are trained. Collectively, the findings were anticipated to complement the ongoing efforts by freshwater ecologists around the world trying to understand the impacts of climate change on mountain stream biodiversity and provide key data from the Eastern Himalaya for global DNA barcode reference databases.

Environmental conservation is one of the four pillars of Bhutan’s development philosophy, “Gross National Happiness.” However, hydropower is the highest revenue earner and subsistence agriculture the largest employer in Bhutan. Both are directly dependent on freshwater streams and rivers but also can have negative impacts on river ecosystems. The findings from the project were anticipated to provide vital data on freshwater biodiversity for the National Biodiversity Centre and other agencies like National Environment Commission to help frame national policies for biodiversity and ecosystem conservation. Furthermore, the findings were expected to serve as baseline data for long-term monitoring of the impact of agriculture on freshwater diversity.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Tshering Dendup and his team completed field visits to selected stream sites, installing temperature data loggers, and collecting macroinvertebrate samples. Across the visits, they replaced loggers previously lost in flash floods and relocated others likely to be spotted and taken or that were at risk of exposure due to drying up of streams or change of stream course. The researchers collected water and air temperature data for 30 streams for six months. The team also engaged 29 first- and second-year students from their university and two laboratory assistants to help sort and identify specimens as part of their hands-on training, completing identification of samples from the orders

Odonata (dragonflies and damselflies), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), among others. The team DNA barcoded 350 specimens collected in these streams, providing a solid baseline for future monitoring of climate change and its impact on freshwater biodiversity.

The PI visited his U.S. partner in Utah, working at Dr. Paul Frandsen's laboratory, receiving tailored hands-on training on DNA barcoding techniques, and participating in in-depth discussions on future project activities and manuscripts. In addition to the research advances and human capacity development, the new equipment procured for the project has also benefited undergraduate and graduate students' research activities, carrying out their project work related to aquatic ecology. Although the project has ended the researchers continue analyzing their samples and data and preparing manuscripts for publication.

BHUTAN - PROJECT 4-187: MONITORING FOREST COVER CHANGES IN BHUTAN USING LANDSAT DATA IN A CLOUD-COMPUTING ENVIRONMENT

PI: Kinley Tshering, Ugyen Wangchuck Institute of Conservation and Environment
U.S. Partner: Kevin Megown, Remote Sensing Applications Center (Funded by the United States Department of Agriculture/ Forest Service)
Dates: November 2015 - September 2018

PROJECT OVERVIEW

The National Forest Policy of Bhutan requires the country to maintain 60% forest cover, but there is increasing deforestation, degradation, and diversion of forest land due to population and development pressures. The Bhutanese government has faced challenges in getting reliable estimates of changes in forest cover over time and keeping track of where actual changes are happening on the ground. Meanwhile, the expanded availability of satellite imagery has led to an explosion of analysis algorithms that are based on the pixel rather than global image statistics, making it possible to examine the state as well as the dynamics of biophysical systems. This pixel-based view of image processing is a fundamental shift in the way remote sensing analysis is performed.

A key scientific objective of this PEER project was to exploit forest cover-related data for Bhutan in the Landsat data archive using Google Earth Engine (GEE). This approach had not previously been applied to detection and monitoring of forest cover change in Bhutan, as well as adjoining countries in the Hindu Kush Himalayas. Forest cover change is an important indicator for not only ecosystems but also for livelihood systems in Bhutan because the predominantly rural population still depends directly on adjoining forests for their daily needs. Spatial and temporal data on changes in forest cover will be key to ground implementation of policies concerning sustainable development and livelihoods, management of natural resources, environmental conservation, and ecosystem services, especially in rural Bhutan.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team produced maps that showed changes in vegetation cover over the years and tracked incidences of previously unknown vegetation change. Researchers can now easily detect changes in the density of vegetation, severity of burnt areas, areas infested by pests and diseases, grazing areas, major landslides, and any other land cover changes. To check the accuracy of their satellite imagery-based maps, the project researchers undertook ground verification trips to forest management units, hydropower construction sites, national highway construction sites, landslide areas, quarries and mining sites, as well as recently burned forest sites.

The project included a significant training component, with two extended visits to the United States by several team members each time, including not only researchers but also operational staff from the Bhutanese Department of Forests and Park Services. In November-December 2017, Dr. Tshering and six colleagues spent two weeks at the Geospatial Technology Applications Center of the USDA Forest Service in Salt Lake City for a training workshop and study tour. They received training on Google Earth Engine, learned how to map burn severity, and collaborated with USFS counterparts to develop and test a forest change detection algorithm for use in Bhutan. They also familiarized themselves with the operations of the USFS Forest Inventory and Analysis unit. In August 2018, the PI and three colleagues returned for another visit with their USFS partners, followed by visits to the Bhutan Foundation in Washington, DC, and the lab of Dr. Edward Cook at the Lamont-Doherty Earth Observatory of Columbia University.

The PEER team also organized a Regional Technology Sharing Workshop with participants from Bangladesh, Bhutan, India, and Nepal. The PI has won two grants worth a total of $300,000 to carry forward this PEER project work and a related project on forest fires, as part of a World Bank-funded project on REDD+ Readiness for Bhutan, and the Bhutan Trust Fund for Environmental Conservation.

CAMBODIA

CAMBODIA - PROJECT C-01: USING 4-S TECHNIQUE TO ANALYZE RURAL INCOME IN DEVELOPING COUNTRIES

PI: Sok Serey, Royal University of Phnom Penh; Co-PI: Kim Vandy, Forest, and Livelihood Organization (FLO)

Project Dates: May 2022 – August 2023

PROJECT OVERVIEW

This PEER project sought to produce a toolkit for analyzing rural income in developing countries through the 4S problem-solving technique. Organizations and government officers in Cambodia previously did not have clear guidelines or principles for such analysis. The toolkit is designed to make the analysis more systematic and scientific. Beyond the research objective, the project was designed to promote community engagement in academic research. Key stakeholders include commune councils, community-based organizations (CBOs), and nongovernmental organizations (NGOs). The team sought to design a toolkit through engagement that would be useful for these stakeholders for future data collection and analysis of rural incomes.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and his team organized a workshop to collect inputs among staff and the community-based organizations to prepare the first draft of their toolkit. The researchers also interviewed 800 households across four provinces, working with FLO, a community-based organization in Kratie, and with undergraduate researchers from the Royal University of Phnom Penh (RUPP) in the three other provinces (Pursat, Takeo, and Preah Vihear). The undergraduate students, who got involved in their project because of their interest in community development and engagement, were trained in data collection techniques. The PEER team analyzed data from these households to inform the toolkit and a serve as the basis for a future academic article.

Team members also worked with commune and district officers, community-based organization members, and NGO staffers, including during a field visit where they shared concepts and project findings with more than 40 district and commune officers. The researchers conducted a third workshop at RUPP to train on analyzing rural income based on the Toolkit.

The toolkit has been disseminated across Cambodian government agencies (Ministry of Planning; Ministry of Agriculture, Forestry and Fisheries; Ministry of Environment; Ministry of Education, Youth, and Sports, Ministry of Culture and Fine Arts; and Ministry of Planning), local and international NGOs, and academic institutions and is being used as one of the key training tools to analyze rural income, income inequality, and the poverty line in Cambodia. The team is preparing a paper on their results for an international journal and a policy paper for a local journal.

The PEER team has received $200,000 through several additional grants, including from the Johns Hopkins University and Rutgers School of Public Health, to support ongoing work. The PI Dr. Serey also became a full professor during this project period.

CAMBODIA - PROJECT C-02: IRRIGATION AND NUTRIENT MANAGEMENT FOR IMPROVING SMALL-HOLDER'S VEGETABLE PRODUCTION IN BATTAMBANG

PI: Nareth Nut, Royal University of Agriculture
Co-Pi: Soth Hong, Department of Agricultural Engineering, General Directorate of Agriculture, Ministry of Agriculture Forestry and Fisheries
Project Dates: June 2022 – September 2023

PROJECT OVERVIEW

Ang Kamping Puoy Agricultural Cooperative (AKPAC) is located in a rural area facing persistent water shortages, particularly in the dry season, which has caused poor agricultural productivity. This PEER project aimed to promote sustainable agriculture practices in the community and learn more about managing applied nutrients and irrigation properly on the vegetable crops in Battambang Province, Cambodia. Through the project implementation, a series of training workshops and education related to sustainable agriculture were introduced in the AKPAC community. The project team conducted a workshop on irrigation management through drip irrigation and maintenance to inform farmers of the latest techniques for managing irrigation properly. Irrigation based on actual crop water needs is very important, particularly in the context of water deficit and climate change.

The use of chemical pesticides and fertilizers is common, and as the AKPAC community is located upstream of the Ang Kamping Puoy Reservoir, education on sustainable agriculture to the farmers in the community is very important to reduce the environmental impacts of agricultural farming practices and minimize contaminants in the water in the reservoir.

The researchers tested conservation agriculture methods and small drip irrigation in the community, collecting data to understand crop growth and nutrient leakage in the system. This research was jointly conducted by the PI's students and community members to enable the community to learn more about the process of scientific research.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers established experimental plots of cherry tomatoes and white cabbage in an open field near the community leader's home, testing both conservation agriculture and conventional tillage methods. Shortly after initial data collection from the experimental plots, however, severe flooding in the area destroyed the plants. In early 2023, the PI and team restarted the experimental plots for cherry tomato cultivation. They were able to collect soil samples to analyze for soil organic carbon matter, as well as crop data like stem height, diameter, shoot length, number of shoots and branches, and yield.

The PEER team hosted a series of training and education workshops related to sustainable agriculture in the AKPAC community, including one on crop irrigation, maintenance, and specific crop water needs. The team made recommendations regarding the most efficient irrigation amounts for some popular crops grown in the community, helping farmers to save irrigation water and diesel used for the water pumps. Other workshops taught farmers how to make compost and environmentally friendly pesticide alternatives, including safety instructions on preventing pesticide contamination.

Farmers were advised to produce bio-fertilizers and pesticide alternatives to apply to their crops instead of using chemicals to help save the environment, protect people's health, and save money.

The AKPAC community has shared the knowledge and experiences they've learned as part of the project with other communities in Battambang, particularly Kantueu Pir Agricultural Cooperative (KPAC). The team members demonstrated the irrigation system to high school students and teachers visiting the Faculty of Agricultural Engineering at the Royal University of Agriculture. This project also supported the research and thesis work of two female students on the team.

PUBLICATION

Sourn, T., Pok, S., Chou, P., Nut, N., Theng, D., & Prasad, P. V. V. (2022). Assessment of land use and land cover changes on soil erosion using remote sensing, GIS and RUSLE model: A case study of Battambang Province, Cambodia. Sustainability, 14(7), 4066. https://doi.org/10.3390/su14074066

CAMBODIA - PROJECT C-03: ICT USES FOR INCLUSIVE CASHEW VALUE CHAIN AND AGRICULTURAL INPUTS IN CAMBODIA

PI: Nget Raby, Royal University of Agriculture
Co-Pi: Neang Sarin, Department of Argo-Industry
Dates: May 2022 – June 2023

PROJECT OVERVIEW

This PEER project sought to identify and test information and communication technology (ICT)-mediated initiatives involving farmer-trader credit interactions in villages, specifically in cashew trading in Cambodia. The researchers used informal discussions with suppliers, traders, and stakeholders, as well as semi-structured interviews with farmers on land tenure and management, technology adoption, crop production, sale price, planting advice, technical assistance, market information, storage, and processing. After analyzing these data to identify problems faced by farmers, the researchers introduced them to ICT-based solutions that link them with different sources of information and post products for sale. The team also served as a resource for farmers to consult by sending photos of problems (evidence of insects, plant diseases, and nutrient deficiencies) and receiving advice on solutions. The team analyzed the outcome of this intervention through before and after surveys.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project team interviewed the community leader in the Krayea community in Kampong Province, as well as an agricultural inputs supplier, traders, and farmers about problems related to cashew nut production. They interviewed 52 cashew nut farmers in the study area and found that low prices and high input costs adversely influenced farmers' cashew production. There was also price fluctuation and a lack of multiple market channels to determine prices. Traders took advantage of this, offering a low price to increase their own profit. The team conducted trainings with farmers in the area. One set was focused on using apps like Messenger and Telegram to share information among farmers about prices and sell their products. The second focused on planting techniques, care, harvesting, and storage to increase cashew nut productivity.

The researchers concluded the project with a field visit after all trainings were completed, conducting a survey to understand farmers' perspectives on ICT and price changes for cashews in the community. The team created three technical reports on their project, trained community leaders on ICT possibilities, and connected them to agro-industry researchers at the Royal University of Agriculture to learn more about post-harvest technology.

CAMBODIA - PROJECT C-05: UNDERSTAND THE MANAGEMENT AND SUPPORT FOR THE ANLONG SVAY PROTECTED AREA COMMUNITY

PI: Samnang Nguon, Ecosystem Services and Land Use Research Center, Royal University of Agriculture

Dates: May 2022 – June 2023

PROJECT OVERVIEW

The Anlong Svay Protected Area Community is located in the Kbal Tek Commune in the Kampong Chhnang Province of the Phnom Aural Wildlife Sanctuary. Created by the Ministry of Environment in 2003, the community covers more than 1200 hectares of semi-dense and bamboo forest and includes four villages. Residents of the community mainly rely on growing rice (through both the paddy and intercropped chamkar production systems), raising livestock, and harvesting non-timber forest products.

The PI and his team carried out a needs assessment to identify the main priorities for the community to improve its management, focusing on a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. The team sought to help the community identify the main challenges and highest priorities for improving their community, as well as provide a training base for the community. The researchers undertook this assessment through interviewing residents, key persons within the communities, and tourists in the area.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team and student interns first visited the Anlong Svay community to meet with local residents, present the project plan, and interview key stakeholders, including the commune chief, community heads, and other important community members. With these experiences in mind, the team reviewed the relevant literature and developed the research questionnaires and methodologies for the field surveys. The three student interns were trained on formulating, testing, and using questionnaires, as well as data entry. They, along with the rest of the project team, undertook an initial round of in-depth interviews with the community members and tourists, then refined the questionnaires for a second round of interviews. The researchers also held a focus group discussion and designed another questionnaire to interview community members to understand their perceptions of community management.

The PEER team presented their initial findings to the local communities. From these findings, they also developed and hosted three trainings, including on home gardening, production of compost fertilizer and environmentally friendly alternatives to pesticides, and financial and community management. They also installed 11 trash bins for waste management in the community and encouraged ecotourism development in the area.

The project supported the three undergraduate interns in finishing their theses and degrees. Thanks to the solid foundation built through the PEER project, the team received six additional grants worth a total of more than $120,000 to support their work.

CAMBODIA - PROJECT C-07: DIAGNOSTIC INVESTIGATION OF WATER EUTROPHICATION IN STUNG TRENG RAMSAR SITE, CAMBODIA

PI: Saret Bun, Institute of Technology of Cambodia
Co-Pi: Sothearoth Chea, Yea Catalyst
Dates: June 2022 – August 2023

PROJECT OVERVIEW

The Stung Treng Ramsar Site covers a stretch of approximately 37 km of the Mekong River in Stung Treng Province, northern Cambodia. The lower boundary of the site is approximately 3-4 km upstream from Stung Treng town, extending upstream to within 2-3 km of the border with Laos. The total area of the site is estimated as 14,600 hectares, and it is home to a great diversity of wildlife—mammals, birds, reptiles, fish, and vegetation. Four critically endangered species have been found in this site: Irrawaddy dolphin, Sarus crane, Mekong giant catfish, and Siamese crocodile. Many villagers live along the Mekong River and rely on fisheries and forestry for food security and livelihoods. Recent development changes, including hydropower plants and shifts in agricultural land use, have posed a threat to the site's ecological systems, including dramatic decline in the Irrawaddy dolphin population. Yet little is known about this area, especially its hydrology—including water quality—and biology.

Having no historical data to track the changes in ecological conditions makes it hard to protect nature and respond to local disasters. Residents are concerned about algae accumulation, which blooms in freshwater during warmer weather and slow-flowing river conditions. They are the result of the water eutrophication process, which occurs through the presence of excessive nutrients in the water stream. While relevant stakeholders have raised concerns about algae accumulation, no single scientific study existed on the cause, prior to the current PEER study. This project aimed to investigate the water eutrophication at Stung Treng Ramsar Site in Cambodia, using a field survey questionnaire, water quality assessment and algae species identification.

FINAL SUMMARY OF PROJECT ACTIVITIES

Researchers from the PEER project began with an introductory seminar for all project stakeholders, including rangers, the community fishery chief, and community fishery members from three towns, gathering their input on specific sites where water sampling would take place. Four discussion groups covered the community's perspective on the health of the Mekong River, changes in ecosystems around the river, changes of land use around the site, and algae blooms at the site. At the end of the session, the research team demonstrated the water sampling process for the community.

The team also held a community training on the water sampling process and conducted practice sampling sessions for village members paired with researchers. Participants included eleven residents from three villages, as well as the staff from My Village organization who also wanted to apply this type of research in their target community fisheries in Siem Pang Commune.

Researchers collected water samples from nine different sites across four different time periods (both dry and rainy season) and analyzed them for various chemical and physical properties such as dissolved oxygen, conductivity, resistivity, salinity, pH, and turbidity. Additional analysis at the laboratory included total nitrogen, total phosphorus, ammonia, orthophosphate, chemical oxygen demand, and hardness.

Through surveys of the local communities, the PEER team found that the highest rate of algae bloom was three years prior to their survey, and most residents considered the bloom harmful to the river. Almost all surveyed said the most common place to find algae blooms was attached to large stones in the river. Their water quality findings identified the highest pollution in upstream and downstream zones during the rainy season and in the upstream and middle stream zones during the dry season. The PEER team identified algae species found as filamentous species, cyanobacteria, and synedra species. These types of algae can affect human skin and health through skin absorption and ingestion pathways, respectively.

The team presented their findings on water analysis and algae species identification at a workshop attended by members of eight community fisheries from three villages (Koh Snaeng, Phum Thmey, and Orun) and a local partner from Angkor Meas Stung Treng town. Community members expressed a desire to continue the project to monitor the algae situation in the area even though the algae level was decreasing at the time, and they asked the research team to investigate the quality of the drinking water. The team has received four new grants, worth a total of $43,000, connected to their work researching water quality.

CAMBODIA - PROJECT 7- 088: RAPID ASSESSMENT OF THE PESTICIDE NETWORK AND ITS INFLUENCE ON THE USE OF PESTICIDES IN CAMBODIAN AGRICULTURE

PI: Vichet Sorn, General Directorate of Agriculture
U.S. Partner: Buyung Hadi, International Rice Research Institute (Funded by the United States Agency for International Development)
Dates: November 2018 - August 2021

PROJECT OVERVIEW

The increasing pesticide use in Cambodia is a widely acknowledged problem, with limited solutions. In the last decade, pesticides imported into Cambodia increased 285 times, implying a significant rise in pesticide use. This research aimed to understand the network disseminating information and pesticide-based technologies and generate insights into how this network spread pesticides in Cambodia. Such insights can help create targeted interventions for pesticide policy and support Integrated Pest Management (IPM).

The first objective was to assess the pesticide network in Cambodia in terms of composition, function, and methods to bring information and products to farmers. This involved identifying stakeholders at national, provincial, and community levels and understanding the linkages in the innovation system around pesticides. The second objective was to examine the arrangements and practices in farming communities that maintained and encouraged pesticide reliance. This included understanding community-level practices that supported the spread of information on pesticides and promoted accessibility of pesticide products to farmers. To achieve these objectives, the team mapped the pesticide network through interviews with representative stakeholders, generating an overview of the network, its key players, and important linkages. They conducted interviews with key stakeholders to understand the importation and distribution of pesticides and held focus group discussions with community-level stakeholders in four Cambodian provinces.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project focused on three main objectives: assessing the pesticide network, testing management options for fall armyworm (FAW), and conducting regional consultation workshops. To assess the pesticide network, the team interviewed various stakeholders, including public sector officials, pesticide importing companies, dealers, and farmers. This assessment aimed to understand the network's composition, function, and effectiveness in bringing products to farmers.

The researchers discovered that all pesticides in Cambodia are imported, with no local production. Pesticide importing companies must complete a business registration with the Ministry of Commerce (MoC) and a process with the Ministry of Agriculture, Forestry, and Fisheries (MAFF) to ensure they can handle pesticide products. This process is managed by the Department of Agricultural Legislation (DAL), which coordinates with the National Agricultural Laboratory (NAL) for product testing and the Department of Plant Protection, Sanitary, and Phyto-Sanitary (DPPSPS) for field tests. After receiving a permit, companies import pesticides and distribute them to dealers and retailers in the provinces, with the Provincial Department of Agriculture, Forestry, and Fisheries (PDAFF) responsible for inspections and enforcement.

Interviews with 57 pesticide companies revealed that these companies sold an average of six different types of products, with insecticides and herbicides being the most common. Only 6% sold bio-control agents or products safe for organic farming. The companies generally understood the registration process and found it relatively easy to navigate. However, a few mentioned difficulties such as communication with government agencies and high costs. The registration process takes two to four months, with permits valid for three years, requiring companies to re-register every two years.

The team's experiment on FAW management options during the 2019 and 2020 wet seasons included treatments such as doing nothing, applying pesticides as per farmers' practices, applying recommended pesticides, and using bio-control agents. Results showed lower plant infestation damage scores for pesticide treatments compared with the control and bio-control treatments. The highest yields were obtained with specific pesticide treatments, while bio-control treatments showed yields not much higher than doing nothing.

In conclusion, the research identified a dense network of pesticide industry actors in Cambodia governed by a policy process for pesticide registration, importation, sale, and use. The connections between national-level importers and government agencies support local-level actors, including dealers, retailers, and farmers, facilitating product distribution. However, there is a significant gap in bringing sustainable products to market. The PEER team held five dissemination meetings in 2021 to brief PDAFF officials and stakeholders, sharing technical findings and recommendations for greater adoption of sustainable options. Mr. Sorn was involved in discussions within the government to devolve responsibility for wholesale and retail pesticide sales permits to the Provincial Administration, aiming to improve the permit issuance process and compliance monitoring for the pesticide law.

CAMBODIA - PROJECT 7- 086: ESTABLISHING CROPLAND DATABASE IN CAMBODIA FROM REMOTE SENSING SATELLITE DATA

PI: Sanara Hor, Royal University of Agriculture

U.S. Partner: Robert Hijmans, University of California, Davis (Funded by the United States Agency for International Development)

Dates: February 2019 - October 2021

PROJECT OVERVIEW

Agriculture is a crucial sector in Cambodia, contributing more than one-quarter of the country's gross domestic product and employing over 8 million Cambodians. Accurate information regarding land use in a user-friendly format is a valuable tool for farmers and government planners alike. The overall purpose of this study was to establish a cropland database in Cambodia using remote sensing satellite data. The specific objectives included (1) identifying appropriate satellite images and derived remote sensing products for cropland mapping; (2) developing a rapid cropland mapping tool based on cloud services for multiple time periods; (3) mapping different crop types across lowland and highland cropland regions; (4) exploring pathways to use the research results and technology to benefit Cambodian farmers; and (5) strengthening the research capacity of junior Cambodian researchers.

Working in cooperation with their U.S. partners, the principal investigator and his team examined remote sensing data from multiple sources, including Landsat, MODIS, Sentinel-1, and Sentinel-2, and selected the appropriate data for estimating cropland area in Cambodia based on availability, coverage, and cost. They compiled the data into a database covering specific sites representing complex cropping practices ranging from lowland to upland regions in the provinces around Tonle Sap Lake. The team presented their results to various stakeholders through training programs, seminars, and lectures. The results and findings from the project were also incorporated into the teaching curriculum at the Royal University of Agriculture (RUA).

In the past, cropland mapping had been unavailable to countries like Cambodia due to cost. This project provided an inexpensive means to map and monitor cropland from satellite images. The research also provided basic cropland data that could be used in subsequent analyses, such as crop yield estimations or environmental impact assessments, enabling better agricultural planning. Rapid crop mapping and measuring also supported the implementation of crop insurance products in Cambodia, benefiting farmers at risk of extreme weather events. Additionally, the project facilitated better land use management, benefiting government officials from various departments. The team conveyed the results to them interactively, using overlays in Google Maps, to assist in their planning efforts and encourage the diversification of agricultural land uses.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project was completed with a significant effect on professional education on land management and land administration in Cambodia. The PI Dr. Hor reports that the project's most significant achievement has been the introduction of remote sensing technology and related analytical methodology for students in the BSc program in the Faculty of Land Management and Land Administration at RUA. Currently, BSc students are required to achieve 146 credits to graduate within 4 years. Within that total of 146 credits, Dr. Hor and his team offer 27 credits of courses on land use survey, remote sensing, GIS, photogrammetry, cartography, geodesy, and data application. Using the methods and technology included in this PEER project, they improved the remote sensing and photogrammetry courses with a total of 6 credits. Project team member Dr. Pok Sophak used the data collected in the project as an example for his students to use in learning to classify images from Sentinel-2 and Landsat. As of early 2022 when the project ended, there were 183 students who had benefitted from the newly updated course. The new training program created under this project is available not only to students but also to faculty members, and eight faculty members have enrolled in MSc or PhD programs at RUA after being involved in the project.

RUA has seen a dramatic increase in the number of students enrolling in the Faculty of Land Management and Land Administration over the past several years. In 2016, 72 students enrolled for BSc program, but in 2020 there were 183 newly enrolling students. Hence, long-term investment focusing on professional education on land management and land administration should be a priority. To achieve program accreditation, infrastructure, laboratory, and human resources are crucial. In particular, improved computer lab infrastructure with hardware capable of handling graphic analysis and big data is essential.

Based on the team's research results, the General Department of Geography and Cadastral, Ministry of Land Management, Urban Planning, and Construction, Cambodia, introduced Dr. Hor to Dr. Andrew Coote, a consultant for the World Bank, to discuss the Geospatial Information Framework, which the Bank is planning to introduce to the Cambodian government. Recently, Dr. Hor also reports that several private sector representatives, particularly from the agriculture sector, visited RUA to learn more about the team's geospatial technology and see if it might be suitable to meet their needs. While pursuing these future opportunities, Drs. Hor and Pok have also received a new grant to support a project entitled "Crop simulation model for improving and supporting crop production using GIS and remote sensing application to influence on Cambodian economic changes." This research aims at enhancing sustainable and efficient production of crops in Cambodia through integration of crop simulation models with GIS/remote sensing applications. The grant, in the amount of $54,000, is a part of RUA's Higher Education Improvement Project, which is sponsored by the World Bank.

Dr. Hor reports that by implemented this project, he and his team have established a network working on remote sensing for spatial science. The members are primarily staff from Cambodian government agencies, which are potential partners that can put the research results into practice to support local people. For example, the most significant project is collaboration between the Department of Agricultural Land Resources of the General Department of Agriculture, which is interested in spatial science for mapping agricultural land suitability. The PEER team is providing the huge spatial dataset for GIS to apply land suitability assessment in the future.

PUBLICATIONS

Iwahashi, Y., Ye, R., Kobayashi, S., Yagura, K., Hor, S., Soben, K., and Homma, K. (2021). Quantification of changes in rice production for 2003–2019 with MODIS LAI data in Pursat Province, Cambodia. Remote Sensing, 13(10). https://doi.org/10.3390/rs13101971

Sok, S., Chhinh, N., Hor, S., and Nguonphan, P. (2021). Climate change impacts on rice cultivation: a comparative study of the Tonle Sap and Mekong River. Sustainability, 13(16), 8979. https://doi.org/10.3390/su13168979

Sourn, T., Pok, S., Chou, P., Nut, N., Theng, D., Rath, P., Reyes, M. R., and Prasad, P. V. V. (2021). Evaluation of land use and land cover change and Its drivers in Battambang Province, Cambodia, from 1998 to 2018. Sustainability, 13(20), 11170. https://doi.org/10.3390/su132011170

Tsujimoto, K., Ono, K., Ohta, T., Chea, K., Muth, E. N., Hor, S., and Hok, L. (2021). Multiyear analysis of the dependency of the planting date on rainfall and soil moisture in paddy fields in Cambodia, 2003–2019. Paddy and Water Environment, 0123456789. https://doi.org/10.1007/s10333-021-00863-6

Open Data

Data from the project are included in the Rural Household Multiple Indicator Survey (RHoMIS) of 35,713 farm households in 32 countries, available at https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/TFXQJN

CAMBODIA - PROJECT 7-85: CLIMATE CHANGE IMPACT ON RICE YIELD AND FOOD SECURITY IN THE RIVERINE COMMUNITIES IN CAMBODIA

PI: Serey Sok, Royal University of Phnom Penh
U.S. Partner: Aniruddha Ghosh, University of California, Davis (Funded by the United States Agency for International Development)
Dates: November 2018 - October 2021

PROJECT OVERVIEW

This research project focused on assessing the impacts of climate change on rice yield, leading to food insecurity in Cambodia. Climate change contributes directly or indirectly to declines in rice yield, exacerbating food insecurity. The vulnerability of agricultural systems to extreme climate events is often tied to the adaptive capacity of local farmers. Therefore, improving local adaptive capacity is crucial for sustaining the rural livelihoods of riverine communities in Cambodia. The researchers conducted this project to build upon statistical and geospatial modeling techniques, using information from various sources of secondary data and fieldwork at national and provincial levels, particularly through interviews with key informants. This research combined conceptualization with empirical data through statistical analysis and Geographic Information Systems (GIS) to assess the negative impacts of climate change, leading to declines in rice yields and increased food insecurity. It also involved interviews with local people and officials from government agencies and NGOs, an extensive literature review, and case studies.

Previous studies focusing on Tonle Sap Lake had mostly been conducted by regional and international organizations. While these findings were broad, they did not always comprehensively fit the Cambodian context. Domestic institutions had often been the subjects of project evaluations or assessments, but this study was led by a local Cambodian academic researcher. He and his team engaged a wide range of stakeholders, including regional and national experts, local villagers, and representatives of government agencies and NGOs throughout various stages of the project. Consultative meetings were organized to facilitate interaction among stakeholders, present preliminary findings, collect feedback, and discuss policy applications and future planning. This development dialogue among stakeholders was critical for bridging gaps between academic research, planning, and policy implementation.

FINAL SUMMARY OF PROJECT ACTIVITIES

The results of this three-year project, which ended October 31, 2021, fall into three main categories: (1) publications, (2) course integration, and (3) sharing of lessons learned and best practices among practitioners. On the first, one paper (see citation below) was published in the journal Sustainability in August 2021. In it, Dr. Serey and his co-authors adopted the United Nations risk assessment framework “interaction of vulnerability factors” to assess the vulnerability of rice farmers in the Tonle Sap and the Mekong River Basin to climatic hazards in Cambodia as they tend to be aligned with disaster risks. The findings covered in the paper provide insights into the negative impacts of climate variability on riverine communities that are reliant on rain-fed rice cultivation. The study addresses a gap in the literature by contributing a comparative empirical study on the vulnerabilities of rice farmers in the Tonle Sap and the Mekong River Basin to climate variability and the adaptation and resilience strategies applied in response. Identification of attributes for the four types of the vulnerability outlined further requires a highly participatory approach involving all the key stakeholders. The authors argue that this framework is also applicable for other riverine communities in Mekong countries such as Laos, Vietnam, and Thailand, where climatic hazards are also associated with disaster risks. In addition, adaptation measures by local authorities at commune and district levels require long-term integrated water resources management approaches to mitigate these negative impacts collectively. Regarding course integration, the PI reports that he has incorporated his experience and findings from the PEER-supported fieldwork into teaching his students at the bachelor's, master's, and PhD levels. In addition, a master's student in biodiversity is using some data collected under this project for his thesis.

As for sharing lessons learned and best practices among practitioners, Dr. Serey has been invited frequently by various NGOs in Cambodia to give talks, especially online, during the COVID-19 pandemic. In late December 2021, has been invited by local NGOs to share with university students the findings of his research on the impact of climate change, adaption, and resilience in communities along the Mekong River. All of his master's and PhD students hold positions as officials of NGOs, international organizations, and Cambodian government agencies, which has greatly facilitated sharing of the findings of this research with key stakeholders for planning and policy applications. In addition, Dr. Serey presented a paper on the impact of climate change on food security at the Mekong-U.S. Partnership Track 1.5 Policy Dialogue on October 22, 2021.

Dr. Serey and his colleagues are continuing their efforts even now that PEER support has ended. As of December 2021, they were analyzing data and writing a manuscript based on the Rural Household Multi-Indicator Surveys (RHoMIS) data they collected in Battambang, Pursat, Prey Veng, and Kompong Cham provinces. They are also writing another paper on the impact of the COVID-19 pandemic on food security in different geographical regions of Cambodia. A book chapter co-authored by the PI is also expected to appear in 2022 (see below).

PUBLICATIONS

Sok, S.; Chhinh, N.; Hor, S.; Nguonphan, P. Climate Change Impacts on Rice Cultivation: A Comparative Study of the Tonle Sap and Mekong River. Sustainability 2021, 13, 8979. https://doi.org/10.3390/su13168979

"Remote sensing of agriculture in South-Southeast Asia: land use and changes" in Productivity, damages, and losses of rice in Cambodia: past, present and future trends in the Mekong and Tonle Sap regions, edited by Krishna Vadrevu, Thuy Le Toan, Shibendu Shankar Ray, and Chris Justice. Springer (in press).

CAMBODIA - PROJECT 7-80: GIS BASED WEATHER, SOILS, LAND USE AND AGRICULTURAL MANAGEMENT DATABASE IN CAMBODIA

PI: Nareth Nut, Royal University of Agriculture
U.S. Partner: Gilbert Sigua, Agriculture Research Service Coastal Plains Soil, Water, Plant Research Center (Funded by the United States Department of Agriculture/ Agricultural Research Service)
Dates: February 2019 - July 2021

PROJECT OVERVIEW

Because several of Cambodia's agricultural areas have degraded soils, the country is pursuing sustainable agriculture to conserve and improve soil quality. In partnership with U.S., French, and Brazilian researchers, local Cambodian scientists developed technologies that enhanced soil quality and intensified the production of upland grain, tuber, vegetable, forage, and lowland rice crops under conservation agriculture. The PEER-supported research project aimed to evaluate the capacity of the Soil and Water Assessment Tool (SWAT) to predict soil carbon sequestration in conservation agriculture systems compared with traditional farming systems. The project also established a GIS-based weather, soil, land use, and agricultural management database housed in a central location to help global users predict environmental degradation from current practices. SWAT was used to simulate environmental and economic benefits for Cambodia if sustainable intensification practices like conservation agriculture were promoted by the government and private industry.

With PEER support, Cambodian researchers collaborated with their U.S. partner to gather and format inputs for SWAT simulation, including digital elevation maps and data on climate, soils, land use, crops, agricultural management, and fertilizers. The results of the simulations were compared with measured data to assess their reasonableness. The U.S. partner provided technical expertise and access to equipment and laboratory instruments for analyzing water, soil, and plant samples. The project improved agricultural management practices in Cambodia and provided synthesized data useful globally. Capacity building for faculty members of the Royal University of Agriculture was enhanced through training and implementation activities. The GIS-based digital data allowed research using SWAT to analyze the impact of deforestation and agriculture on the Mekong River's natural flows. Different sustainable intensification production systems were recommended, and environmental conservation was simulated using SWAT, linking predictions to food production, improved yield and income, and the community's capacity to meet its food needs.

FINAL SUMMARY OF PROJECT ACTIVITIES

By the time this two-and-a-half-year project ended in July 2021, the PI Mr. Nareth Nut reported many achievements, mainly in terms of capacity building to himself and his students on SWAT and APEX modeling and dissemination of the project results through various national and international conferences or meetings. Ten undergraduate students worked on the project and four graduate students (two males and two females) involved in the project successfully defended their theses in January 2021 under the PI's supervision. One more Master's student whose research focused on building a SWAT model of the Tonle Sap Basin was scheduled to defend his degree research in September 2021. Although the project has ended, the undergraduates continue to apply the SWAT and

APEX models in the Tonle Sap Basin and other parts of Cambodia. Furthermore, the PI is currently a Ph.D. student at the Royal University of Agriculture, and he will integrate the SWAT application in his dissertation.

As part of their efforts to scale up the concept of modeling (SWAT and APEX) to compare and predict the environmental impacts of two management practices (traditional farming and conservation agriculture in Cambodia), the PI teamed up with other universities, government agencies, and international development organizations, including Kansas State University (KSU), the French Agricultural Research Centre for International Development (CIRAD), Swisscontact, the Swiss Federal Institute of Aquatic Science and Technology (Eawag), the Institute of Technology of Cambodia (ITC), University of Battambang (UBB), and French National Research Institute for Sustainable Development (IRD) to prepare a concept note to submit for further funding. They submitted a pre-proposal in response to a call from a Swiss-supported grants program called TRANSFORM. Although the pre-proposal was among the 9 of 90 selected to advance to the full proposal stage, the project was not funded. The various partners involved remain in contact to seek alternative funding sources.

In terms of research findings, the PEER team found that there is a high risk of soil erosion mainly in the agricultural field due to the transformation of forests to agricultural lands, as detailed in their 2021 article. Currently, some conservation agriculture (CA) activities are being implemented in the study area by CIRAD in cooperation with the Conservation Agriculture Service Center (CASC), Ministry of Agriculture, Forestry, and Fisheries. However, these activities mainly focus on analyzing the soil properties changed due to CA implementation in the field plots of the experiment station. Thus, application of the PEER team's modeling-based approaches to predict the impacts and outcomes of various approaches will be useful for policymakers in considering the direction of agricultural development in Cambodia. Although the PEER project has ended, Mr. Nut and his group plan to compare the impacts of soil erosion risk between traditional agriculture and CA and use their findings to inform policymakers and train agricultural extension workers and producers to promote soil conservation practices. Mr. Nut continues to collaborate with his U.S. partner Dr. Gilbert Sigua on development of future manuscripts and formulation of new research projects.

PUBLICATIONS

Nut, N.; Mihara, M.; Jeong, J.; Ngo, B.; Sigua, G.; Prasad, P.V.V.; Reyes, M.R. 2021. Land Use and Land Cover Changes and Its Impact on Soil Erosion in Stung Sangkae Catchment of Cambodia. Sustainability 2021, 13, 9276. https://doi.org/10.3390/su13169276

Nut, N.; Mihara, M.; Jeong, J.; Ngo, B.; Chan, S.; Sigua, G.; Reyes, M.R. (in press, 2022) Impacts of Land Use-Land Cover Changes on Streamflow and Water Balance of Stung Sangkae Catchment Using SWAT. International Journal of Environment and Rural Development, 12 (2). (Accepted and awaiting online publication at https://www.iserd.net/)

Nut, N.; Reyes, M.R.; Sigua, G.; Chan, S.; Mihara, M.; Sourn, T. (in press, 2022) Application of APEX Model in Evaluating Streamflow and Sediment Yield in Stung Chinit Catchment. International Journal of Environment and Rural Development, 12 (2). (Accepted and awaiting online publication at https://www.iserd.net/)

CAMBODIA - PROJECT 7- 079: INCREASING THE ADOPTION OF NUTRIENT MANAGEMENT INNOVATIONS BY CAMBODIAN VEGETABLE FARMERS

PI: Leangsrun Chea, Royal University of Agriculture
U.S. Partner: Zachary Stewart, Kansas State University (Funded by the United States Agency for International Development)
Dates: February 2019 - March 2021

PROJECT OVERVIEW

Vegetable production in Cambodia is largely constrained by access to fertilizer and water. Given that the humid tropical soils of Cambodia are highly weathered, crop nutrient availability tends to be relatively low. Soil amendments such as cattle manure, farmyard compost, and locally available fertilizers were applied in limited amounts to improve soil properties, but mineral fertilizers were usually unaffordable for subsistence-oriented farmers, leading to widespread nutrient deficiency in smallholder vegetable crop production. Farmers often attempted to supplement available nutrients in the soil by applying manure, but household manure availability varied greatly depending on the magnitude of livestock integration in local production systems. Therefore, manure applications often did not meet plant nutrient demands. This loss in productivity, combined with reduced access to available resources and technology, subsequently exacerbated the food insecurity of rural smallholder farmers. Farmers often felt uncertain about how much manure and/or mineral fertilizers to apply in order to maximize yield and profitability. Inappropriate nutrient management often resulted in low yield and poor nutritional quality of the vegetables produced and inversely could have negative environmental consequences. Therefore, proper nutrient management practices were essential for Cambodian vegetable farmers to ensure successful production of quality vegetables. Several fertilizer recommendations for horticultural production currently existed; however, adoption remained low, and fertilizer under and over supply was common. There was a need for the incorporation of bidirectional learning in the research and dissemination pathway that allowed farmers to experiment with new fertilizer recommendation innovations and that learned from farmer feedback to adapt the innovation to better match their needs.

Through financial support provided by USAID through the Feed the Future Horticulture Innovation Lab, the project “Multidimensional Trade-off Analysis of Integrated Animal-Horticulture Farming Systems for Improved Smallholder Farmer Adoption Recommendation” conducted on-station vegetable nutrient management trials that improved nutrient management recommendations of both inorganic and manure-based fertilizers. The PEER project addressed a significant need for additional research and extension activities that promoted the uptake and adoption of this nutrient management decision support innovation. The project aimed to disseminate the adaptive results of the previously conducted research to farmers and extension agents. Even when appropriate fertilizer recommendations had been developed, there were still many barriers preventing their adoption and use. Bidirectional learning between scientists and extension workers and farmers was a critical process in overcoming these barriers and increasing technology adoption, and the PEER project facilitated those efforts. Through the adoption of optimized and efficient nutrient management for vegetable crops, Cambodian farmers were expected to be able to improve their vegetable production efficiency and, ultimately, their vegetable productivity and profitability. The innovation helped diversify household diets and enhance income generation by supplying vegetables to markets. This innovation also minimized negative impacts on the environment by reducing nutrient losses through runoff and leaching due to over-application.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project aimed to assess nutrient innovation practices and enhance their adoption among vegetable farmers. In Year 1, activities included recruiting students and support staff, conducting field visits to previous USAID-funded projects, baseline surveys, and initiating an on-station experiment. A technician was hired to assist with these activities, particularly the baseline survey, on-station trials, field trials, and adoption studies. One Master's and three undergraduate students, including two females, participated, gaining training in field survey techniques, experimental design, and data management.

During the second quarter of Year 1, U.S. partner Dr. Zach Stewart visited Cambodia, meeting with PI Mr. Leangsrun Chea to discuss the activity plan and visit USAID project sites. They identified the potential of living mulch Arachis pintoi for weed and nutrient management in vegetable crops.

Objective 1 involved conducting a baseline survey to understand farmers' nutrient management practices and their perceptions of living mulch integration. The survey, pre-tested in Siem Reap Province with 10 farmers, was later conducted with 155 households across four districts. Results showed heavy reliance on inorganic fertilizers and significant challenges in weed management, highlighting a need for improved practices, like living mulch, to optimize nutrient use and reduce labor costs.

Objective 2 focused on implementing and evaluating on-station and on-farm nutrient management experiments. On-station trials at the Royal University of Agriculture's Technology Park assessed the impact of living mulch and phosphorus levels on chili pepper quality over three crop cycles. On-farm trials involved 31 farmers in three districts, supported by a bachelor's student and technician, though limited by COVID-related travel restrictions.

Objective 3 provided ongoing support to farmers engaged in on-farm trials, including technical advice and training through local extension agents. Collaboration with CE SAIN included organizing lectures on phosphorus fertilization for RUA students.

Objective 4 aimed to gather feedback on the acceptability and profitability of nutrient management tools through surveys and discussions with farmers and extension agents. Interviews with 31 participating farmers assessed adoption of living mulch and its impact on soil quality, supporting an undergraduate thesis and informing future publications.

Objective 5 involved developing technical leaflets on nutrient management recommendations, based on project findings, to support knowledge dissemination among farmers and extension agents.

In total, seven students gained valuable skills in household surveys and experimental design, contributing to their future careers. The project demonstrated potential benefits of living mulch in improving soil health and crop yields, suggesting scalability with further adoption studies. Future proposals aim to build on these findings to enhance vegetable production practices in Cambodia.

CAMBODIA - PROJECT 2-395: BIODIVERSITY OF CAMBODIAN LEAF- AND TREEHOPPERS: SCIENTIFIC TRAINING AND EDUCATION THROUGH DEVELOPMENT OF BIOINDICATORS AND AGRICULTURAL PEST CONTROL

PI: Phauk Sophany, Royal University of Phnom Penh

U.S. Partner: Kevin Johnson, Illinois Natural History Survey (Funded by the National Science Foundation)

Dates: August 2013 to December 2016

PROJECT OVERVIEW

The Cambodian insect fauna has been virtually unstudied, especially compared to the extensive work done on vertebrate biodiversity and management. This poses a problem because insects, comprising a much higher total biomass than vertebrates, constitute irreplaceable components of ecosystem processes and are thus vital for ecosystem health and function. This project was designed to address this shortcoming by inventorying the biodiversity of leaf- and treehoppers (Membracoidea) across space (i.e., all major habitat types and varying degrees of disturbance) and time (i.e., dry/wet season over three consecutive years). Genetic and morphological characteristics were used to identify species and allowed further basic and applied research into membracoid biology and control. The collected samples formed the nucleus for a growing entomology collection at the National Cambodian Specimen Repository (NCSP) at the Royal University of Phnom Penh (RUPP), which has been developed into an active research collection supporting the study of systematics, biodiversity, and natural history of the insect fauna of the Lower Mekong. Assessing membracoid biodiversity laid the baseline for continued biodiversity monitoring under climate change and helped inform conservation decisions by allowing rapid and efficient appraisal of ecosystem health. The study of membracoid biodiversity also provided the framework for identifying pest species in Cambodia, thereby forming the basis for applied entomological research of national and international importance.

Membracoids include several important agricultural pests affecting rice, mango, and citrus, making this project critically important for Cambodian agriculture and food security by establishing the foundation for the development of sustainable pest control practices. The use of genetic markers provided an in-depth understanding of pest population genetics and dynamics, crucial for developing and applying control and management plans. Membracoids serve as ideal bioindicators due to their high host specificity and rapid response to habitat or climate changes compared to vertebrate bioindicators. Identifying and utilizing insect bioindicators thus offers a sensitive insight into rapid changes in habitat health, biodiversity, or ecosystem function. The development of inexpensive and rapid genetic and morphological identification tools was anticipated to have immediate and lasting impacts on biodiversity assessment and conservation practices in the Lower Mekong, enhancing economic valuation of ecosystems.

FINAL SUMMARY OF PROJECT ACTIVITIES

A dozen undergraduates from the Royal University of Phnom Penh join the project team on a field trip to collect leaf- and tree-hopper samples at Kirirom National Park. (Photo courtesy Dr. Phauk).

Over the course of this project, which ended as of December 31, 2016, Dr. Sophany Phauk and his large team of researchers and students conducted temporal biodiversity inventory assessments of Membracoidea in every habitat type and along various grades of disturbance in Cambodia. As a result, they were able to assess the temporal biodiversity of not only Membracoidea but also other insect groups in most habitat types, from agricultural land to national parks, covering more than 120 collecting sites in Cambodia. They have developed an extensive national entomology collection under the auspices of their newly created organization Cambodian Entomology Initiatives (CEI) and honed the curatorial skills of the 15 team members, who have gained valuable experience working with Membracoidea and other groups such as Lepidoptera, Coleoptera, Hymenoptera, Phasmatodea, and other arthropods. Through the PEER project, they also gained expertise in identifying indicator species for habitat health and/or disturbance, allowing rapid classification of habitat value for conservation and ecosystem services. A taxonomic study of insect pest species was another important component of the project, and the researchers have identified a genus of Nephotettix and Nilaparvata that are dominant taxa in rice paddies and other agricultural sites.

Participation in PEER also greatly enhanced the international linkages of the PI and his team. PEER funds supported a month-long training visit in 2014 by three team members to the lab of U.S. partner Dr. Chris Dietrich at the Illinois Natural History Survey (INHS), University of Illinois at Urbana-Champaign. In 2015, with support from the Fulbright visiting research scholar program, Dr. Phauk had the opportunity to spend three months with Dr. Dietrich for additional training and collaboration. During that stay, he received training on advanced classification techniques for Membracoidea and worked with his partner on developing an entomology curriculum that was included in the overall undergraduate study program of the RUPP Department of Biology in late 2016. While in the United States, Dr. Phauk also made a brief visit to the Smithsonian Institution, where he established a working relationship with Dr. Stuart McKamey, a Membracoidae expert at the Institution's Systematic Entomology Laboratory. The PEER funding also facilitated the expansion of ties with Kasetsart University (Thailand), the Royal Belgian Institute of Natural Science, National University of Singapore, the Vietnam National Museum of Nature. The PI is working to develop future collaborations with the Natural History Museum in Vienna, the Museum für Naturkunde in Berlin, and Ateneo de Manila University.

As for future plans and activities, based on the results of this PEER project, the president of RUPP has committed to establishing a National Museum of Science at the university's main campus, and the museum will include some of the materials in the entomological collection created by the PI and his group. The PI recently received a small grant from MaryKnoll - Cambodia to provide ongoing support for curators at the Cambodian Entomology Initiatives (Entomological Collection) and to design an Insect Garden space at RUPP. Thanks to another recent grant provided by the ASEAN-European Union Scientific Consortium for Interdisciplinary Biodiversity Research (SEABIO), Dr. Phauk also has support for a new project aimed at establishing linkages and promoting exchanges of experts from Cambodia, the Philippines, Thailand, and European institutions focusing on aquatic insect diversity. The PI and his colleagues are working on a manuscript on Hemipteran species that will be published for the first time for Cambodia in 2017, as well as a manual on Cambodian insects. The will also continue to maintain the CEI website (https://www.cambodianentomology.org) and Facebook page (https://www.facebook.com/entocollect)

CAMBODIA - PROJECT H1-15: NEWBORN INFECTION CONTROL AND CARE INITIATIVE FOR HEALTH FACILITIES TO ACCELERATE REDUCTION OF NEONATAL MORTALITY (NICCI)

PI: Chivorn Var, National Institute of Public Health
U.S. Partner: Richard Oberhelman, Tulane School of Public Health, and Tropical Medicine
(Funded by the National Institutes of Health)
Dates: October 2014 - March 2018

PROJECT OVERVIEW

Newborn mortality remains unacceptably high in Cambodia, despite reductions in maternal and under-five mortality rates. Evidence suggests that a significant proportion of newborn deaths globally and in Cambodia are due to infections and sepsis, highlighting a critical area for intervention. The recent increase in births at Health Centers, which may not be adequately prepared for higher caseloads, has likely contributed to substandard hygiene practices and delays in referrals. The project aimed to implement and evaluate an integrated intervention to reduce newborn mortality and morbidity by enhancing infection control during the perinatal period, improving detection of newborn illnesses, and facilitating prompt referrals to appropriate care.

The project had two primary objectives: (1) to enhance infection control practices among staff at selected Health Centers and train health workers to communicate infection control messages to pregnant women and new mothers; (2) to improve the referral process for sick newborns by Village Health Support Group (VHSG) volunteers and Health Center staff through better recognition of danger signs and reducing the time between identifying these signs and seeking care at an appropriate health facility. Additionally, the study aimed to investigate the causes of sepsis among infants in specific Health Center catchment areas. Employing an experimental design, the study utilized mixed methods, including formative qualitative research, a stepped-wedge cluster randomized intervention trial, and process evaluation.

The anticipated outcomes of this study included generating data to inform policy actions aimed at improving newborn survival not only in Cambodia but also in similar settings facing comparable health challenges. The findings may support the potential scale-up of an integrated community-facility care model for newborns.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project completed all proposed activities. 114 Health Center staff (HC staff) and 505 Village Health Support Group (VHSG) members were trained to provide education/counseling to pregnant women on newborn care. Educational materials (two types of flip-charts and four types of short videos) were developed for use during training of Health Center staff and VHSGs. These materials will continue to be used by trainers as they continue to disseminate the materials for wider use.

The results from the study indicated positive impacts on improving infection control behavior by the HC staff, as well as improved knowledge on hygiene and newborn danger signs by both HC and VHSGs. VHSGs in the intervention group conducted more home visits than their peers in the control group (through the existing data, the team still needs to look into the quality of the visits and continue to share the findings). Mothers in the intervention group received health messages from VHSGs more than their peers in the control group, but the intervention alone does not change the intended behaviors among the mothers. The team found that other factors such as availability of infrastructure at the household level and motorbike/transportation means contribute to the practices of the positive behaviors including prompt referral of sick newborns. Knowledge and attitude will have little impact on the practices unless there are other enabling factors. This is an important point to share with relevant policy makers/implementer on a comprehensive approach (not only focus on knowledge and attitude, but also enabling factors) toward infection control, hygiene, and referral of newborn care.

PUBLICATIONS

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INDIA

INDIA - PROJECT 9-440: YOUNG WIVES: AN EXPLORATORY STUDY OF MARRIED WOMEN BELOW TWENTY AND THE SOCIO-CULTURAL DETERMINANTS OF THEIR CONTRACEPTIVE BEHAVIOR IN LOW RESOURCE SETTINGS IN INDIA

PI: Sudipta Mondal, Project Concern International

U.S. Partner: Cristine Legare, The University of Texas at Austin (Funded by the National Science Foundation)

Dates: March 2022 - April 2024

PROJECT OVERVIEW

Family planning (FP) remains a critical public health priority in India, with a target fertility rate of 2.1% by 2025. However, FP efforts in India have traditionally emphasized female sterilization over strategies to delay first births, which are particularly relevant for young women establishing families. Despite more than 30 million Indian women expressing a desire to avoid pregnancy, many do not use modern FP methods. Existing knowledge about the general determinants of FP behaviors among Indian couples is insufficient for planning effective interventions, as national surveys often overlook the intricate social norms and gender dynamics influencing fertility decisions, including early marriage and conception.

This PEER project sought to generate the necessary knowledge for designing interventions aimed at enabling young couples to navigate complex socio-cultural norms and make informed FP decisions that safeguard their well-being. The researchers focused specifically on married women aged 15-19 who have been married for at least a year, residing in states with high rates of early marriage and pregnancy. While policy interventions are in place, it is equally important to understand and address socio-cultural norms and gender roles to effectively delay the first pregnancies of young married women. The project aimed to identify the extent to which FP beliefs and behaviors vary between adopters and non-adopters of modern FP methods, considering these socio-cultural factors.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers developed questionnaires and structured interviews for young wives, husbands, mothers-in-law, frontline healthcare workers, and community influencers, as well as household and community observation guides. The PEER team undertook field work in several villages across five districts (Godda, Jharkhand, Dhubri, Assam, and Ujjain), sending appropriate research leads based on cultural expectations and collaborations within each area. These surveys and interviews focused on understanding family planning behaviors and choices of young couples and the role of social norms in determining both.

While there were significant differences between districts and even within villages, the researchers in general found challenges and gaps in family planning among young wives and their husbands, including restrictions on their mobility and decision-making power. Communication about family planning between spouses is lacking, with husbands often making the final decision on contraceptive methods. Misconceptions about family planning methods are common, and access to information and counseling is limited for both young wives and husbands. Regressive social norms related to fertility are a hindrance to higher uptake of contraceptives among newly married young couples in rural areas.

The researchers identified social norms and gender roles are two critical elements that need immediate attention from the FP programs targeted at young wives. They recommended programs break the “silence” around topics related to FP usage by promoting increased discourse at the family and community level, tailoring programming to local norms. The team also identified the importance of engaging not only young wives but also family members, community influencers, and frontline healthcare workers. Family members play significant roles in decision-making regarding reproductive health, so engaging them in discussions and education can lead to more informed choices. The PEER team also recommended that FP initiatives should extend their focus beyond solely measuring the total fertility rate. Instead, they should prioritize timing and spacing on the family-building journey, especially programs that actively contribute to the increasing social and economic ambitions of young women in India.

The PEER team has several papers forthcoming and will use data collected for future research. The PI Dr. Mondal also presented their findings at the Population Research Center at the University of Texas at Austin and several state-level dissemination workshops, as well as collaborated with local and international NGOs. As of May 2024, the researchers had also received three additional grants for this work, for a total of $97,000.

INDIA - PROJECT 8-141: CONVERSION FROM INTERMITTENT TO CONTINUOUS WATER SUPPLY (24 X 7) THROUGH PUBLIC-PRIVATE PARTNERSHIP (PPP): INVESTIGATING GOVERNANCE AND SUSTENANCE ISSUES IN KARNATAKA, INDIA

PI: Nayanatara Nayak, Centre for Multi-Disciplinary Development Research, In Partnership with Karnatak University, Dharwad

U.S. Partner: Emily Kumpel, University of Massachusetts, Amherst (Funded by the National Science Foundation)

Dates: January 2020 - December 2022

PROJECT OVERVIEW

The World Bank's support for Continuous Water Supply (CWS)/24x7 in Karnataka's cities rests on agreements with the state government. While the CWS pilot project succeeded in Hubli-Dharwad, questions persist about whether private sector involvement enhances urban water service delivery in terms of availability, quality, pressure, new connections, maintenance, non-revenue water reduction, billing, and fee collection upon city-wide expansion. Does 24x7 supply address equity and sustainability concerns? Does it reduce waterborne diseases? Does the public-private partnership (PPP) model enhance municipal service quality and capacity? Has 24x7 led to conflicts with traditional water institutions, affecting implementation and scaling? These queries guide the proposed study.

Jayaramu et al.'s (2015) comparison of CWS and Intermittent Water Supply (IWS) in Hubli-Dharwad highlighted higher customer satisfaction with CWS regarding water quality, continuity, quantity, and pressure, contrasting with dissatisfaction under IWS. Moreover, a draft report on environmental and social impacts of CWS in Hubli-Dharwad noted customer satisfaction among daily wage laborers in 24x7 zones, who no longer needed time off work to fetch water. Conversely, Burt and Ray (2014) found that Hubli-Dharwad's 24x7 system did not meet anticipated expectations.

The PEER study used empirical data from urban households and secondary sources including municipal bodies, private operators, financial institutions, and water boards. It aimed to elucidate these issues and contribute to global debates on continuous water delivery.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Nayanatara Nayak and her colleagues conducted a comprehensive study of four public-private-partnership (PPP) models for 24x7 water supply during their project. The first model, a "Demo" or "Pilot" project launched in Hubballi-Dharwad, Belagavi, and Kalaburagi in 2008 with World Bank and state government support, has been operational and successful. The second model involves upscaling 24x7 water supply to entire cities, initiated in 2021 with backing from the World Bank, state government, and local municipal bodies, although it faced delays and challenges with labor issues and civic unrest. The success of this model hinges on addressing technical, administrative, and human factor intrusions. The third model in Ilkal town has been highly successful, becoming the second Indian town to achieve 24x7 water supply under the PPP model with support from the Asian Development Bank and local government contributions. This model demonstrates potential for replication with appropriate conditions such as perennial water sources and community involvement. Conversely, the fourth model in Mysuru under the JNNURM in 2013 failed due to contractor non-compliance, leading to a return to intermittent water supply managed by the municipal government's Vani Vial Water Works.

The study also focused on the water user payment system, revealing widespread household preference for continuous water supply (CWS) despite higher tariffs. However, scaling up CWS from pilot districts has been slow due to implementation challenges, necessitating further evaluation post-project completion. The pricing policy, influenced more by socio-political factors than economic ones, contributes to unsustainable average water tariffs in India relative to costs, highlighting the need for dynamic pricing aligned with service efficiency.

Policy impacts emphasized the advantages of CWS over intermittent supply, including convenience, improved water quality, and higher user satisfaction. However, ongoing concerns persist regarding public confidence in tap water quality and continuity, influencing widespread water treatment and storage practices among residents.

The project's dissemination efforts through regional workshops and international conferences enhanced stakeholder awareness and prompted actions to improve water quality testing and management. Dr. Nayak highlighted successful PPP models characterized by strong local leadership, comprehensive metering, and effective demand management, contributing to operational longevity and service expansion. Public funding models also demonstrated viability but require robust local capacity-building to reduce dependence on external funding.

Looking ahead, Dr. Nayak plans to continue research collaborations with U.S. partners, leveraging new grants to further investigate water supply sustainability and governance issues. The project's impact underscores the urgency for coordinated efforts among stakeholders to enhance water management practices and support decentralized governance initiatives across India's urban landscapes.

PUBLICATIONS

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INDIA - PROJECT 8-79: COLLABORATIVE ADAPTATION PATHWAYS FOR AGRICULTURAL WATER MANAGEMENT IN BHAVANI BASIN, INDIA (CO-ADAPT)

PI: Geethalakshmi Vellingiri, Tamil Nadu Agricultural University
U.S. Partner: Sridhar Venkataramana, Virginia Polytechnic Institute and State University (Funded by the National Aeronautics and Space Administration)
Dates: December 2019 - May 2022

PROJECT OVERVIEW

Agricultural development in Tamil Nadu faces significant challenges due to water scarcity caused by recurrent droughts, increasingly attributed to climate change. This PEER study aimed to recommend adaptation strategies to manage climate risks in the agricultural sector of the Bhavani River basin in Tamil Nadu. Led by Dr. Vellingiri and her team, the study employed CRIDA (Climate Risk Informed Decision Analysis), integrating decision scaling and bottom-up vulnerability approaches in collaborative planning to develop adaptation pathways. CRIDA facilitated the identification of critical thresholds in the agricultural system, assessed future climate impacts, and proposed multiple adaptation options tailored to diverse climate scenarios.

Central to the study was a stakeholder consultation process to refine adaptation pathways, providing policymakers with actionable insights for timely interventions. The study aimed to enhance food security by proposing adaptive measures aligned with the needs of farmers and stakeholders, thereby increasing the likelihood of their implementation. The approach used in this study is expected to have the potential to be replicated at other river basins and sectors.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team members first identified, through conversations with stakeholders, performance objectives and metrics relevant to agricultural department officers and irrigation officers. They then developed a risk matrix by categorizing the risks as low, medium, and high, based on the performance metrics and the plausibility.

The researchers used these metrics while modeling the Lower Bhavani irrigation system using the ArcSWAT and Aquacrop models. They conducted a stress test using the water resources system model to examine how system performance responds to changes in climatic stressors. The stressors considered the range of change in climatic variables such as precipitation and temperature. The system was stressed to understand the response to 168 possible future climate conditions, involving a unique combination of changes in precipitation, temperature, and coefficient of variation. The PEER group analyzed the system performance under various combinations, including the aridity index, which incorporates changes in precipitation and temperature, and climate variability, as indicated by the coefficient of variation of precipitation.

Four adaptation options were identified, all related to demand management or conservation strategies. The options tested included aerobic rice cultivation, alternate wetting and drying, deficit irrigation, and delaying the transplanting of paddy by one month. All these alternative options were also subjected to stress testing using the same system model and were tested for the response in supply-demand ratio. The researchers found the pathway of delayed transplanting had least cost and maximum target benefits associated with it, if implemented as a demand management measure.

The team published their findings in a journal article and presented on risk-informed adaptation in agriculture and bottom-up approach to agricultural water management at two events in Kerala. The PI and her colleagues have received three additional grants to continue related work worth a total of $1.2 million.

PUBLICATION

Ambili G. Kamalamma, Mukand S. Babel, Venkataramana Sridhar, and Geethalakshmi Vellingiri. 2023. A novel approach to vulnerability assessment for adaptation planning in agriculture: An application to the Lower Bhavani Irrigation Project, India. Climate Services 30: 100358. https://doi.org/10.1016/j.cliser.2023.100358

INDIA - PROJECT 8-25: PLANNING PLANTATIONS: PAST LEARNING, TOWARD TRIPLE WINS IN CARBON, BIODIVERSITY AND LIVELIHOODS

PI: Rajesh Thadani, Centre for Ecology Development and Research, in Partnership with Kumaun University

U.S. Partner: Forrest Fleischman, University of Minnesota (Funded by the National Aeronautics and Space Administration)

Dates: November 2019 - August 2022

PROJECT OVERVIEW

Governments worldwide are increasingly focused on expanding tree cover, yet the outcomes of afforestation programs remain poorly understood. Recent assessments highlight unintended negative impacts and tradeoffs among carbon storage, biodiversity protection, and livelihood goals. This proposal complemented an existing NASA-funded project that evaluated the impact of plantations on land cover and the livelihoods of forest-dependent communities in Himachal Pradesh, India. PEER funding enabled CEDAR, an Indian research NGO, to measure carbon storage and biodiversity in these plantation areas and disseminate results through events, collaborating closely with a local university. The project evaluated how afforestation projects achieved the triple win of storing carbon, protecting biodiversity, and enhancing rural livelihoods, fully considering both benefits and costs in the Himalayas. It provided critical data on carbon and biodiversity across different age cohorts and ecological types of plantations, introducing methodological innovations for analyzing these impacts alongside land cover changes and livelihood outcomes. India, with its extensive history of plantation programs, significant biodiversity, and large forest-dependent population, provided an ideal context for this study.

The project addressed the growing demand in India for accurate assessments of carbon stocks and biodiversity impacts from tree plantations, crucial for evaluating afforestation effectiveness. It filled a longstanding gap by integrating social and ecological data in the Himalayan region, where such integrated studies are rare. The findings contributed to understanding which afforestation strategies were most effective in achieving triple wins, informing Indian forestry policies through planned events and advancing methods adaptable to other countries. Additionally, the project aligned with USAID's Forest PLUS program in India by developing innovative methods to identify conditions favorable for achieving synergies among carbon storage, biodiversity, and livelihood goals. It engaged forest-dependent communities, forest departments, and NGOs through training workshops and involvement in data collection and dissemination, enhancing the representation of vulnerable groups in forest decision-making processes.

FINAL SUMMARY OF PROJECT ACTIVITIES

Under this project, Dr. Rajesh Thadani, co-PI Dr. Vishal Singh, and their team at CEDAR conducted a comprehensive assessment of forest carbon storage in Kangra District, Himachal Pradesh. They measured above ground biomass (AGB) in 42 large plots and 60 smaller plots using established allometric equations, while also evaluating mycorrhizal diversity through monitoring mushroom sporocarps during the monsoon season. The project aimed to assess how afforestation projects achieve carbon storage, biodiversity conservation, and livelihood enhancement in the Himalayas, despite facing delays due to COVID-19 interruptions requiring multiple no-cost extensions.

The team found AGB values ranging from 100 to 350 metric tons per hectare across different plantation types in Kangra, comparable to Singh and Singh's (1992) findings for good secondary forests in the central Himalaya. These plantations demonstrated significant biodiversity with diverse mycorrhizal and saprophytic mushroom fruiting bodies, akin to natural forests. However, challenges included repeated planting in some areas without adequate baseline data on original forest conditions, hindering precise assessment of biomass changes over time. The study highlighted the ecological success of old plantations resembling natural forests but also noted failures due to fire damage and grazing impacts, particularly in areas where community involvement was limited.

Despite fieldwork constraints, the project facilitated two consultative workshops in Himachal Pradesh, engaging forest officials, community representatives, and ecology experts to derive policy recommendations. Additionally, the publication of a mushroom identification manual enhanced public understanding of forest diversity and functioning. The PEER collaboration allowed CEDAR to expand from Uttarakhand to Himachal Pradesh, forging partnerships with local research networks and international collaborators like Dr. Forrest Fleischman (University of Minnesota), Dr. Harry Fischer (Swedish University of Agricultural Sciences), and Dr. Alark Saxena (Northern Arizona University). While the PEER project has concluded, Dr. Thadani and his team plan to continue research on forest plantations and expand into studying forest fires, with ongoing funding from FORMAS and potential support from GIZ and other funders.

PUBLICATION

Anvita Pandey, Rajesh Thadani, N.S.K. Harsh, and Vishal Singh. 2022. Mushrooms in forest plantations of Kangra Valley. Centre for Ecology Development and Research.
Available for free download at https://www.cedarhimalaya.org/images/pdf/masrooms.pdf

INDIA - PROJECT 7-360: OFF-GRID, CLEAN ENERGY COOLING FOR AFFORDABLE STORAGE OF PERISHABLES FOR BOP FARMERS

PI: Sangeeta Chopra, Indian Council of Agricultural Research-Indian Agricultural Research Institute

U.S. Partner: Norbert Mueller, Michigan State University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Dates: January 2019 - June 2023

PROJECT OVERVIEW

A stand-alone, battery less, off-grid, solar-refrigerated evaporatively cooled (SREC) structure was field evaluated for the first time by smallholder base-of-the-pyramid (BOP) farmers, achieving daytime temperatures as low as ~5-10 °C when daily maximum temperatures outside reached approximately 45 °C. This innovative technology showed promise in enhancing the capacity and stability of BOP farmers by utilizing passive evaporation from chamber walls for cooling, employing a split evaporator coil system for thermal diversion, and integrating advanced inverter technology to optimize solar efficiency. The use of a cold-water reservoir instead of batteries for overnight cooling reduced environmental impact and operational costs while ensuring reliable refrigeration independent of the electrical grid. Farmers found the design suitable for self-construction with locally available materials, minimizing labor and initial investment, and making essential components like solar panels and inverters readily accessible in India. The project successfully replicated initial technical achievements through farmer-led field trials, evaluating energy efficiency, storage quality, household benefits, and market impacts across villages in three hot and dry Indian states.

Deploying these innovative SREC structures in farmers' fields contributed significantly to India's low-emission economy by expanding decentralized solar PV capacity and mitigating market disruptions during grid failures. On-farm cold storage reduced income loss from distress sales and spoilage, allowing for pre-processing of perishables. This technology not only improved market confidence and control but also boosted household incomes, enhancing living standards, and supporting education for women and children. Educational initiatives trained farmers and local tradesmen in SREC construction, empowering communities and creating new economic opportunities. Extension professionals were equipped to promote SREC adoption and advocate for sustainable practices in rural areas. The project's success underscored the potential of such innovations to transform agricultural practices, improve livelihoods, and contribute to environmental sustainability in developing regions like India.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Chopra and her colleagues successfully designed an off grid, battery less solar refrigerated and evaporative cooled (SREC) structure, also called the Farm SunFridge, that can be self-built by smallholder farmers. Several innovative features have been incorporated, including a "water battery" (a thermal reservoir) to provide nighttime cooling, a dual-use refrigeration coil to cool the thermal reservoir and interior air simultaneously, and a solar adaptive controller to regulate power demand by refrigeration compressor based on available solar energy. Two SREC designs were built with frames of concrete (c-SREC) and iron (i-SREC) and evaluated for their ability to regulate temperature and humidity. The Farm Sunfridges were constructed and evaluated in the northern part of India (Delhi, Haryana, and Rajasthan) from 2017 to 2022, and the design proved able to reduce the interior temperature relative to ambient between 5 and 35 °C, varying throughout the day and across the seasons. During the hot, dry season of the year, the temperatures inside the i-SREC structures were lower than those in c-SREC structures; however, when solar insolation declined during the monsoon season, the two structure types performed similarly. The i-SREC out-performed the c-SREC during periods of high solar radiation, likely a result of the much reduced thermal mass of the roofing materials in the i-SREC. A significant reduction in storage temperature and improvement in storability of perishables can be achieved, relative to ambient and relative to evaporative cooling alone, in SREC (Farm Sunfridge) structures, and it has been proven as feasible for perishables storage by smallholder farmers and farmer organizations.

To illustrate the impact the FSF is having on its users, the young farmer Abhishek and his local farmer producer organization (FPO) near the project site at Cullakpur, New Delhi, use the FSF to store cabbage, tomatoes, and spinach. They have constructed a collection center and light processing platform adjacent to the FSF, and the farmer is buying, storing, and selling his produce from the FSF facility. The farmer and other members of the FPO said that FSF was working better than their expectations. The SunFridge at Cullakpur is working very well, with low temperatures ranging from 0 to 5 °C, when there was no loading/unloading of produce, and 10 to 15 °C when there was significant product movement. The SunFridge and cold room environment has permitted growers to enter the premium market segment for sale of spinach (washed, trimmed, and bound in bunches) and red cabbage (long-term storage), and they are making increased profits thanks to the FSF. The other units built at Chamrara, Haryana, and at the exhibition ground of IARI are working well also, with the latter also serving as a demonstration unit for policy makers, growers, and students visiting IARI. The latest FSF has been built at the village of Choti Bhitarwali, Dehradun, using IARI funds.

The Farm SunFridge has garnered a lot of attention and popularity among growers and policy makers in India. The Director of IARI has provided funds to build two of the structures, and in response to the rising demand for FSF technology, IARI has selected FSF to be built under its revolving fund scheme. Under this scheme, the tenders are floated and based on the bids received, the contractors are identified for construction of the FSF, wherever and wherever there is a demand. The innovative technologies incorporated into the FSF have also attracted attention from other researchers. Two groups of scientists have contacted Dr. Chopra and her group, and together they have prepared three proposals to USAID for the construction of FSF units in Kenya and Ethiopia for smallholder farmers.

Although the PEER grant has now ended, the PI and her colleagues will be continuing their work on further enhancements to the FSF design, including to expand its storage capacity in response to feedback from its users. They will also be supervising students studying the use of the FSF with other mangoes, marigolds, and milk. Further publications on their work are expected, and they have filed for a patent in India. Dr. Chopra and her U.S. partners feel the future for upscaling the FSF looks bright, given that users of the pilot units have demonstrated strong and rapid return on investment and industry and government agencies at various levels have expressed interest.

With funding provided through a PEER Research to Action supplement, Dr. Chopra and her colleagues prepared an FSF construction manual, something that has been requested by farmers and policy makers alike. In addition, they have written a detailed project report with relevant economic analysis that will help interested parties obtain bank loans for building the structure.

PUBLICATIONS

Chopra, S., Mueller, N., Dhingra, D., Pillai, P., Kaushik, T., Kumar, A., & Beaudry, R. (2022). Design and performance of solar-refrigerated, evaporatively-cooled structure for off-grid storage of perishables. Postharvest Biology and Technology, 197, 112212. https://doi.org/10.1016/j.postharvbio.2022.112212

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Mahangade, P. S., Mani, I., Beaudry, R., Mueller, N., & Chopra, S. (2020). Using amaranth as a model plant for evaluating imperfect storages: Assessment of solar-refrigerated and evaporatively-cooled structures in India. HortScience, 55. https://doi.org/10.21273/HORTSCI15249-20

Chopra, S., & Beaudry, R. (2018). Innovative composite wall designs for evaporative cooled structures for storage of perishables. Indian Journal of Agricultural Sciences, 88(11), 1692-1695. https://doi.org/10.56093/ijas.v88i11.84895

Chopra, S., & Beaudry, R. (2018). Redesigning evaporatively cooled rooms to incorporate solar powered refrigeration in India. Acta Horticulturae, 1194, 609-616. https://doi.org/10.17660/ActaHortic.2018.1194.88

INDIA - PROJECT 5-550: DEVELOPMENT OF COMPREHENSIVE PERFORMANCE EVALUATION AND O&M STRATEGY FOR INDIAN SOLAR SECTOR

PI: Dibin Chandran, World Institute of Sustainable Energy
Partner: Deepak Sagi, Ge India
Dates: December 2016 - March 2019

PROJECT OVERVIEW

This project focused on developing a strategic plan and methodology for conducting performance evaluation and operations and maintenance (O&M) activities for solar power projects in India. It addressed current practices such as data collection, analysis, and scheduled and unscheduled maintenance, anticipating increased reliance on non-conventional energy sources in the future. Fluctuations in production from these sources were identified as potential challenges for the overall grid performance, necessitating strategic predictive maintenance and forecasting.

Key objectives included developing a comprehensive performance evaluation strategy, standardizing O&M methods, building capacity among government and private stakeholders for long-term implementation, designing policy recommendations based on project outcomes, and supporting India in achieving its 2022 solar targets. Documentation of performance evaluation methods and O&M strategies was crucial for measuring performance guarantees, assessing system performance, and verifying models applicable to new systems. Despite the straightforward nature of performance metrics, complexities arising from weather variations and imperfect data collection underscored the need for systematic handling.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project aimed to improve the quality of solar PV power plant operations and maintenance (O&M) while introducing best practices in performance evaluation. It encompassed comprehensive activities including data collection, analysis, stakeholder capacity building, and the development of O&M materials. The engagement began with a program in Pune, followed by visits to over 120 solar projects across India. The second year involved qualitative data analysis, stakeholder meetings, and the creation of a detailed O&M manual.

To ensure wide reach, the team launched a web portal and conducted seminars nationwide. A "Best Practices Handbook," finalized by November 2018, was refined based on feedback from seminars in Guwahati and Secunderabad. Covering topics from plant overview to safety measures, data monitoring, operation, performance evaluation, and maintenance, the handbook was a pivotal resource. A promotional strategy paper was also prepared and presented in key seminars, notably in Delhi and Pune, culminating in the official release of the handbook during a Delhi seminar attended by industry stakeholders and government officials. Copies were distributed to state agencies, educational institutions, and other stakeholders, with NISE endorsing the project outcomes and committing to integrate PE and O&M topics into their training programs.

INDIA - PROJECT 4-216: THE BANNI GRASSLANDS IN A TIME OF CHANGE: ECOLOGICAL AND SOCIOECONOMIC RESILIENCE IN A COUPLED HUMAN-NATURAL SYSTEM

PI: Ankila Hiremath, Ashoka Trust for Research In Ecology and the Environment
USDA Forest Service Collaborator: Susan Cordell, Institute of Pacific Islands Forestry
Dates: December 2015 - September 2021

PROJECT OVERVIEW

India's unique ecosystems, like Banni, Asia's largest tropical grassland in Gujarat's arid Kutch District, are facing increasing vulnerability. Banni, historically home to 22 pastoralist communities of the Maldharis and rich in biodiversity, including migratory cranes and flamingoes, has undergone significant transformation in recent decades. Pastoralism has shaped Banni's landscape, with unique breeds like the Kankrej cow, Banni buffalo, and Kharai camel.

Banni's challenges are exacerbated by attitudes that view arid grasslands as wastelands fit for conversion to carbon-sequestering forests, wind and solar farms, or industrial estates. A key driver of change is Prosopis juliflora, an introduced nitrogen-fixing tree that now covers nearly half of Banni. While seen by some as successful land reclamation, P. juliflora has displaced native flora, altered habitats for wildlife, and reduced grazing areas for livestock. Its spread has also fostered a charcoal economy, profoundly impacting pastoral livelihoods and cultures.

This project aimed to understand the dynamics of P. juliflora spread under climate change scenarios, assess its ecological impacts, and evaluate management options for enhancing Banni's ecological and socioeconomic resilience. Insights gained into the ecological impacts of P. juliflora, feasibility of grassland restoration, and sustainability of charcoal harvesting informed the development of adaptive management scenarios.

The Maldharis of Banni, leveraging their traditional knowledge and supported by this project, have sought community rights to manage and conserve their landscape under the Forest Rights Act of 2006. This legislation empowers local communities to sustainably manage landscapes they have customarily used. By diversifying livelihood options through this PEER project, Banni's Maldharis aim to reduce vulnerability to climate change while enhancing carbon stocks and sustaining pastoral traditions.

This initiative not only benefits Banni but also serves as a potential model for similar landscapes worldwide, aligning with USAID's Feed the Future efforts.

SUMMARY OF RECENT ACTIVITIES

This project originally aimed to achieve three main objectives: understanding Prosopis juliflora distribution and spread patterns, assessing its ecological impacts, and evaluating the feasibility of grassland restoration for livestock and wildlife. Under the guidance of PI Dr. Ankila Hiremath, graduate students and postdoctoral scholars played crucial roles. Postdoctoral associate Madhura Niphadkar conducted mapping of Prosopis using remote sensing and analyzed soil salinity changes in Banni from 1989 to 2014. This research provided insights into the relationship between Prosopis spread and increasing salinity levels.

PhD student Chetan Misher focused on studying the impacts of Prosopis on wildlife habitats, particularly on canid behavior and habitat use. His work resulted in the publication of one paper, with another paper under review as of January 2022. Collaborating with Dr. Sonali Saha, Dr. Hiremath and her team investigated water use characteristics and salinity tolerance of Prosopis compared to native woody species through nursery experiments and field measurements. Their findings shed light on why Prosopis has a competitive advantage over indigenous flora.

The team also explored Prosopis' ecohydrological impacts on water table depth and soil salinity using experimental plots across Banni. This research, currently under revision for publication, aims to deepen understanding of Prosopis' broader ecological footprint.

Ashish Nerlekar collaborated with the team on experimental Prosopis removal plots, investigating the effectiveness of uprooting and lopping methods for grassland restoration. Their findings were published in Restoration Ecology, contributing valuable insights into restoration strategies.

Postdoctoral associate Nirav Mehta utilized allometric equations derived by the team to study Prosopis lopping for charcoal production, contributing to the project's third objective. PhD student Ramya Ravi examined the socioecological impacts of Prosopis on Banni's communities, highlighting its role in shaping novel social-ecological systems and advocating for a holistic restoration approach that integrates socioeconomic and cultural perspectives.

In addition to research, the project fostered key collaborations with filmmakers from Srishti Films, resulting in impactful documentaries on Prosopis' ecological and socioeconomic impacts in Banni. These films, well-received for their sensitivity and effectiveness in communication, have helped disseminate the project's findings to broader audiences.

Furthermore, through a PEER Evidence-to-Action supplement, the project engaged system dynamics modelers Mihir Mathur and Kabir Sharma from DESTA to develop a model integrating biophysical and socioeconomic data of Banni. This model, designed as an insight-building tool, explores various management scenarios for Banni under future climate change conditions. An Android app based on this model facilitates community engagement and dialogue on landscape management options.

The project's outreach efforts extended to training programs conducted in collaboration with Sahjeevan and Kutch University, where project findings were integrated into educational modules. These initiatives have catalyzed larger-scale Prosopis removal and grassland restoration efforts led by Sahjeevan in partnership with local communities. Additionally, discussions with the Forest Department have explored collaborative approaches to landscape management in Banni.

Despite challenges posed by the COVID-19 pandemic, including necessary no-cost extensions and disruptions to field activities, the project persevered. However, governance issues and community tensions led to the cancellation of a planned final project dissemination workshop, impacting direct stakeholder engagement.

Looking ahead, Dr. Hiremath and her team are transitioning their focus from project implementation to synthesizing their learnings in a comprehensive book on Banni. This publication aims to consolidate insights from the PEER project and other research efforts spanning the past decade in the region.

In Memoriam, the PEER team honors two individuals who made significant contributions to the project but passed away during its course: Salim Node (Salim Mama), a respected Banni elder whose insights and support were invaluable, and Nirav Mehta, a dedicated colleague who coordinated field work and data collection in Banni.

Publications resulting from the project include studies on Prosopis management strategies and wildlife impacts, contributing to the scientific understanding of invasive species and ecological restoration in arid ecosystems.

PUBLICATIONS

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INDIA - PROJECT 3-207: EFFECTS OF CLIMATE CHANGE ON CRYOSPHERE-RIVER LINKAGES: INSIGHTS FROM SEASONAL AND INTER-ANNUAL VARIATION OF GLACIAL MELT DISCHARGE IN THE HEADWATERS OF THE GANGES RIVER

PI: Indra Sen And Co-Pi Rajiv Sinha, Indian Institute of Technology--Kanpur
U.S. Partner: Bernhard Peucker-Ehrenbrink, Woods Hole Oceanographic Institution
(Funded by the National Science Foundation)
Dates: September 2014 to July 2017

PROJECT OVERVIEW

Global warming and climate change have adversely affected the Himalayan glaciers, which feed several large rivers in the Indian subcontinent, including the Ganges River. The increased runoff from snow and ice melt in the Ganges River basin and heightened flood risks, along with concerns about future water supply and food security, have raised significant alarms. However, the impact of climate change on the hydrological budget of the Ganges River was not well understood. This research project aimed to assess how climate change affected the linkages between the Himalayan Cryosphere and large river systems.

The research team investigated the impact of climate change on the hydrological regime of the Ganges River. Temporal variability in contributions from snow and ice melting over seasonal to inter-annual timescales was quantified. A hydro-geochemical model for snow/ice meltwaters to the headwaters of the Ganges River was developed based on time-series observations of water discharge and physical and chemical parameters of water samples from glaciated Ganges headwaters. Seasonal and inter-annual variability in $\delta^{18}O$ and $\delta^{2}H$ of Ganges River headwaters was characterized, and multi-component isotope and geochemical mixing models were constructed to quantify the relative contributions of rainwater, glacial melt, snowmelt, and groundwater flow to total discharge. Source apportionment of river water assessed the impact on downstream ecosystem services due to modifications in the hydrological regime and enabled predictions of future changes.

The findings of this project provide important insights into the effects of climate change and retreating Himalayan glaciers on the hydrological budget of the Ganges River. These results are expected to be of broad interest to researchers in climate change, glaciology, hydrology, and river dynamics, as well as those focused on water and food security issues. A river water storage facility was built at IIT-Kanpur to archive water samples for future analytical work. Additional time-series water samples were collected to support the work of other researchers. Given the challenging access to these remote locations, these additional samples are a valuable asset for the scientific community interested in understanding the impacts of climate change on large river system dynamics.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ended as of July 31, 2017, allowed the PI Dr. Sen to support researchers and students (including sending some for extended training in the United States), facilitate substantial fieldwork and travel to key professional conferences, upgrade the water sample archive at his institution, and purchase vitally needed reagents and supplies. With special authorization from the program sponsors, some PEER funds were also used to help the institute purchase a vehicle suitable to transport researchers into the high-altitude, hard-to-reach areas where they conduct their fieldwork.

In his final report, the PI Dr. Sen noted that his team's PEER-supported work focused on the relative contributions of Himalayan glacier meltwater and precipitation received during the annual Indian Summer Monsoon (ISM) to the water flow in the large river systems that provide water security to about 750 million people in South Asia. The role of ISM in Himalayan deglaciation and its effect on stream hydrology are poorly constrained, so in their PEER study Dr. Sen and his colleagues used an oxygen and hydrogen isotope-mixing model to "fingerprint" the water sources in the nine headwater tributaries of the Ganges. They estimated the discharge-weighted glacier melt, precipitation, and baseflow fractions over various stages of the annual hydrologic cycle between 2014 and 2016. They found that the post-monsoon months (October and November) before the onset of winter consistently featured the highest glacier meltwater proportions compared to the pre-monsoon period (April and May) or the peak summer months. This observation was contrary to the conventional wisdom that glacial melt proportions are highest during the pre-monsoon or summer months due to elevated temperatures causing increased glacial melt runoff. To explain the observed enhanced glacial melt proportions during post-monsoon months, they hypothesized that monsoon precipitation acts as a trigger for enhanced melting and develops an efficient englacial drainage network for melt water transport. The heat released by rainfall cooling and freezing within glaciers causes enhanced melting, whereas opening of the englacial conduits creates an efficient englacial drainage network. They estimate that heat released by rainfall cooling and freezing could contribute up to 3-12% of total glacial melt discharge. Their findings suggest that ISM is one of the important drivers of enhanced glacial melt runoff in the Himalayan Rivers.

In early 2018 the team published a paper on some of their work: Sen, I. S., Boral, S., Ranjan, S., and Tandon, S. K. Small But Important – The Role of Small Floodplain Tributaries to River Nutrient Budgets. ACS Earth and Space Chemistry, 2018, 2(1), 64-71 (available online at https://pubs.acs.org/doi/abs/10.1021/acsearthspacechem.7b00112). They have also created a project website at http://www.iitk.ac.in/geochemistry/research featuring their findings.

By the time his project ended, Dr. Sen reported that he had received two grants totaling about US $145,000 to support his continued research activities. One was from the Keshava Deva Malaviya Institute of Petroleum Exploration (a division of the Oil and Natural Gas Corporation Ltd.) and the other was from the Science and Engineering Research Board of the Government of India. He is also seeking additional grants and expects that he and his team will publish other papers on the research completed with PEER support. A documentary directed by Dr. Sen highlighting river science can be viewed online at: https://www.youtube.com/watch?v=yyacLgSRTTA

INDIA - PROJECT 2-171: EVOLUTION, DIVERSIFICATION AND BIOGEOGRAPHY OF CICADAS (INSECTA: HEMIPTERA: CICADIDAE) ON THE INDIAN SUBCONTINENT

PI: Krushnamegh Kunte, National Center for Biological Sciences
U.S. Partner: Chris Simon, University of Connecticut (Funded by the National Science Foundation)
Dates: August 2013 to December 2015

PROJECT OVERVIEW

Most of the scientific knowledge on Indian biodiversity is 60 to 100 years old, dating back to the pre-independence era. During this time, there have been tremendous scientific developments in areas such as evolution, molecular phylogenetics, biogeography, and conservation genetics. This has substantially advanced our understanding of the evolution and dispersion of biodiversity on Earth. Unfortunately, much of this development has largely excluded India, which is unfortunate considering the crucial biogeographic role that the Indian Subcontinent plays. India is at the junction of the Palearctic and Oriental zoogeographic regions and is believed to have been critical in the evolution and exchange of many important faunal elements across these regions. Thus, understanding the evolution and biogeography of Indian faunas is important in constructing a more complete picture of biological diversification in the Palearctic and Indo-Australian Regions.

Using cicadas as a tractable invertebrate group, this project aimed to: (1) study the origin and diversification of cicadas in India in relation to neighboring regions, (2) generate a higher-level phylogeny of Indian cicadas that formed a backbone of all subsequent studies, and (3) help inventory cicada diversity, including cryptic species, with the help of molecular data. The researchers involved intensively sampled cicadas across the length and breadth of India and applied DNA sequencing, phylogenetic methods, and recently developed genomic methods. This work generated valuable new information on the taxonomy, diversity and endemism, biogeography, and conservation needs of cicadas and other invertebrates.

With its burgeoning industries, high gross domestic product, and an already considerable and yet ever-increasing population of technically and technologically well-trained youth, India is poised to become a significant scientific and technological power in the near future. However, the country has been struggling to meet the demand for ecologists and conservation biologists. This project supported two Master's-level students to study the diversity, taxonomy, and biogeography of Indian cicadas, with the aim of promoting the development of indigenous biological expertise and local involvement in documenting and conserving biodiversity in India. Improvements were also needed in local infrastructure to complement research in frontier areas of biology.

At present, the best reference research collections on Indian fauna are outside the country, thus keeping certain kinds of research, such as species discovery and evolution of biodiversity, out of reach for most Indian biologists. The research collection that Prof. Kunte built at his institution began to tackle this issue. This collection now holds more than 3,000 specimens, including several dozen cicada specimens, which are well-curated with geo-referenced data and a DNA library associated with each specimen. The collection has space and instruments for microscopy, high-resolution close-up photography, sound recording, and electronic data archival and retrieval systems. This collection, freely accessible to Indian and foreign scientists, has become a major infrastructural resource, especially for Indian biologists, boosting the breadth and depth of biological research in India.

FINAL SUMMARY OF PROJECT ACTIVITIES

In September 2015, Dr. Kunte conducted two workshops at the Student Conference on Conservation Science—Bangalore 2015 (SCCS), Indian Institute of Science, Bengaluru. The day-long workshop, "Ecological Monitoring of Tropical Insect Diversity: Field and Lab Techniques," instructed 15 students in field and lab techniques for studying tropical insects, including cicadas. A subsequent two-hour workshop on "Ecological Monitoring and Conservation of Tropical Insect Biodiversity" engaged approximately 100 students in discussions on monitoring insect populations and diversity in tropical areas, focusing on cicadas, butterflies, and dragonflies.

Dr. Kunte and colleagues met with state forest department officials in three states, sharing updates on their Indian cicada research. This led to collaboration with one state forest department to develop educational materials highlighting insect biodiversity in India. Discussions with local World Wildlife Fund members included sharing survey findings, notably from Arunachal Pradesh. In the project's final weeks, Dr. Kunte utilized the Natural History Museum, London's collection of Indian cicadas for ongoing taxonomic work from November 1 to December 15, 2015.

Following the December 2015 conclusion of the PEER award, all cicadas collected were curated, forming one of South Asia's premier collections with over 800 specimens of nearly 60 species from across India. Housed at the National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru, this collection features a DNA library and geo-referenced data. Sequencing critical species essential for global cicada phylogeny, the team shared data with U.S. partner Prof. Chris Simon, supporting his NSF-funded work.

The team launched the website http://www.indiancicadas.org/, a citizen-science project, compiling and freely sharing ongoing information on Indian cicadas, now featuring over 50% of India's known species. They developed features such as mapping modules and image galleries, enhancing its value. Their collaborative research produced a synonymic catalogue of Indian cicadas, updating taxonomy after nearly 80 years, provisionally accepted by Biodiversity Data Journal. This paper is crucial for future cicada studies.

Since August 2013, the project trained two research assistants and approximately 400 students through workshops and talks at SCCS Bengaluru in 2014 and 2015, advancing insect survey methods, data analysis, and specimen curation.

INDIA - PROJECT 2-61: TARGETING LOW-ARSENIC AND LOW-FLUORIDE GROUNDWATER TO REDUCE EXPOSURE IN RURAL PUNJAB, INDIA

PI: Chander Kumar Singh, Teri University; With Co-PIs Saumitra Mukherjee, Jawaharlal Nehru University; Umesh Kumar Garg, Adesh Institute of Engineering and Technology; And Manpreet Singh Bhatti, Guru Nanak Dev University

U.S. Partner: Alexander Van Geen, Lamont-Doherty Earth Observatory of Columbia University (Funded by the National Science Foundation)

Dates: August 2013 - July 2017

PROJECT OVERVIEW

Groundwater drawn by millions of handpumps in several regions of India, including Punjab state, has caused serious health problems due to elevated concentrations of arsenic (As) and fluoride (F). Rocks and sediments were identified as the natural sources of As and F entering groundwater, with human modifications of the hydrological cycle potentially exacerbating concentration buildup in certain areas. A notable characteristic of As and F distribution in handpump water was its spatial variability, which remained relatively stable over time. Many rural households in Punjab with unsafe handpumps were found to be located within walking distance of safe alternatives, although the majority of handpumps had never been tested.

This project aimed to assess the predictability of spatial distribution and temporal variability of As and F in groundwater across the affected region of Punjab. The approach involved (1) testing a large number of handpumps in villages along two representative transects and (2) using this extensive dataset to target detailed process studies through drilling and installing monitoring wells at two geological transitions. The new field data facilitated testing of hypotheses concerning the impact of various factors and processes on local hydraulic regimes and groundwater As and F concentrations.

The lack of handpump testing in the region had led people to consume groundwater without knowledge of its safety. Alongside its research objectives, this project tested approximately 20,000 handpumps for As and F in alluvial aquifers of the region. Field measurements using kits were complemented by laboratory quality control, demonstrating to local authorities the feasibility and necessity of a comprehensive testing campaign using current technology. Assuming an average dependency of 10 people per handpump and that half of the tested wells were unsafe, with half of those affected switching to nearby safe alternatives, the testing initiative alone significantly reduced exposure and improved health for approximately 50,000 individuals.

This extensive dataset, coupled with process studies at geological transitions, provided predictive insights to prioritize future testing efforts in thousands of specific villages across the region.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project commenced with a pilot testing campaign from July 24-30, 2013, involving U.S. partner Alexander van Geen, co-PIs Manpreet Singh Bhatti, Umesh Kumar Garg, and students from TERI University and local universities. During this initial survey, seven villages were tested for various water quality parameters using field test kits recommended by the U.S. partner. Additional groundwater samples were collected and analyzed at Columbia University, Barnard College, and Guru Nanak Dev University (GNDU).

Based on pilot survey results, the project expanded its scope by adding a third transect, increasing the total number of villages to be tested to 200. The decision was also made to include nitrate testing alongside fluoride and arsenic due to significant nitrate contamination findings. Metal placards indicating water safety were installed on approximately 13,000 wells across the tested villages.

Geographical analysis revealed distinct contamination patterns, with arsenic predominantly found in the northern study region (43 out of 73 villages), while nitrate concentrations were higher along the Beas River transect (>45 ppm). Fluoride and high electrical conductivity were prevalent in the southern study area. The project's fieldwork also trained 20 local villagers to conduct groundwater testing using field kits, enhancing community involvement and sustainability.

In addition to supporting fieldwork and data analysis in India, the PEER project facilitated productive exchange visits. PI Dr. Chander Kumar Singh and doctoral scholar Mr. Anand Kumar visited Columbia University in October 2014 to analyze and map water sample data. They returned for further work and coursework in 2015, refining their research questions and planning additional field studies along the Ravi River floodplain.

The project's outreach efforts included organizing a national symposium in April 2016, attended by 250 participants, and briefing officials from the Department of Water Supply and Sanitation, Government of Punjab, and other relevant bodies. Despite concluding in July 2017, ongoing data analysis and manuscript preparation have garnered additional local and international funding, totaling $120,000, and recognition as one of India’s top scientific achievements in 2018.

PUBLICATIONS

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INDIA - PROJECT 1-32: INSTITUTIONAL DYNAMICS OF ADAPTATION TO CLIMATE CHANGE AND URBANIZATION: ANALYSIS OF RAIN-FED AGRICULTURAL-URBAN LAKE SYSTEMS IN BANGALORE, INDIA

PI: Harini Nagendra, Ashoka Trust for Research in Ecology and the Environment
U.S. Partner: Tom Evans, Indiana University (Funded by the National Science Foundation)
Dates: May 2012 - May 2016

PROJECT OVERVIEW

This project examined how institutions can facilitate adaptation to climate change and urbanization in the highly vulnerable, rain-fed, semi-arid agricultural-urban system of Bangalore. The study focused on a network of 65 lakes in southeastern Bangalore. Differences between lakes within and outside the city boundary provide useful contrasts to address core questions. While both lake subsets have a similar exposure to climate change, the lakes outside the city exhibit greater institutional nestedness compared to lakes within the city, while the city municipal institutions have greater technical and financial resources.

The PEER project addressed three core research questions: the historical evolution of institutional regimes of water allocation, the current role of institutional nestedness in enabling adaptation to climate change, and future assessments of the ability of user groups to respond to potential climate change. Researchers used an interdisciplinary approach, integrating data on changes in climate and precipitation, historical datasets on land cover and common property resources, current land cover from high resolution satellites, ecological and environmental analyses of lake condition, archival and policy research, interviews with individuals, communities and government institutions, and qualitative scenario building.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team was able to procure village maps, high resolution satellite imagery to develop a GIS database on lakes and commons in the study area, mapping changes in lakes, wells, cultivation and tree cover from 1791 until 2015. Through field visits to over fifty villages, researchers identified 20 lakes for further in-depth study. In those lakes, they conducted water testing, interviews with local residents and government officials, taking measurements before and after monsoon season. The PEER team also conducted larger scale field visits on lakes across the city, as well as archival research on changes in governance from the colonial period onwards to investigate centralized vs decentralized governance's impacts on the condition of the lakes.

Three female PhD students and one Master's student worked on the project and used their research as part of their required theses. The PI incorporated material from the project for an undergraduate course on remote sensing she presented at Macalester College in Minnesota, a Master's in Development course on land change at Azim Premji University, and a course on sustainability in planning and practice also at Azim Premji. As part of this latter course, students visited five community-restored lakes in Bangalore that the PEER project studied, using the information gathered from the project to guide field-based learning about issues of sustainability in practice in the context of Bangalore's lakes. By the time the final report was submitted in 2016, the research team had published 11 journal articles and two book chapters and made more than four dozen conference presentations and public talks. Researchers contributed input to lake restoration work by communities, civic and government bodies, and corporate groups. They also led heritage walks around lakes at two festivals, introducing participants to sacred and keystone trees, birds and insects, and fishing and grazing areas.

PUBLICATIONS

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INDIA - PROJECT PP-27: NSF-PIRE COLLABORATION: DEVELOPING LOW-CARBON CITIES IN INDIA: FOCUS ON URBAN INFRASTRUCTURES, CLIMATE RISKS, AND VULNERABILITY

PI: Sachchida Nand Tripathi, Indian Institute of Technology-Kanpur
U.S. Partner: Anu Ramaswami, University of Minnesota (Funded by the National Science Foundation)
Dates: January 2013 - January 2017

PROJECT OVERVIEW

This PEER project addressed climate change, renewable and sustainable energy interventions, water sustainability, and environmental engineering solutions in cities in India, covering several key USAID priorities. The PI and his team conducted field research on human development risks and climate risks associated with current and future infrastructure trajectories in Indian cities, exploring the extent to which low-carbon infrastructures in India can improve human well-being in cities. To address this issue, the research developed analytic tools to help quantify human co-benefits of low-carbon interventions in Indian cities.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers estimated airborne particulate matter (PM) concentrations in Indian cities using satellite data and related these to fossil energy use and human development impacts. The team also purchased and set up environmental beta attenuation mass (EBAM) instruments to monitor PM 10 and PM 2.5 and conducted sampling in Delhi and Hyderabad. A U.S. colleague from Georgia Tech visited to take part in the experiment work. The PI and one of his students on the team visited the United States for research work on conducting climate simulations using the WRF/Chem model incorporating spectral downscaling.

Team members made aerosol measurements in Kanpur and Agra and also organized a summer school at IIT Kanpur with international and Indian lecturers to discuss sustainable cities. A total of 24 students from different universities attended. The researchers have published several papers from their findings and presented their work at various workshops, the Indian Aerosol Science and Technology Association, and the Annual American Geophysical Union conference.

PUBLICATIONS

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INDIA - PROJECT PP-26: NSF-PIRE COLLABORATION: DEVELOPING LOW-CARBON CITIES IN INDIA: FIELD RESEARCH ON WATER-ENERGY-CARBON BASELINES AND LOW-CARBON STRATEGIES IN INDIAN CITIES

PI: Emani Kumar, ICLEI – Local Governments for Sustainability, and Rakesh Yadav, Resource Optimization Initiative
U.S. Partner: Anu Ramaswami, University of Minnesota (Funded by the National Science Foundation)
Dates: January 2013 - June 2016

PROJECT OVERVIEW

The overall goal of this project was to conduct innovative, interdisciplinary research that facilitates the development of low-carbon cities in India through mitigating greenhouse gas emissions while also offering local water efficiency benefits; reducing waste, pollution, and climate vulnerability; and promoting governance for sustainable development. In alignment with several key USAID priorities in the country, this project addresses climate change, renewable/ sustainable energy interventions, water sustainability, climate risks, and environmental engineering solutions in cities in India.

The project applied an interdisciplinary framework to integrate urban infrastructure engineering, industrial symbiosis, urban planning, environmental/climate sciences, social sciences, and public policy. Research opportunities were offered to about 50 students from the United States (with separate funding from the National Science Foundation) and 50 students from India drawn from diverse disciplines, which were intended contributed to training the next generation of leaders in the two nations. The expectation was to build capacity among academic institutions in India for innovative interdisciplinary research and education on sustainable cities and build capacity among nongovernmental organizations to translate research insights to community-based action for sustainability.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the project, the project team conducted research surveys on industrial symbiosis in the cities of Mysore and Coimbatore, located in Karnataka & Tamil Nadu states, respectively. The results were drafted into reports indicating the existence of symbiotic relationships that saved resources and also found there is still potential to explore symbiotic relationships in future. These were explored during a January 15, 2015 workshop titled "Industrial Symbiosis: How to Conduct Industrial Symbiosis Research in India?" which was attended by stakeholders including 110 student participants (45 males & 50 females). Following the workshop and in compliance with India mandate on CSR activities relating to public-private partnerships for sustainable development, the project team met with government and private sector officials resulting in a case study with PepsiCo on the collaborative approach of CSR in achieving sustainability. Finally, the team developed a database of industrial symbiosis case studies in India, US, and China for further research & comparisons.

In terms of education, the project developed one day training program on industrial symbiosis focusing on conducting industrial symbiosis in India. It sponsored two TERI students to participate in the Summer School organized at IIT Kanpur, India and recruited 11 students (nine females and two males) from Sri Jayachamarajendra College of Engineering (SJCE) to conduct field research in Mysore and one female project lead and four students from Park College of Engineering to conduct field research in Coimbatore. The students were also trained on conducting industrial surveys and are now well placed in their professional careers.

INDIA - WMSG2-003: UNDERSTANDING MYCOBACTERIUM TUBERCULOSIS MEDIATED HOST METABOLOMICS IN PULMONARY TUBERCULOSIS: CORRELATION WITH DISEASE SEVERITY AND TREATMENT COURSE

PI: Senbagavalli Prakashbabu, Jawaharlal Institute of Postgraduate Medical Education & Research (JIMPER)

Dates: February 2022 – July 2023

PROJECT OVERVIEW

TB induces changes in the host's metabolism, which may provide an opportunity to identify specific markers of Mycobacterium tuberculosis (MTB) infection. This PEER project studied the differences in MTB influenced host metabolomics in mild and severe disease groups. The researchers studied the dynamic changes of host metabolites at baseline, during, and at the end of the standard anti-TB treatment regimen and examined whether there is a correlation between host metabolomics, disease severity, and treatment course.

The PI, while having a strong background in human immunology and research methodologies, had not recently undertaken research because of her job as a project manager. This project allowed her to focus on this research and in the process to support mentees in gaining hands-on research experience in handling and processing human samples and contributing to extensive statistical analysis and manuscript writing.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers used plasma samples and associated data that were collected and stored as part of the RePORT India Common Protocol (CP) Phase I. Treatment naïve, culture confirmed, adult pulmonary TB patients and their household contacts without any comorbidities were included in this study. TB cases were grouped as mild or severe based on chest x-ray findings and sputum smear grading at diagnosis. The team performed metabolomic analysis of the plasma samples of eight mild and severe cases at baseline, one month after treatment initiation, and at the end of treatment. For control contacts, only baseline samples were analyzed. The PI is currently developing a manuscript for publication on the findings as she continues in her career progression as a TB metabolomics researcher.

INDIA – WMSG2-010: "CREATING A HOPE": A MIXED-METHOD APPROACH TO IDENTIFY MOST ACCEPTABLE EVIDENCE-BASED PSYCHO-SOCIAL INTERVENTION TO IMPROVE THE RETENTION IN CARE AMONG INDIAN YOUTH DIAGNOSED WITH MULTI-DRUG RESISTANT TB (MDR-TB)

PI: Gauri Dhumal, Johns Hopkins, BJ Government Medical College

Dates: February 2022 - March 2024

PROJECT OVERVIEW

The incidence of tuberculosis increases rapidly during adolescence to peak in early adulthood in high TB transmission settings. This age group, particularly those with Multidrug Resistant tuberculosis (MDR-TB), face specific age-related challenges in accessing appropriate care. Few studies have identified adverse impact of MDR-TB treatment in adolescents, such as serious physical and neurological side effects. These create psychological distress for adolescents leading to treatment discontinuation. Two studies from South Africa and India reported delays in diagnosis, lack of follow up, and refusal to take medication as serious issues. These data and experiences highlight the high vulnerability of many adolescents and young adults (AYA) with MDR-TB and the challenges of successfully engaging them in care. Exploring the psycho-social barriers to treatment adherence and retention and identifying the most preferred psycho-social interventions for this population are critical to mitigating these barriers and improving their engagement in care.

This PEER project involved a mixed-method study with AYA with MDR-TB to investigate psycho-social barriers, health-system related barriers, and satisfaction with their current health condition. The researchers sought to identify the barriers to retention of care, identify evidence-based effective psycho-social interventions for youths through literature research, and assess the acceptability of proposed youth-friendly psycho-social interventions. The PEER project also involved a mentoring and training component focused on three female researchers involved in the project.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team conducted six in-depth interviews and 30 semi-structured interviews with AYA with MDR-TB between April 2022 to March 2023 registered at a public MDR-TB hospital. Questions involved gathering individual-level data on psycho-social barriers such as mental stress, suicidal thoughts, feelings of stopping medicines, perceived and experienced stigma, and socio-economic burden, as well as health system-related barriers, including delayed diagnosis, drug stockout, and negative experience with healthcare providers.

The mentees involved in this project received intensive training in the fundamental principles of clinical research, acquiring proficiency in essential qualitative methodologies, development of data collection tools, ethical considerations, and interviewing skills. The mentee team members also participated in critical paper discussions, literature reviews, and abstract writing exercises. All mentees actively contributed to synthesizing the research findings and played integral roles in disseminating results through scientific forums and events. One mentee, who is now enrolled as a doctoral candidate, independently conducted qualitative analysis and contributed to drafting the study's abstract.

As part of the study, the researchers developed several policy recommendations, including integrating mental health screening in the healthcare system for this population. PEER team members presented their findings at the Union World Conference on Lung Health 2023 and at the tertiary care TB Chest Hospital at Aundh, Pune, India, in December 2023, where more than 50 key personnel from the National TB and HIV programs across the city discussed the findings and shared their insights. The researchers plan to publish their findings in a TB-related journal.

INDIA – WMSG2-001: ASSESSING PREPAREDNESS OF URBAN COMMUNITY HEALTH WORKERS FOR TUBERCULOSIS (TB) CONTROL- AN EXPLORATORY STUDY IN TWO CITIES OF INDIA

PI: Dr. Shilpa Karvande, Foundation for Medical Research

Dates: March 2022 - February 2023

PROJECT OVERVIEW

Community health workers in urban areas of India (urban Accredited Social Health Activists, or ASHAs) are now involved in a biannual active tuberculosis (TB) case finding survey and have recently started working as TB treatment supporters. Scientific research on urban ASHAs' preparedness in general and particularly in supporting TB care and patients is limited. Their counterparts in rural settings have been relatively more studied and reviewed. This PEER project was therefore undertaken to evaluate the ASHA program in Mumbai and Pune, specifically to assess their preparedness for TB control. The research focused on the needs of community health workers specific to urban settings.

The project also supported the research and mentorship of five young female scientists, and the initial results have opened several avenues for developing research and intervention ideas for TB patients and urban community health workers. Dr. Karvande and her colleagues also made specific recommendations for the improvement of the TB program, including capacity building for urban ASHAs and better placement of these workers within the primary health system.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers selected areas within the two cities with a greater number of working ASHAs and a relatively higher burden of TB in consultation with city program officials. Fifty percent of the urban ASHAs working in these areas were surveyed (n = 222), selected by the proportionate random sampling technique, and participants of qualitative components of this research were selected purposely. Both components sought to understand ASHA knowledge related to TB training, their role in TB care, their perceptions regarding TB and nutrition, stigma, and people-centered care.

The PEER team found TB-related knowledge was generally low. Only about 30% of the ASHAs surveyed could identify symptoms other than cough and weight loss, while fewer than 2% knew about diagnostic tests such as nucleic acid amplification tests and culture drug susceptibility testing. Knowledge of contact tracing and prevention strategies beyond cough etiquette were below 20%, while knowledge of adverse drug reactions and information about the TB direct benefit transfer were below 50%.

The researchers reported that these and other subjects were not covered in-depth during the existing half-day session of TB training for ASHAs. Among the key suggestions for better supervision and reporting by the stakeholders were standard templates for home-visit interaction and inclusion of TB indicators in routine reporting. Stigma was another key issue identified. More than half of the ASHAs (57.7%) perceived TB patients faced stigma. Fear among TB patients in sharing their diagnosis affected the urban ASHAs in their role of TB control.

The young female scientists in this PEER project gained skills through semi-structured interviews with ASHAs, and three of the five mentees have continued on to PhD programs in public health. All mentees took online classes to develop effective skills in writing and formatting scientific manuscripts and grant proposals and in dealing with ethical issues in publication. They discussed these topics during regular in-person mentoring sessions. One mentee joined the data collection phase as part of her summer internship program and learned about data collection and tuberculosis more widely.

The research team shared the results of this study with key Mumbai city officials and TB program officials. The findings also inspired three newspaper articles, in the Hindustan Times, the Times of India, and Sakal, a local Marathi-language newspaper.

INDIA – WMSG2-011: "BRIDGING THE GAPS": UNDERSTANDING THE BARRIERS AND FACILITATORS IN THE TUBERCULOSIS PREVENTION CARE CASCADE FOR OPTIMIZING ISONIAZID PREVENTIVE THERAPY UPTAKE AMONG ADULTS LIVING WITH HIV IN INDIA, A MIXED-METHOD APPROACH

PI: Neetal Nevrekar, Byramjee Jeejeebhoy Government Medical College, Johns Hopkins Clinical Research Site IN Pune, India

Project Dates: February 2022 - February 2024

PROJECT OVERVIEW

India accounts for 26% of the TB cases worldwide, and almost 40% of its population is infected with latent TB. The country ranks third in the share of HIV burden and has an estimated 71,000 HIV-TB co-infection cases. Nearly 25% of all deaths among people living with HIV (PLHIV) in India have been estimated to be due to TB. Prevention of TB disease is a critical component of the National Strategic Plan for TB elimination in India, and scaling up Isoniazid Preventive Therapy (IPT) could accelerate the rate of decline in TB incidence. In 2017, India rolled out a nationwide IPT policy, but implementation has been challenging and coverage has been low. IPT coverage among eligible PLHIV in 2019 was only 43-45%.

Studying the barriers to and facilitators for IPT uptake serves a public health need for the prevention of TB among adult PLHIV in India and similar HIV-TB burdened settings. This PEER project investigated the barriers to IPT uptake among adult PLHIV and sought to identify possible strategies and facilitators to improve the uptake of IPT. The project also included a mentoring and training component for young female researchers.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers conducted in-depth interviews with adult PLHIV and healthcare providers, followed by more than 200 semi-structured interviews with only PLHIV to assess factors influencing IPT uptake. The in-depth interviews identified time constraints, IPT side effects, and limited counseling as barriers among PLHIV, while healthcare providers highlighted challenges in TB screening, staff shortages, and medication stockouts. Facilitating factors for PLHIV included TB/IPT knowledge, perceived benefits, self-motivation, and trust in healthcare workers, while the providers reported definitive IPT prescription and assertive counseling.

The semi-structured interviews indicated an IPT uptake of 45%, with 59% reporting missed doses and 24% experiencing side effects. Major barriers included frequent drug stockouts, adverse reactions, lack of motivation, and forgetfulness. Facilitators included counseling by HCPs, self-motivation, and support from family and friends.

Final data analysis is ongoing, and the PEER team expects to submit findings to a journal. Meanwhile, the researchers presented their findings at the 2023 International AIDS Society Conference and at a dissemination event at the tertiary care TB Chest Hospital at Aundh, Pune, India. The dissemination event drew more than 50 participants from the national TB and HIV programs across the city. Policy recommendations from this study include strengthening the healthcare system by ensuring adequate staffing and periodic training sessions, maintaining a steady supply of IPT medicines, increasing awareness of IPT benefits, and providing counseling about its side effects.

As for the mentorship component, the mentees received training in clinical research principles, including research ethics, study design, data collection and management, statistical analysis, and interpretation of results. They were actively involved in various aspects of the research project, such as design of the interview guide and tools, participant recruitment, data collection, data entry, data cleaning, and data analysis.

INDIA – WMSG2-005: POST TB SEQUELAE –METABOLIC SYNDROME AND THE UTILITY OF PLASMA BIOMARKERS IN PULMONARY AND EXTRAPULMONARY TUBERCULOSIS PATIENTS FROM SOUTH INDIA

Pi: Priyadarshini Padaki, St. John's Medical College and Hospital, India

Project Dates: February 2022 - March 2024

PROJECT OVERVIEW

This PEER project conducted a joint study on the occurrence of metabolic syndrome in patients with TB and sought to facilitate the diagnosis and improve the prognosis of both extrapulmonary TB (EPTB) and pulmonary TB (PTB) in South India. The main goals of the research included assessing the incidence of metabolic syndrome over a two-year period in newly diagnosed TB patients; identifying differences in plasma biomarkers in diagnosis of EPTB vs PTB vs a control group; and assessing the role of plasma biomarkers as prognostic indicators in PTB and EPTB patients. This project also supported mentoring of undergraduate medical students at St. John's National Academy of Health Sciences, including training in research and proposal development and a scholarship program.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers recruited 428 tuberculosis patient, monitoring their treatment adherence, clinical measurements required to diagnose metabolic syndrome, and outcomes every six months. The prevalence of metabolic syndrome in the Indian adult population is 30%, and the researchers theorize that the lower prevalence at baseline among TB patients could be attributed to weight loss and other metabolic changes in the body. Factors associated with TB could also explain changes at the one-year mark, indicating the need for regular follow up of tuberculosis patients at least for two years to screen for and prevent development of cardiovascular events.

In a separate study, the PEER team recruited 60 subjects, 25 with PTB, 35 with EPTB, and 30 control samples from healthy volunteers for analysis of biomarkers. The initial findings point to two biomarkers that could be suitable for assessing prognosis, but this study needs to be extended with analysis on a larger subset of TB patients.

The team conducted a half-day workshop on November 4, 2022, for undergraduate students with the focus on research skills, project proposal writing, and ethical concerns. A total of 18 students participated in the workshop. Following the workshop, the students were asked to submit brief concept notes on tuberculosis-related research. A total of 12 students were selected for a small scholarship to work on six different projects under the mentorship of senior PEER team members Dr. Minu Rose Mani, Dr. Priyadarshini Padaki, and Dr. Mamatha V. after obtaining ethical clearance.

Several manuscripts related to the PEER project are in the works. In addition, three of the research assistants working on the team have applied to doctoral programs in microbiology. The PEER team members have presented a variety of papers on their TB work at conferences like the 2023 International TB Conclave. In addition, one of the PEER team members, Dr. Mamatha V., is now the vice chair for Bangalore in the State Task Force for TB.

INDIA – WMSG2-004: SAMPLING WITH MASK AND REVERSE TRANSCRIPTASE (SMART)-PCR FOR DIAGNOSIS OF PEDIATRIC TUBERCULOSIS

PI: Ambreen Shaikh, Foundation for Medical Research, India
Dates: March 2022 - February 2023

PROJECT OVERVIEW

Despite efforts to eradicate tuberculosis, a 56% gap exists in India between the estimated 0.34 million cases of TB in children and the 0.15 million cases reported each year, hampering elimination efforts. The difficulty in diagnosing TB in children is one of the main reasons for the large gaps in notification. A reliable diagnosis frequently necessitates the use of invasive sample collection methods and advanced facilities. Most children with tuberculosis in India do not have access to these methods, resulting in fewer than 20% of the children having microbiological confirmation of the disease, and majority of children are initiated on treatment based on a clinical diagnosis. All of this, results in severe over/under diagnosis and mortality. A non-sputum-based, child-friendly diagnosis tool that can provide equitable access to all children is on the WHO and India's national tuberculosis elimination program's roadmap for tackling TB in children.

FINAL SUMMARY OF PROJECT ACTIVITIES

Through this project, the team developed a simplified non-invasive sampling based scalable diagnostic workflow (SMaRT-PCR) that can be adapted in a hub-and-spoke model of testing with the potential to provide equitable access and address the diagnostic gaps in pediatric TB. Their improved SMaRT-PCR workflow now combines simple, non-invasive sample collection with optimized sample storage and transport conditions, allowing for sample collection even in remote locations with limited resources. Following sample collection, the sample processing protocol has been simplified and works efficiently with low bacterial load samples, making it best suited for samples obtained from children with paucibacillary TB disease. Finally, the project team developed a sensitive molecular test for the microbiological diagnosis of pulmonary tuberculosis in children akin to COVID-19 RT-PCRs routinely carried out in current times and hence can be used in RT-PCR laboratories established at the district level as part of COVID-19 control efforts. Aside from being non-invasive, this method (SMaRT-PCR) would also allow for drug resistance testing to diagnose MDR-TB, allowing children to begin appropriate treatment. The use of a refined SMaRT-PCR workflow for children could aid in the early diagnosis of tuberculosis, reduce reliance on clinical diagnosis, and possibly improve TB detection rates. It could pave the way for earlier and better disease management, as well as a reduction in overall incidence, a critical step towards India's TB elimination goal of 2025.

In terms of impact, according to the PI, this PEER seed grant was a bridge between the pilot studies and the planned multi-site SMaRT-PCR workflow studies. In the pilot investigations, the team examined the feasibility of collecting samples from a small subset of patients in a controlled environment at a handful of tertiary care centers. To implement the SMaRT-PCR method in clinical and programme settings, more study and test development were required, which included point-of-care sample collection, building a scalable workflow, and having a drug resistance determination assay. With the help of the PEER seed grant, the team were able to address all of these issues and develop a more efficient SMaRT-PCR methodology, which is now ready for large-scale field testing in an envisioned hub and spoke system. From the research perspective, the most significant results of the seed grant were the development of a single-step multiplex RT-PCR assay for simultaneous TB

detection and resistance determination, and the optimization of sample transit and storage conditions.
The PEER seed grant also included a component for the PIs' professional growth and mentoring of other junior female researchers in the organization. Using a variety of mentoring initiatives, the project team were able to help upskill the junior women researchers on the project and in the organization The mentees gained knowledge on topics such as self-improvement, teamwork, communicating scientific findings, expanding research interests, and striking a work-life balance. The seed fund also helped the team reach out to new audiences and set up crucial early encounters with potential collaborators who will be vital in taking the project to the next level. From a professional standpoint, the project has given both PIs the opportunity to gain expertise, and expand their knowledge of the field, and facilitate the transfer of knowledge via mentoring.
This study's results were disseminated to local, state, and national pediatric TB stakeholders on February 18th, 2023, in Mumbai. The findings were also presented at two national conferences: (1) India TB summit which was held on 12-13th March 2022; (2) National conference for Fostering Partnerships to End Tuberculosis, which was held on March 18, 2023, in Vadodara, Gujarat, and was attended by senior USAID India staff, state and district TB officers from Gujarat and Madhya Pradesh, as well as representatives from the corporate sector who are part of the corporate TB pledge.
Two news articles highlighted the study's findings:(1)February 19, 2023, *Times of India*: City scientists come up with special face mask to detect TB quickly in children; (2) February 23, 2023, *Sakal*: New mask technology for TB detection in children.

INDONESIA - COV-159: IMPROVING PUBLIC ACCEPTANCE OF COVID-19 VACCINE IN YOGYAKARTA, INDONESIA: AN APPLICATION OF COMMUNITY ETHIC GOTONG ROYONG AND THE PROTECTOR SCHEMA

PI: Retna Padmawati, Universitas Gadjah Mada

U.S. Partner: Abram Wagner, University of Michigan (Funded by National Institutes of Health)

Dates: September 2022 -March 2024

PROJECT OVERVIEW

This PEER project delved into two key aspects of health communication: gotong royong and the protector schema. Gotong royong, rooted in Javanese culture, embodies a sense of communal belonging and contribution. In health communication, a protector schema serves as a strategy to promote healthy behaviors, such as vaccination, by appealing to individuals to safeguard specific people. Achieving high vaccination coverage is paramount to controlling the spread of vaccine-preventable diseases, and understanding community perceptions is instrumental in improving vaccination rates. The research team believes that reducing negative perceptions toward vaccines hinges on fostering trust in the healthcare system, and that can be achieved through gotong royong.

The researchers sought to conduct a needs assessment and identify barriers and enablers of COVID-19 vaccine acceptance, examine within-household differences in vaccination acceptance of COVID-19, develop the systems-level and communication strategy targeted towards high-risk population groups, and evaluate effective delivery service systems and media communication in the community.

The overall goal of the project was to accelerate public acceptance of the COVID-19 vaccine through community engagement in Yogyakarta. The project team members developed policy recommendations that take local cultural values into consideration and include differentiated messages across population groups.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team members began by conducting a literature review on strategic communications for vaccine uptake in low and middle-income countries, emphasizing the need for culturally sensitive approaches, as well as a qualitative study with key stakeholders in the community. These included community and religious leaders, health sector representatives, NGOs, and community police officers. Through a combination of qualitative and quantitative surveys, the aimed to gather insights from both urban and rural areas, ensuring a holistic understanding of the local context. A total of 804 individuals participated in these surveys on perceptions, attitudes, and information needs related to COVID-19 vaccination.

In addition to the surveys, the team conducted in-depth interviews on vaccine acceptance with 30 people, strategically categorized as concordant positive (the family has similar perspectives on accepting COVID-19 vaccine), concordant negative (the family has different perspective on accepting the vaccine), and discordant (the family has similar perspectives on refusing the vaccine). These interviews explored the factors underlying individuals' attitudes towards vaccination, providing a better understanding of the challenges and opportunities in promoting vaccine acceptance in the community.

Based on their findings, the research team recommended specific media types for effective communication, including short videos (3-5 minutes), animations, and face-to-face education sessions led by health workers. Furthermore, the community engagement strategy emphasized the importance of role modeling by health workers, neighbors, and sub-village leaders, particularly targeting people with lower levels of education through WhatsApp groups.

The PEER team used this strategy to draft and assess a communication strategy consisting of customized media content to increase COVID-19 vaccine acceptance and spread accurate information in the community. Educational materials, including pocket-sized books and videos, were disseminated to vulnerable groups in Gunungkidul after the pre-test phase and in Bantul following the post-test phase. In Gunungkidul, collaborations with community leaders, cadres, and neighborhood associations were leveraged to disseminate messages through various channels, including community meetings and WhatsApp groups. The researchers then conducted post-tests in both Gunungkidul and Bantul to assess knowledge, attitudes, and intentions regarding COVID-19 vaccination. They also held a focus group in Karangrejek Village to shed light on factors contributing to COVID-19 vaccine fatigue. Insights from participants highlighted the challenges of information overload and the influence of differing economic statuses on vaccine attitudes. By the time the project ended, they had submitted two journal articles for publications.

INDONESIA - COV-128: COST-EFFECTIVENESS OF SARS-COV-2 SURVEILLANCE ON WASTEWATER AND ENVIRONMENTAL SAMPLING (SWESP) AS AN EARLY WARNING SYSTEM FOR COMMUNITY COVID-19 TRANSMISSION IN INDONESIA

PI: Indah Kartika Murni, Universitas Gadjah Mada
U.S. Partner: David Boyle, Path (Funded by National Institutes of Health)
Dates: October 2022 – December 2023

PROJECT OVERVIEW

Wastewater-based epidemiology (WBE) surveillance systems for SARS-CoV-2 RNA have been established in many high-income countries and piloted in a few low- and middle-income countries (LMICs). WBE surveillance has been used as a mechanism to inform COVID-19 control strategies, including as an early warning system to flag community outbreaks and to identify levels of ongoing community transmission within a confined population.

Determining the burden of disease for COVID-19 in LMICs has been challenging and is likely underreported due to logistical and practical barriers as well as low testing rates. In LMICs, where widespread testing of individuals to determine the community burden of COVID-19 is impractical, the assessment of community burden by testing of wastewater may be a cost-effective option. However, the cost-effectiveness of such methods in Indonesia has not been adequately evaluated due to the relatively new laboratory procedures involved.

The research team sought to evaluate cost-effectiveness and establish a sustainable WBE surveillance program that can be performed by local health systems and potentially included in the traditional surveillance program executed by relevant government agencies.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted WBE surveillance as part of their study, collecting more than 200 samples from 18 sampling points over three months. Laboratory sample processing was conducted simultaneously. The researchers assessed the positivity rate by week and by type of sampling location, created a map to compare the positivity rate detected in the sampling with the confirmed clinical cases in the community, and undertook a time series analysis to identify the ability of WBE surveillance to forecast confirmed clinical cases reported in the community.

The PI and her colleagues also conducted a cost-effectiveness analysis (CEA). They gathered national health insurance claims data related to COVID-19, as well as data on decision making on lockdowns, travel restrictions, and clinical surveillance through focus group discussions at provincial government and health offices. They considered the costs of setting up a wider-scale WBE surveillance system and ran an economic analysis using the COVASIM model, comparing the WBE scenario with real data on confirmed cases and deaths.

They found that WBE surveillance systems can be a cost-effective alternative to support early warning systems in pandemic situations in countries with lower to middle incomes. However, a strong and timely policy support, along with an effective public health response, is crucial in determining the effectiveness of any surveillance systems.

The PEER team held several meetings with the Ministry of Health (MoH) from the beginning of the project onward, as well as with the World Health Organization office in Indonesia. Towards the end of the project, representatives of the Agency for Health Policies Development, MoH, visited the PI's campus to directly observe the sampling and laboratory processes. The MoH representatives shared that they were in the stage of procuring laboratory equipment and planned to build networks with sentinel laboratories, before training and implementation.

The researchers have encouraged the integration of COVID-19 WBE surveillance into the existing environmental surveillance for polio and are drafting an academic article on the findings of the cost-effectiveness analysis with four distinct scenarios. They were awarded a grant of more than $600,000 from the Gates Foundation to expand their WBE surveillance research to other pathogens, such as typhoid.

INDONESIA - PROJECT 8-237: DEVELOPMENT OF WOOD IDENTIFICATION SYSTEM AND TIMBER TRACKING DATABASE TO SUPPORT LEGAL TRADE

PI: Ratih Damayanti, Forestry Research Development and Innovation Agency of the Ministry of Environment and Forestry, Indonesia, in Partnership with Bogor Agricultural University
U.S. Partner: Michael Wiemann, U.S. Forest Service, Forest Products Laboratory
Dates: February 2020 – October 2021

PROJECT OVERVIEW

This project aimed to develop a wood identification system using a combination of computer vision and spectrometry to achieve quicker and more accurate results. The technology was integrated with the Indonesian Forest Product Administration Information System (SIPUHH) as part of the Indonesian Timber Legality Assurance System. The expertise of U.S. partners Dr. Wiemann and Dr. Hermanson from the USDA was critical in developing and testing the new system. Dr. Wiemann is a wood anatomist at the Forest Products Laboratory, and Dr. Hermanson developed a machine vision-based wood species classifier (XyloTron). This PEER project also aimed to establish a wood species database for timber tracking to support legal trade. Data from the Xylarium Bogoriense was integrated with new data from other regions in Indonesia. The digital collection is useful for mapping wood biodiversity, providing carbon stock information, and listing active compounds identified by spectrometry.

The project aligns with Indonesian and USAID objectives for sustainable forest management. The Ministry of Forestry established the Timber Legality Assurance System in 2009 to improve forestry governance and combat illegal logging. The Lacey Act requires verification of timber origins for international trade with the United States, but difficulties arise due to limited knowledge, technology, and staff capabilities. An automated wood identification system and wood species databases would enhance the legal timber verification process, support legal timber trade, reduce illegal logging, and preserve forests. The integrated wood database would also improve forest product management for various stakeholders, including the Ministry of Environment and Forestry, Customs, forest concessions, local governments, and communities.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ended on October 31, 2021, had five main outputs. Following is a brief overview of progress made on each:

- Improving the existing automatic wood identification system (AIKO-KLHK Version 1): Dr. Damayanti and her team collected 350 additional wood specimens and developed the system in two languages. AIKO-KLHK Version 2, accommodating 1,180 wood species, was launched and a national patent registered.
- Developing WIDER (Wood Identifier): The team completed specimen preparation, sensor design, and data analysis for 15 wood species, registering a national patent. WIDER can identify wood species in milliseconds with over 95% accuracy and is portable for field use. Further research will improve the database and sensor flexibility.

- Assessing the current wood legality system: Trials were conducted to integrate AIKO-KLHK into the SVLK system, with Focus Group Discussions held with TLAS auditors and policymakers.
- Developing the Integrated Xylarium Bogoriense Database: Researchers recorded 232,020 wood specimens representing 6,679 species, registering a national copyright.
- Creating the ECVT 4D Dynamic Tree Monitoring System: A national patent was registered. This technology monitors tree physiological processes in real-time, aiding in forest productivity and climate change adaptation.

Despite COVID-19 challenges, the team achieved more than expected, training 40 research assistants and private company staff in wood identification, 27 researchers in developing wood identification systems, and 43 researchers in patent drafting. They registered 4,054 users for AIKO-KLHK, launched AIKO-KLHK Version 2, produced a WIDER prototype, and created a monitoring system for tree physiological processes. Policy documents for improving the Indonesian TLAS and integrating the wood identification system were prepared, and an integrated Database of the Xylarium Bogoriense Wood Collection was made public. Six wood industry organizations used AIKO-KLHK, and Dr. Damayanti received four new research grants totaling about $82,000.

The project's impact extended to higher education, leading to a new university course and increased attention to wood identification systems. Dr. Damayanti emphasized the significance of PEER support in making previously impossible ideas and methods a reality, fostering integration with the timber legality system, and attracting international cooperation.

PUBLICATIONS, PATENT APPLICATIONS

Rahmanto, R. G. H., et al. (2021). Anatomical comparison of branches and trunks of seven commercial wood species. IOP Conf. Series: Earth and Environmental Science, 914(1), 012071. doi:10.1088/1755-1315/914/1/012071.

Indonesian Patents: P00202106065, P00202106083, P00202106087.
Integrated Xylarium Database Copyright: EC00202138462.

DATABASES

AIKO-KLHK: http://aiko.menlhk.go.id/dashboard/
Xylarium Bogoriense: Xylariumklhk.com (login required).

INDONESIA - PROJECT 8-124: ADVANCING SHARK CONSERVATION THROUGH INNOVATIVE MOLECULAR AND MULTI-STAKEHOLDER APPROACHES

PI: Andrianus Sembiring, Yayasan Biodiversitas Indonesia, in Partnership with Udayana, Diponegoro, and Nahdlatul Ulama Universities
U.S. Partner: Paul Barber, University Of California, Los Angeles (Funded by the National Science Foundation)
Dates: November 2019 – October 2023

PROJECT OVERVIEW

Intensive shark fishing, driven by the high demand for shark fins from China, Hong Kong, and Singapore, is rapidly depleting global shark populations, with corresponding negative impacts on marine ecosystems. To combat these declines and preserve ecosystem function, a consortium of stakeholders is taking important steps to protect global shark populations. One important step is listing 12 shark species as critically endangered under the Convention on International Trade in Endangered Species (CITES). Indonesia is among the world's leading shark fishing nations and Indonesian regulations on shark fisheries follow CITES guidelines. But these regulations are nearly impossible to enforce because of high volume and because the landings come in a form (fins) that precludes species identification. The inability to identify shark fins entering the global market prevents enforcement, contributes to ineffective management of shark fisheries, and allows the illicit trade of protected elasmobranchs.

DNA barcoding is a molecular genetic technique where an unknown sample can be identified by species by comparing its DNA sequence to a reference database. It takes several days to DNA barcode a sample of interest, and this time lag severely hampers the ability of regulators to identify samples from shark fin shipments because many countries, including Indonesia, only provide 24 hours for species identification prior to shipment. Therefore, there is a critical need for a reliable, fast, and cost-effective method for positive species identification of shark products entering international markets. This PEER project focused on developing tools to provide the data required for meaningful enforcement, including working towards a DNA-based field deployable assay to identify and detect CITES-listed sharks, providing current information on shark exploitation in Indonesia, and integrating genetics and traditional fisheries data to support sustainable shark fishing and trading policies.

FINAL SUMMARY OF PROJECT ACTIVITIES

Researchers collected more than 100 samples from a fish market and shark exporting company in East Java and analyzed the samples using DNA barcoding and real-time PCR (rtPCR). They also collaborated with the Coastal and Marine Resources Management Center (BPSPL) Denpasar, which sent its shark samples as part of the verification process for export. The PI Mr. Sembiring and his colleagues tested several kinds of DNA primers for shark identification on the CITES list.

The PEER team hosted several workshops and trainings on genetic tools for species identifications attended by researchers, students, representatives from private companies, and staff from an Indonesian government institution focusing on protecting marine resources. The researchers trained some of the participants on DNA extraction from shark samples and on species identification using rtPCR methods.

Through the PEER project, the team awarded research scholarships to six undergraduate and two graduate students for research related to shark genetics. They also hosted three intern students who learned to do laboratory work, including DNA extraction, PCR, and data analysis.

On the outreach side, more than 200 middle and high school students in North Bali attended a shark and marine conservation program run by the PEER team. The program sought to increase student awareness and understanding of protected marine biota in their local region, as well as understanding of marine conversation. The researchers published several articles about their results in international journals and participated in the 5th Asia Pacific Coral Reef Symposium (APCRS) in Singapore. They also collaborated with IPB University to hold the 6th Embrio International Symposium, attended by participants from 10 countries.

PUBLICATIONS

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Wardana, E. D., Putra, I. N. G., Al Malik, M. D., Yusmalinda, N. L. A., Ningsih, E. Y., Pertiwi, N. P. D., Salim, M. G., Kanedi, M. M., Putra, M. I. H., & Sembiring, A. (2023). Population genetic structure of the bentfin devil ray (Mobula thurstoni) in the South Indonesia Sea with limited sample based on ND5 gene. BIODIVERSITAS, 24(7), 3743-3749. https://doi.org/10.13057/biodiv/d240711

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Al Malik, M. D., Putra, M. I. H., Topan, E., Pertiwi, N. P. D., Artiningsih, E. Y., Sari, S. K., Lewis, S., Prabuning, D., & Sembiring, A. (2022). Genetic variation of oceanic manta ray (Mobula birostris) based on mtDNA data in the Savu Sea, Indonesia. BIODIVERSITAS, 23(3), 1700-1706. https://doi.org/10.13057/biodiv/d230362

INDONESIA - PROJECT 7-304: INTEGRATED GEOSCIENCE STUDIES FOR HAZARD MITIGATION AT THE AGUNG-BATUR VOLCANIC SYSTEM, BALI, INDONESIA

PI: Sri Widiyantoro, Institut Teknologi Bandung
U.S. Partner: Jacob Lowenstern, USGS Cascades Volcano Observatory
Dates: November 2018 – November 2021

PROJECT OVERVIEW

After more than 50 years of dormancy, Agung volcano erupted explosively on November 21, 2017, following a seismic crisis that began more than two months earlier with earthquakes reaching rates of over 1,000 events per day. Indonesian and USGS/VDAP scientists feared a repeat of the 1963 eruption, which killed over 1,500 people. Fortunately, the 2017 eruption waned by April 2018 without any deaths, thanks to successful evacuations and the limited size of the eruption. Despite this success, the eruption surprised scientists as it occurred more than a month after the peak in seismicity and without obvious seismic precursors. Satellite data suggested the magma intrusion that triggered the eruption occurred northwest of Agung, between Agung and the Batur caldera, linking the two volcanoes.

The PI and his team, in collaboration with USGS, aimed to understand the Agung-Batur volcanic system and its hazards. The main goals of this PEER project were to: (i) understand the physical processes leading to Agung's eruption, (ii) estimate future hazard potential, (iii) provide additional analysis to policymakers, and (iv) support volcanic disaster risk education for the community.

The project enhanced the ability of scientists to assess volcanic unrest and forecast future eruptions at Agung, Batur, and similar volcanoes worldwide, directly impacting the safety of hundreds of thousands of people in Bali. Improving eruption forecasts and volcanic hazard education will help ensure the safety of at-risk populations and minimize economic losses in future eruptions. The geophysical studies conducted strengthened collaborations among Indonesian agencies (CVGHM, Disaster Mitigation Research Center), ITB university colleagues, and USGS/VDAP scientists, serving as a model for further collaborative efforts to improve volcano monitoring and risk mitigation in Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main results of this PEER project can be summarized as follows:

1. Newly acquired Integrated geosciences data on the Agung-Batur volcano complex: The installation of integrated geosciences stations to monitor the activity of the Agung volcano started in mid-December 2018. The installation was helped by CVGHM, which provided accommodations and legal assistance during the survey. In total, 25 new seismological stations and 4 geodetic GPS stations covering the Agung-Batur complex volcano were installed thanks to the PEER project. The data were used as the basis for the project team's scientific analysis, the results of which they published in several journals and conference proceedings and socialized to the community through numerous outreach events.

2. Newly acquired Integrated geosciences data on the Lembang fault and Tangkuban Perahu volcano: The researchers deployed a total of 65 seismographic stations across Tangkuban Parahu volcano and the Lembang fault, West Java, Indonesia for seven months from November 2020 to June 2021. The 14

seismographs consist of six from the PEER Program, four from ITB, and four rented from an external party. The deployment was done five times by using 14 moving instruments for a one-month observation period for each term. The team further added 8 rented stations in the last 2 months to augment the station coverage for the Tangkuban volcano.

3. Conference presentations: The results of the PEER research have been disseminated in 11 conferences from 2019 to 2021. The published proceedings cover all geological, seismological, geodetic aspects of volcano monitoring. The novelty of this research comes from the integrated volcano monitoring performed, which could illuminate the ascent of the magma migration through various methods.

4. Journal publications and copyrights: Eight international journal publications during the research period (2019-2021) cover all geosciences aspects of volcano monitoring. Five of the publications had been published and three others were still under review as of the end of December 2021 in reputable international journals. The citation rate of some of the publications is already high, indicating that the results obtained in this study are having a great impact in the academic community. In addition to the publications, the research team also produced four software solutions that have been granted Indonesian copyrights.

5. Dissemination and outreach: The project team carried out nine dissemination and outreach programs during the study period. The spectrum of their outreach program was very wide, from technical disseminations to the Indonesian institution responsible for volcano monitoring (CVGHM) to hazard mitigation and anti-hoax training for people living near volcanos. The public outreach and training campaigns were conducted in collaboration with community organizations and local schools.

6. Educational Impacts: Taking into account the comprehensive geoscience understanding gained during the project regarding volcanic hazard mitigation in Indonesia, the PI and his team at ITA have updated existing course materials and added new courses related to earthquake and volcano mitigation. These updated and new courses are in the Geophysical Engineering Master's program, the Geological Engineering Master's program, and the Geodetic and Geomatics Engineering Master's program.

Although the PEER project has ended, the PI and his colleagues plan to continue their work in collaboration with their U.S. partners and Indonesian stakeholders. They will apply the knowledge of volcano monitoring they gained during their research on Agung volcano to other volcanoes in Indonesia. Through their PEER project, they showed that integrated data management and processing could increase the accuracy of the volcano monitoring decisions. For instance, they showed that the seismic crisis that occurred prior to the 2017 Agung eruption indicated the reactivation of the nearby fault and not necessarily an imminent eruption. By the end of 2021, the team had already received an additional $57,000 in funding from Indonesian sources to continue their work, and with the data they have in hand and the technical infrastructure built under their PEER project, they feel confident in their ability to attract further sponsors.

PUBLICATIONS, VIDEOS, AND NEWS REPORTS

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Kusumawati et al., 2021, Fault Instability and Its Relation to Static Coulomb Failure Stress Change in the 2016 Mw 6.5 Pidie Jaya Earthquake, Aceh, Indonesia. Frontiers in Earth Science 9 (282). DOI: 10.3389/feart.2020.559434

Ardianto et al., 2021. Imaging the subsurface structure of Mount Agung in Bali (Indonesia) using volcano-tectonic (VT) earthquake tomography. Frontiers in Earth Science 9. DOI: 10.3389/feart.2021.619587

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Syahbana et al. 2019. The 2017–18 activity at Mount Agung in Bali (Indonesia): Intense unrest, monitoring, crisis response, evacuation, and eruption, Scientific Reports 9, 8848. https://doi.org/10.1038/s41598-019-45295-9.

“Seismicity and Tomographic Imaging of Agung Volcano,” June 5, 2020, presented by Dr. Devy K. Syahbana, Dr. David P. Sahara, and Dr. Zulfakriza (https://youtu.be/yiUG9PnOnZ0)

“Deformation of the Agung Volcano,” June 12, 2020, presented by Dr. Irwan Meilano, Dr. Endra Gunawan, and Dr. Asep Saepuloh (https://youtu.be/2knK9eq4vRU)

“Geovirtual of the Agung Volcano: from Surface to the Deep,” June 19, 2020, presented by Dr. I.G.B. Eddy Sucipta, Dr. Asep Saepuloh, and Adzkia Norma Arifa (https://youtu.be/PDqO5rf2Ba8)

https://balebengong.id/agar-sekolah-rawan-bencana-tetap-siaga/
https://www.itb.ac.id/news/read/56959/home/itb-lakukan-studi-terpadu-untuk-memahami-dinamika-gunung-agung
https://siedoo.com/berita-15427-pahami-dinamika-gunung-agung-itb-lakukan-studi-terpadu/
http://www.balipost.com/news/2019/01/16/66241/ITB-Pasang-Alat-Pendeteksi-Gempa...html

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"DIGI" software for databasing digital geosciences data recorded during volcano monitoring. One problem in volcano monitoring is that there are several data monitoring formats from various studies. It is difficult to integrate the data, but this software facilitates standardizing the data format and data type and storing them in a database. This software has been granted copyright from the Indonesian government in 2020 No. 039/DivKI-ITB/SPMH/XI/2020.

"Geomecca: automatic Moment Magnitude Detection using Spectral Analysis" software for automatically determining the moment magnitude of a seismic event. This will help CVGHM in analyzing the status of ascending magma intrusion by using magnitude event data in semi-realtime. This software has been granted copyright from the Indonesian government in 2020 No. 000222427 on December 1, 2020.

"Geomecca: A Software For Magnitude Of Completeness and b-value Estimation" software for automatically determining the b-value or the specific number representing the magnitude distribution of seismic events. b-value is very helpful in analyzing the stress level on the rock and will help CVGHM analyze the status of ascending magma intrusion by using magnitude event data in semi-realtime. This software has been granted copyright from the Indonesian government in 2020 No. 000180183 on February 19, 2020.

"qtTomoDD" software for imaging the velocity structure beneath surface using recent technology of Double Difference. The software also incorporates a waveform cross-correlation technique for improving the resolution of the velocity structure. This software has been granted copyright from the Indonesian government in 2021 No. 000276530 on September 29, 2020.

INDONESIA - PROJECT 6-446: DELINEATING STOCK STRUCTURE FOR TUNA FISH WITHIN SULU SULAWESI REGIONS

PI: Ida Astarini, Udayana University and BIONESIA

U.S. Partner: Allen Collins, National Systematics Lab of NOAA's Fisheries Service and Smithsonian Institution

Dates: December 2016 – November 2022

PROJECT OVERVIEW

Sulu Sulawesi, a highly diverse marine region in the Coral Triangle, faces threats from human activities like overfishing and destructive fishing practices. These threats have led to the establishment of the Sulu Sulawesi Marine Eco-region (SSME) in 1999 by Indonesia, Malaysia, and the Philippines. The SSME promotes sustainable fisheries by gathering baseline information on the growth rate, migration, and stock structure of species like longtail tuna (Thunnus tonggol). Stock structure is typically assessed using genetic approaches to understand population mixture and migration patterns. Genetic data can also identify effective population size, crucial for determining population vulnerability and informing sustainable management decisions. However, defining stock structure in SSME regions is challenging due to limited conservation genetic expertise and insufficient lab tools and training. As a result, research capacity has developed sporadically and is not tailored to support conservation and policy, risking ineffective management and conservation efforts.

This project aimed to provide essential scientific information to support policy design and ensure effective sustainable fisheries practices within SSME regions. The first major activity was understanding the stock structures of longtail tuna in the Sulu-Sulawesi Sea. The team collected 30-50 samples per population/location at sites in Indonesia, the Philippines, and Malaysia. These samples underwent 2b-RAD analysis at the Smithsonian Institution, conducted by visiting research team members during three-month internships with guidance from U.S. partners. In Indonesia, the team organized training and outreach activities, including a molecular genetic and biodiversity workshop and a next-generation DNA sequencing workshop. These workshops trained students and faculty from partner universities in modern molecular genetic research. Near the end of the project, the PI and her team hosted a national seminar on sustainable fisheries of tuna and other commercial species to discuss the study's findings. The seminar provided a platform for stakeholders to share ideas on emerging fisheries issues and discuss how research can be applied to effective sustainable fisheries management strategies.

FINAL SUMMARY OF PROJECT ACTIVITIES

Under a final no-cost extension in 2022, PI Dr. Ida Astarini and her team achieved many project goals. Sample collection had been completed in previous years, so they focused on analyzing mitochondrial data and preparing the RAD data library. By December 2022, they were finalizing a manuscript on mitochondrial data analysis for publication. For RAD library preparation, they identified a genomic lab in Taiwan and switched from 2b-RAD to RADseq due to methodological differences.

In 2022, the PEER team produced 10 papers, including six research articles by mini-grant awardees, one by undergraduate students, two by team staff, and one undergraduate thesis. They hosted two internship students from Udayana University at the Bionesia Lab from January to June.

The team organized three workshops: a "Workshop on Journal Access – Science Direct" in January with 140 participants, a "Workshop on Intellectual Property Rights – HAKI" in April with 150 participants, and an "International Training on Fish Taxonomy 2022" in June in collaboration with BRIN and Udayana University, attended by 20 participants from several countries. Additionally, they collaborated with IPB for the MarBioUtiCoM 2022 seminar in August, where PEER researcher Ni Luh Astria Yusmalinda presented on longtail tuna genetic structure. They also prepared for the 2nd International Seminar on Fish and Fisheries Sciences and the International Summer Course on Tropical Mangrove Ecosystem for June 2023.

Dr. Astarini reported successful sample collection from the Indonesian and South China Seas, though plans for the Sulu Sulawesi Sea were hindered by the difficulty of finding longtail tuna. The team completed mitochondrial data collection but will continue working on RAD data. The project supported several researchers through mini grants, resulting in published scientific articles, and provided mentorship to undergraduate students. Collaborations were built with universities, government institutions, and the research community through workshops and conferences. Three senior researchers enhanced their skills during PEER-supported fellowships at the Smithsonian Institution in 2019.

Going forward, the team plans to continue collaborating with their U.S. partner and various institutions to collect more data on longtail tuna genomics. They established new partnerships with the University of Malaysia Sarawak, the Indonesian Ichthyology Community, BRIN, and several Indonesian universities to expand their research on fisheries and conservation.

PUBLICATIONS

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Astarini, I. A., Ningsih, E. Y., Simanungkalit, D., Ardiana, S. A., Al Malik, M. D., Yusmalinda, N. L. A., Sembiring, A., Pertiwi, N. P. D., Cahyani, N. K. D., & Collins, A. (2021). Genetic variation of longtail tuna Thunnus tonggol landed in four fish markets in Indonesia based on mitochondrial DNA. Biodiversitas, 22(4), 1644-1651. https://doi.org/10.13057/biodiv/d220408

Ardiana, S. A., Astarini, I. A., Putra, I. N. G., Pertiwi, P. D., Sembiring, A., Yusmalinda, A., & Al Malik, D. (2021). Keragaman genetik dan filogenetik longtail tuna (Thunnus tonggol) yang didaratkan di pasar ikan Pabean, Surabaya. Musamus Fisheries and Marine Journal, 3(2), 107-115. https://doi.org/10.35724/mfmj.v0i0.3375

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Abdullah, H., Restu, I. W., Pratiwi, M. A., & Kartika, G. R. A. (2020). Aspek reproduksi ikan tongkol abu–abu (Thunnus tonggol) yang didaratkan di pelabuhan pendaratan ikan Kedonganan. Current Trends in Aquatic Science, 3(2), 30-36. https://ojs.unud.ac.id/index.php/CTAS/article/view/55711

Saraswati, P. N. A., Julyantoro, P. G. S., Kartika, G. R. A., & Pratiwi, M. A. (2020). Jenis makanan dan area makan ikan tongkol abu–abu (Thunnus tonggol) yang didaratkan di PPI Kedonganan pada musim barat. Current Trends in Aquatic Science, 3(2), 24-29. https://ojs.unud.ac.id/index.php/CTAS/article/view/55591

Mahmud, M. A., Restu, I. W., Pratiwi, M. A., & Kartika, G. R. A. (2019). Pertumbuhan ikan tongkol abu–abu (Thunnus tonggol) yang didaratkan di pangkalan pendaratan ikan (PPI) Kedonganan. Current Trends in Aquatic Science, 2(2), 1-8. https://ojs.unud.ac.id/index.php/CTAS/article/view/49412

Alamsyah, N., Iqbal, T. H., Damora, A., Batubara, A. S., & Muchlisin, Z. A. (2020). Morphometric variations of longtail tuna (Thunnus tonggol) population in the Aceh Sea waters. Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah, 5(1), 34-43. https://www.researchgate.net/publication/341055342_VARIASI_MORFOMETRIK_IKAN_TONGKOL_ABU-ABU_Thunnus_tonggol_DI_PERAIRAN_LAUT_ACEH

Pratiwi, M. A., & Kartika, G. R. A. (2021). Biologi reproduksi ikan tongkol abu–abu (Thunnus tonggol Bleeker, 1851) yang tertangkap di perairan Selat Bali. Journal of Marine and Aquatic Sciences, 7(1), 43-49. https://doi.org/10.24843/jmas.2021.v07.i01.p07

Rahmah, A., Makhfirah, A. M., Damora, A., Miswar, E., Aprilla, R. M., & Sembiring, A. (2019). Vulnerability status of longtail tuna (Thunnus tonggol) in Southwest Aceh waters, Indonesia. IOP Conference Series: Earth and Environmental Science, 348(1), 012116. https://doi.org/10.1088/1755-1315/348/1/012116

OPEN DATA

The team has published a portion of their mitochondrial control region data on the public platform Genbank. All of the sequence data were deposited with accession numbers MT542205-MT542319, MW658015-MW658124, and OM993540-OM993546

On November 24, 2020, project team member Ni Putu Dian Pertiwi was invited by Universitas Pendidikan Ganesha (Undiksha) to give a general talk about the project and the team's ongoing research efforts. Her presentation was part of a webinar entitled "Implementasi Genetika Tingkat Lanjut" [Advanced Genetics Implementation], which was attended by more than 150 students, faculty members, and lecturers of Undiksha, as well as biology teachers from various schools in Bali (see https://www.youtube.com/watch?v=iuQxueYEJCo).

On January 11-13, 2021, members of the PEER team presented an online short course entitled "Genetika Konservasi Laut" [Marine Conservation Genetics] in collaboration with Nusa Cendana University and Nusa Nipa University in Kupang-East Nusa Tenggara Province. The course is available to the public at the following links: Day1 https://youtu.be/4qbxhx3N9l0; Day 2 https://youtu.be/CZ77mRlqVT8; Day 3 https://youtu.be/OXRK6MRGjDE). The training activity was co-funded by a grant from the Rufford Foundation.

INDONESIA - PROJECT 6-52: INTEGRATING ISLE IN INTEGRATED SCIENCE INSTRUCTION TO IMPROVE SCIENCE TEACHER'S ABILITIES ON STEM EDUCATION

PI: Irwandi Irwandi, Syiah Kuala University

U.S. Partner: Eugenia Etkina, Graduate School of Education, Rutgers, the State University of New Jersey (Funded by the National Science Foundation)

Dates: December 2017 – August 2022

PROJECT OVERVIEW

Since the Program for International Student Assessment (PISA) was first administered, Indonesia consistently performed poorly in science, technology, engineering, and mathematics (STEM). In 2015, Indonesia ranked 63rd in mathematics and 62nd in science out of 70 countries. Current results from the Trends in International Mathematics and Science Study (TIMSS) also showed that Indonesian students' abilities to apply and reason in science and math were below average. One reason could be that common teaching practices in Indonesia rarely promoted critical thinking skills. Therefore, improvement was needed in teacher content knowledge and skills in STEM education. Responding to this challenge, in late 2013 Indonesia launched a new curriculum promoting critical thinking, called "Curriculum 2013" or K-13. K-13 introduced the scientific approach as a teaching methodology following five stages: observing, questioning, experimenting, rationalizing, and communicating. The Indonesian government invested significantly in training teachers in K-13, but many problems were encountered in implementation, as the teachers were not ready and lacked sufficient pedagogical content knowledge to integrate the scientific approach into their instruction.

Investigative Science Learning Environment (ISLE), an approach developed by U.S. partner Dr. Eugenia Etkina of Rutgers University, improves students' scientific abilities by bringing actual science practice into the classroom. In ISLE, students learn by observing real phenomena, analyzing patterns, devising explanations, and testing them experimentally (Etkina, 2015). Inspired by taking an ISLE training workshop from Dr. Etkina in 2015, PI Dr. Irwandi and his team used their PEER support to develop ISLE-based integrated science instruction to improve teachers' abilities in STEM education. In the initial phase, they applied ISLE instruction in integrated science courses at the secondary school level in Indonesia, and later applied it in the lab instruction component of a university-level basic physics course.

FINAL SUMMARY OF PROJECT ACTIVITIES

The most significant achievement of this project was the creation of the Science, Technology, Engineering, and Mathematics (STEM) Research Center at Syiah Kuala University, and the activities of the PI and his team at the Center produced several key results and impacts over the course of the five years the PEER project was in operation. Over the course of the project, the PI and his team held dozens of STEM training activities for students and teachers at the kindergarten, elementary, junior high, high school, and vocational school levels. To give some idea of the scope of the training offered, following are some figures from the PI's final report highlighting activities only in the last year of the project (2022):

- 60 high school science teachers from Aceh Province trained on the STEM Character (STEMC) modules developed by the PEER team so they can establish a local-content curriculum for secondary education in collaboration with the Aceh Provincial Education Office

- 20 elementary school teachers and principals trained on improving 21st-century skills through STEMC learning
- 50 students from Syiah Kuala University trained on they use of drones and robots
- 60 teachers and students in Aceh Besar trained on electrical, magnetic, and robotic STEMC modules
- 117 teachers, researchers, and students provided with materials for the International STEM Learning Webinar for Distance Education

The Center and its staff also contributed to the modification of the curriculum for the Master of Science in Physics program at Syiah Kuala University, with the Center designing and offering several of the courses in the new curriculum, including STEM Learning, Multimedia Physics Learning, Misconceptions in Physics Learning, and Physics Teaching Aids.

As mentioned above, the PI and his team developed several ISLE-based STEM, Remote STEM (RSTEM), and mobile/smartphone STEM (mSTEM) modules during the course of their project. They have presented their results in several peer-reviewed papers and conference presentations (see citations below) and plan to continue developing the modules and publishing additional papers even now that the PEER project has ended.

The PI Dr. Irwandi reports that local education officials and teachers are increasingly interested in STEM Education at the primary and secondary education levels, especially in Aceh. STEM-Based Character (STEMC) is one element the project team has recommended for school implementation. They have conducted STEMC module training for high school teachers throughout Aceh Province, and they also conduct roadshows to schools to implement STEMC-based learning for elementary school students. The response of teachers and students to STEMC is reportedly very positive. Several schools have contacted the STEM Research Center asking the researchers to provide special training related to STEMC to their teachers and students. The PEER team has worked closely with the Aceh Province Education Office over the course of the project to ensure that his team's findings and recommendations can be scaled up. They have also signed cooperation agreements with several universities and secondary schools interested in implementing their instructional modules.

Now the project has ended, Dr. Irwandi indicates that he and his colleagues will continue building their network of educational research counterparts initiated under the PEER project. In 2020, they launched the first South East Asia International Science-Technology, Engineering, and Mathematics (SEA-STEM) Conference, held virtually due to the COVID pandemic. This conference has become an annual event, with the second annual conference being held in Thailand in 2021 and the third annual conference in Malaysia in 2022. The PEER team has also discussed cooperation with the private sector on developing their instructional technology. In 2023, the STEM Research Center is also expected to be proposed to the Indonesian Ministry of Education as the national Center of Excellence in Higher Education Science and Technology STEMC-Integrated Learning Systems.

PUBLICATIONS

Nufus, F., Irwandi, I., Nur, S., & Evendi, E. (2022). Study of ISLE-based STEM approaches and models in its use for teacher professionalism development in geometric optical case studies. Jurnal Penelitian Pendidikan IPA, 8(2), 681–686. https://doi.org/10.29303/jppipa.v8i2.1352

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INDONESIA - PROJECT 6-42: DEVELOPING BIODIVERSE AGROFORESTS ON REWETTED PEATLANDS IN INDONESIA

PI: Sonya Dewi, International Centre For Research In Agroforestry (ICRAF) Aka World Agroforestry Centre
U.S. Partner: Randall Kolka, USDA Forest Service Northern Research Station
Dates: December 2017 - December 2021

PROJECT OVERVIEW

The policy on peatland restoration in Indonesia requires rewetting, with a minimum water table of 40 cm below the surface, to prevent future fire and haze episodes. While rewetting is effective for restoring peatlands' biophysical conditions, the social and economic aspects are often overlooked. Key constraints to effective tropical peatland management include a lack of scientific understanding of peatland and vegetation responses, government reluctance or inability to act within existing legislative and economic realities, and unattractive land-use options for smallholders and communities near peatlands. Significant progress has been made to address government-related constraints, but challenges remain in understanding vegetation responses and developing appealing land-use options.

This project aimed to fill knowledge gaps by rigorously assessing vegetation responses to drainage and rewetting in disturbed peatland conditions. The research focused on root-system adaptations to wet conditions and involved interviews with smallholders and the broader community to understand local knowledge, perceptions, and preferences for peatland restoration and economic development. Specific objectives included assessing peatland tree and plant species richness and composition, evaluating plant functional attributes in response to rewetting, determining the domestication potential of adapted species, and providing policy and practice advice. U.S. partners guided study design, restoration methods, and data interpretation, contributing to scientific publications and policy-relevant synthesis.

The project aimed to produce options for peatland restoration that promote local economic sustainability, create a scientific database for future studies, and develop synthesis publications to inform policymakers and practitioners. The findings were expected to benefit those involved in peatland restoration, including private, industrial, and governmental sectors, by providing evidence-based information on species choices for economic gain and domestication potential. This information could support extension programs assisting smallholders and communities in restoring peatlands and improve local livelihoods through various land-use options.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project aimed to support peatland restoration through agroforestry systems in Central Kalimantan, with the goal of using the findings to inform restoration strategies in other tropical peatlands.

The assessment of peatland tree and plant species richness and composition revealed a weak correlation between rewetting and the natural regeneration of native trees. Natural regeneration depends on degradation levels and the presence of wildlife as seed dispersers. The study found that 60-80% of tree species in rewetted peatlands are dispersed by animals, while wind-dispersed species predominate in more degraded areas. To support the regeneration of native trees in rewetted areas, planners should prioritize planting animal-dispersed species, such as fruit trees, which provide food for wildlife and promote natural regeneration. This research produced three undergraduate theses from Palangkaraya University, a paper submitted to an international journal, and a tree inventory dataset from 48 plots.

The assessment of plant functional attributes in response to rewetting focused on traits like growth rate, wood density, and hydraulic conductivity. The researchers found that the fast-growing timber tree species sengon is unsuitable for peatlands due to poor growth. These findings can help convince government agencies not to develop sengon plantations in peatlands. This research resulted in nine undergraduate theses from IPB University, a published article in Sustainability, a paper submitted to an international journal, and a dataset on natural tree vegetative succession in 40 semi-permanent plots.

The assessment of the domestication and adoption potential of adapted species revealed that the utilization of peatland species by farmers is influenced by their knowledge and interaction with the species. The Dayak people have better knowledge of species utilization compared to the Javanese, who have no history of living in peatlands. Economic aspects are not the only reason for domesticating peatland species; the length of interaction and subsistence needs also play significant roles. Most recommended peatland species still have limited domestication techniques and market potential, which need further investigation. This research produced three undergraduate theses from Palangkaraya University, findings on species utilization and market potentials, a published article in the Journal of Ecological Engineering, and datasets from interviews and focus group discussions.

The synthesis and dissemination of policy advice showed that farmers' knowledge on the suitability and benefits of peatland species is crucial for adopting suitable tree species in rewetted agroforestry systems. There are limited extension services to help farmers select appropriate species that provide economic and environmental benefits. This research resulted in a training event, a draft field guide for agroforestry in rewetted peatlands, and a draft policy brief on rewetted peatland agroforestry.

Thanks to approximately $18 million in new grant funds obtained by the PI Dr. Sonya Dewi and her team, they are in an excellent position to build further on their results from the PEER project.

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INDONESIA – PROJECT 6-25: CONVERGING CLIMATE CHANGE ADAPTATION AND DISASTER RISK REDUCTION STRATEGIES INTO AGGLOMERATION POLICY FOR COASTAL METROPOLITAN PLANNING

PI: Harkunti Pertiwi Rahayu, Institut Teknologi Bandung

U.S. Partner: Louise Comfort, University of Pittsburgh (Funded by the National Science Foundation)

Dates: December 2017 - September 2022

PROJECT OVERVIEW

Existing and planned urban agglomerations in Indonesia, especially in coastal areas, are exposed to the impact of climate change and various coastal hazards, including tsunamis. Of the 146 coastal municipalities in the country, 130 (or 89%) are exposed to tsunami risk. In the coming decades, climate-induced extreme events are expected to increase (IPCC, 2014), and for Indonesian coastal cities, the impact may range from sea level rise (Latief et al, 2012) to changes in precipitation and increased surface temperature that may lead to negative impacts across sectors (Bappenas, 2014). Moreover, the increasing concentration of economic activities in urban areas will make those agglomerated cities highly sensitive to impacts of disasters and climate change.

This PEER project aimed at filling the gaps in current climate change adaptation (CCA) and disaster risk reduction (DRR) strategies in Indonesia, which tend to work in silos. The project developed locally relevant integration of DRR and CCA strategies that could protect and enhance the resilience of economic growth centers and agglomerated coastal cities.

This research project, which advocated an integrated concept and implementation guidelines on DRR and CCA for urban coastal areas in Indonesia, had a positive impact on promoting resilient development. The research focus included national strategic areas in the Mamminasata (Makassar-Maros-Sunggumiansa and Takalar) metropolitan area in South Sulawesi Province and the ITBM Palapa metropolitan area (Indarung, Teluk Bayur, Bungus, Mandeh, Padang, Pariaman, and Padang Pariaman) in West Sumatra Province. The ITBM Palapa metropolitan area provides the logistical and transportation hub for other provinces on the west coast of Sumatra Island, while Mamminasata plays a greater role as the key and main port for both Sulawesi island and the rest of eastern Indonesia. Given the high level of development and high economic growth rate in these two areas, protecting and improving the resilience of both ITBM Palapa and Mamminasata from various coastal hazards should have a positive impact on Indonesia's development in general. Both provinces are also champions in terms of innovative development, so if an integrated DRR-CCA effort could be introduced there, it is likely that other provinces in Sumatra and Sulawesi would follow suit. ITBM Palapa and Mamminasata can become models of disaster- and climate-resilient investment and development.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which ran nearly five years and ended on September 30, 2022, produced several outputs of direct practical relevance to disaster planning in Indonesia both overall and in the specific areas Dr. Harkunti and her team studied. The two focus areas were Mamminasata (the Makassar-Maros-Sungguminasa-Takalar metropolitan area on the island of Sulawesi) and Palapa (the Padang-Lubuk Alung-Pariaman metropolitan area on the island of Sumatra):

1. Convergence of CCA-DRR framework and indicators
2. Flood model in Mamminasata and Palapa metropolitan areas
3. Tsunami model in Mamminasata and Palapa metropolitan areas
4. Risk profile in Mamminasata and Palapa metropolitan areas
5. Compilation of community resilience factors in both study locations
6. Discourse network model
7. Multi-level stakeholder model in DRR and CCA
8. List of DRR-CCA priority activities

The PI and her colleagues formulated these outputs into a policy brief or vision paper for both case study locations. The local government in those areas can refer to the vision paper to develop a science-based policy for agglomeration areas. For example, the Mamminasata metropolitan area is currently revising its spatial plan. Therefore, the PEER team's results provide them with a better understanding of key stakeholders regarding disaster and climate change impacts in Mamminasata. By knowing the disaster conditions in the area, policymakers can plan developments according to their situations, which should result in agglomeration resilience.

In addition to the outputs listed above, this project significantly enhanced training and capacity building for Indonesian students, officials, and practitioners. As a faculty member at ITB, Dr. Harkunti modified and improved the curricula for four courses, which were taken by 589 students: Disaster Management Planning Studio, Introduction to Disaster Mitigation, Climate Change Adaptation and Disaster Aspects in Tourism Planning, and Disaster Aspects in Urban Planning. The undergraduate elective course on Disaster Aspects in Urban Planning has also been selected for inclusion in the nationwide program Independent Campus, Freedom to Learn (Merdeka Belajar - Kampus Merdeka), allowing students to earn up to 40 percent of their degree credits from courses offered outside their own universities.

Several training courses were conducted during the project, including a Training of Trainers on Tsunami Evacuation Maps, Plans, and Procedures (TEMPP-3) hosted by the Agency for Meteorology, Climatology, and Geophysics (BMKG) at its Training and Education Center in Indonesia, from November 22 to December 1, 2018. This training was part of the partnership with IOC-UNESCO in support of IOTIC. Participants collaborated on developing Tsunami Evacuation Maps, Plans, and Procedures. Dr. Harkunti served as a resource person, and research assistant Deri S. Rohman participated as a trainee. Dr. Harkunti also contributed to Standard Operating Procedures Training by ICG/IOTWMS and presented lectures on Tsunami Hazards and Risk Reduction in a six-part online series by UNESCO-IOC IOTIC in September-October 2020. This program targeted community leaders, disaster management offices, and NGOs to promote the UNESCO-IOC Tsunami Ready Program, with approximately 360 participants joining each session.

By the final report submission in 2022, Dr. Harkunti and her team had secured over $329,000 in new research grants from international and Indonesian funders. The team aims to integrate research results into agglomeration area planning policies for broader, measurable impact. Although the PEER project has ended, Dr. Harkunti and her colleagues continue their work with U.S. partner Dr. Louise Comfort and various Indonesian stakeholders. They plan to replicate their research model in other areas with different disaster characteristics. As of late 2022, the team was researching hydrometeorology disasters in Jabodetabek and developing their methodology for Bandung Raya, which faces geological hazards, hydrometeorology, and pandemics. Ongoing projects include tsunami early warning systems funded by the Swiss Re Foundation in Padang and Mentawai Island, and further study in Makassar supported by Yayasan Anak Bangsa Bisa (YABB), covering Lampung and Semarang for comparison. The team is also working on book manuscripts and scientific papers for peer-reviewed journals.

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INDONESIA - PROJECT 5-497: INCREASING TB NOTIFICATION THROUGH ONE STOP CLINICS AND ENGAGEMENT WITH PRIVATE HEALTH CARE PROVIDERS IN BANDUNG, INDONESIA (INSTEP)

PI: Bachti Alisjahbana, TB-HIV Research Center, Universitas Padjadjaran

U.S. Partner: Megan Murray, Harvard Medical School (Funded by the National Institutes of Health)

Dates: May 2017 - November 2019

PROJECT OVERVIEW

The PEER project was comprised of three studies that covered the whole assessment of services delivered for TB patients in the private sector in Bandung Municipality, Indonesia. The overall study objective was to describe the health care pathways of patients seeking treatment for TB and to describe the behavior, and reasons behind the behavior, of Private Practitioners who diagnose and initiate treatment of TB patients. Specifically, the team investigated health care pathways of newly diagnosed TB patients according to their socio-demographic characteristics and type of healthcare facility (sub-study 1). The PEER project also assessed the quality of TB case management by private health care providers, including their diagnostic, referral, and treatment practices, by using standardized patients (sub-study 2); and understood which factors and reasons were associated with the choice of diagnostic, referral, and treatment practices among private practitioners (sub-study 3). Cross-sectional, observational, and qualitative study designs were used to reach the stated objectives.

The study was intended to provide the national TB program a better understanding of the current practices of TB care and management, especially in the private sector. This information was vital since a large proportion of TB cases in Indonesia come to private providers as the first point of care when they first experience sickness. The proposed study method in evaluating the performance of private providers was different from previous studies conducted in Indonesia by employing an approach that allowed the team to investigate real practices performed by private providers.

FINAL SUMMARY OF PROJECT ACTIVITIES

Completed in December 2019, INSTEP was a two-year mix method study to assess the services delivered for TB patients in the private sector of Bandung Municipality, Indonesia. Most Indonesian TB patients visit multiple public and private health care sites and suffer significant delays before diagnosis and initiation of treatment. This increases transmission, incurs significant costs, and hampers treatment outcomes and the majority of private practitioners incorrectly managed TB cases. These findings confirm that Indonesian PPs do not adhere to National Tuberculosis Program (NTP) guidelines. The use of chest x-rays as a first diagnostic test may be rational and helpful in the diagnosis of TB and other diseases, but wide prescription of fluoroquinolones can increase drug resistance. Project activities took place under three sub-studies.

A total of 448 TB patients completed interviews in sub-study 1. The study revealed that most patients first visited either private practitioners (36%) or informal providers such as pharmacies (41%). TB diagnosis was mostly made in hospitals (62%), while treatment was mostly provided in primary healthcare centers (40%). One-third of patients (37%) sought care from more than four healthcare providers before diagnosis. The median time was 30 days (IQR 14-61) from the onset of symptoms to visiting a formal healthcare provider, 63 days until TB diagnosis, and 67 days until the start of TB treatment.

In sub-study 2, 12 trained actors were sent to 320 private general practices, 20 private internist and pulmonologist practices, and 30 puskesmas as a comparator. General practitioners correctly managed 32.1% presumptive TB cases, and specialists correctly managed 22.2% presumptive TB cases. In comparison, puskesmas correctly managed 86.7%.. The number of chest x-ray referrals was higher than sputum examination. Incorrect prescription of anti-tuberculosis drugs and/or fluoroquinolones was identified.

In sub-study 3, in-depth interviews revealed that the higher use of x-rays over smear microscopy was due to to the perception that sputum examination has limited sensitivity, patient's preference, and clinical benefit by excluding other lung abnormalities as underlying reasons. With regard to fluoroquinolone use, patient expectations, absence of TB-specific symptoms, risk of losing patients, and disease severity were mentioned. Low notification rates were attributed to a lack of resources, simplified mechanisms, standard reporting protocol, and knowledge regarding mandatory TB notification.

There is a strong need for better integration of public and private services to help TB control in Indonesia. Re-education and further approaches and strategies are needed to help private practitioners adhere to current tuberculosis management standards and engage in recording and reporting efforts.

INDONESIA - PROJECT 5-429: SCIENCE TEACHING IN INDONESIAN RELIGIOUS SCHOOLS

Pi: Askuri Ibn Chamim, Indonesian Consortium for Religious Studies
U.S. Partner: Joel Kuipers, George Washington University
Dates: January 2017 - December 2020

PROJECT OVERVIEW

The underachievement of Indonesian science education reform efforts and the continued problem of Indonesian low scores on international assessments of science education at the pre-university level are matters of serious concern. Not only do these problems have implications for the future of Indonesia's workforce, but their continued neglect could also affect the future of Indonesia's democracy and international stability. Among the lowest scoring of the Indonesian student populations are those who graduate from the country's religious schools, currently 20% of the student population. The study drew on best practices in science education and linked them with professional development practices tied to curriculum units that were actually used in classrooms.

The objectives of the project were to (1) determine and describe how science was taught in Indonesian Islamic schools and propose a curriculum intervention that was aligned with the national curriculum; (2) apply the intervention in the classroom and describe and analyze its implementation; and (3) compare the intervention with control groups and report the findings. The work involved significant partnerships with leading universities in three key cities in Java: Yogyakarta, Malang, and Surabaya. Enhancing the capacity of the Indonesian educational research community to describe and evaluate its own educational system was an important benefit of the proposed research.

This research produced a model for the treatment of science education in religious schools. A key feature of the treatment program was to develop a learning method that integrated religious motivation with motivation to learn science. The results of this research were disseminated to stakeholders of educational providers in Indonesia, especially operators of religious schools, to be adopted and developed in their respective contexts. The largest operators of religious schools in Indonesia, NU and Muhammadiyah, two major Muslim organizations in the country, cooperated with Mr. Askuri and his team to implement the science education curriculum integrating the religious approach. Furthermore, these organizations were encouraged to develop this new approach further in their individual contexts.

This project also trained dozens of researchers from various universities in Indonesia and built their capacity through workshops and interdisciplinary collaborative research. In addition, dozens of science teachers were trained in the latest scientific learning methods. One output of the project was teaching materials that could be used by teachers for classroom instruction and by students for independent study. This teaching material was created in open-source digital format, so it could be replicated broadly by other schools not included in the project.

FINAL SUMMARY OF PROJECT ACTIVITIES

The long-term goal of this now-completed project was to encourage the emergence of a more anthropological science education policy that considers the sociocultural context to boost students' enthusiasm for studying science. In Indonesia, where 88% of the population is Muslim, religion (Islam) can effectively encourage Muslim students to study science enthusiastically. The PI, Dr. Askuri, noted that the growth of Islamic piety in Indonesia could be leveraged to boost enthusiasm for learning science.

Beginning in 2017, the team conducted baseline research in 18 Islamic schools to understand the current status of science education and identify barriers to improvement. Schools were selected based on stratified random sampling, including rich, average, and poor schools, both public and private. The baseline phase revealed that the quality of science education in Islamic schools was low, but teachers and students believed that Islam and science are interrelated. However, they did not know how to integrate the two in practice.

Based on these findings, Dr. Askuri and his colleagues developed a new science education curriculum module using an Islamic approach. This included exploring Koranic verses and contextualizing them with scientific themes, along with hands-on learning methods. The module was tested for one semester in the 18 partner schools, with treatment and control classes. Teachers received intensive training on the new module and were equipped with skills for assembling practical instructional materials. Researchers recorded the trial processes using ethnographic video methods, observation, focus group discussions, and in-depth interviews.

The trial showed that treatment classes made better progress than control classes. Students in the treatment classes grasped basic science concepts more effectively through experiments and science projects. Interviews revealed that students realized that science is part of their religion and daily lives as Muslims. The PI and his team refined the module based on feedback and created PowerPoint presentations to aid teachers.

Outreach efforts targeted Muhammadiyah, the Ministry of Religious Affairs, the Ministry of Education and Culture, and PT Ruang Guru. Muhammadiyah expressed interest in further developments, and the Ministry of Religious Affairs included the module in their training programs. Many schools began adopting the new module directly.

Over the past three years, more than 3,000 students from the 18 partner schools have used the new curriculum, with this number expected to grow. The Ministry of Religious Affairs trained 79 science teachers from 79 Islamic schools, potentially reaching around 11,850 students. Muhammadiyah designated 100 schools to implement the new curriculum, estimating 30,000 students would receive the new curriculum treatment beginning in early 2021.

Collaborations with various stakeholders led to the creation of new courses for Muhammadiyah universities, including "Islam and Science" and "Islam and Midwifery," accessed by tens of thousands of students per semester. The PEER team also developed a new online learning website, www.sahabatbelajar.net, to facilitate online learning during and after the COVID-19 pandemic.

Although the PEER project has ended, Dr. Askuri and his colleagues plan to establish an Islamic Consortium for Science Education to integrate additional Islamic networks into the program, representing a long-term investment for Muslims and the Indonesian nation in adequate science education for the younger generation

INDONESIA - PROJECT 5-408: IMPLEMENTING A COMBINATION OF RAPID DIAGNOSTIC TESTS, BIOMARKERS AND STANDARD OF CARE PROCEDURES FOR THE DIAGNOSIS OF PNEUMONIA IN PEDIATRIC PATIENTS TO IMPROVE CLINICAL MANAGEMENT IN INDONESIA

PI: Herman Kosasih, INA RESPOND

Clifford Lane, National Institute of Allergy and Infectious Diseases, National Institutes of Health

Dates: December 2016 - February 2021

PROJECT OVERVIEW

While advances have been made in the management of childhood pneumonia, gaps remain that may hinder efforts to reduce morbidity and mortality. These gaps include the absence of a universally accepted diagnostic gold standard for childhood pneumonia, especially one that can also differentiate between bacterial and nonbacterial pneumonia. This PEER project evaluated an algorithm using several rapid diagnostic tests (RDT), biomarkers, and standard of care (SOC) procedures in differentiating these different pathogens in pediatric patients admitted to Tangerang and Kariadi hospitals in Indonesia. The study's secondary goals included identifying the etiologies of pneumonia in children in Indonesia; documenting outcomes; evaluating the use of each RDT (influenza, respiratory syncytial virus, Pneumococcus), biomarkers (C-reactive protein, procalcitonin), and SOC in distinguishing viral and bacterial pathogens; and providing updated strains of circulating viruses, bacteria, and antibiotic resistance.

The researchers aimed to help impact case management in children with pneumonia, from accurate diagnosis to appropriate treatment and development of prevention strategies, reducing childhood morbidity and mortality in Indonesia. Improved information regarding the pathogens causing pneumonia will help to identify and highlight research priorities in pediatric pneumonia and also enable health programs to develop improved control and prevention measures at the community level.

FINAL SUMMARY OF PROJECT ACTIVITIES

Pneumonia accounts for 15% of all deaths in children under five years of age. The high rate of morbidity in children with pneumonia may be prevented by promoting exclusive breastfeeding, vaccination, and an improved environment, whereas mortality can be reduced by providing appropriate management, including appropriate antibiotic treatment for bacterial infection. Diagnosing pneumonia using current World Health Organization pneumonia diagnostic criteria is challenging, as no one clinical feature is sufficient to diagnose pneumonia definitively. To improve diagnostic performance, a combination of clinical features has to be used. Chest X-rays are neither sensitive nor specific. Radiological findings lag behind clinical findings and are unable to differentiate between viral and bacterial etiologies of pneumonia. Differentiation between viral and bacterial pathogens is becoming more important since the introduction of Hib and pneumococcal vaccines that may shift the substantial causes of pneumonia to viruses. This distinction is also important for guiding appropriate antibiotic treatment. The gold-standard for microbiological pathogen assays require specimens that are difficult to collect, such as nasopharyngeal wash or bronchoalveolar lavage, and may need several days for the results to be available.

To develop an algorithm for the diagnosis of viral and bacterial pathogens in pediatric patients with pneumonia, Dr. Kosasih and his team conducted an observational cohort study among pneumonia patients aged between 2 months and 5 years. The PEER team undertook screening enrollment for the study across five hospitals and conducted monitoring visits at each site. They screened a total of 564 patients, and enrolled 188 subjects in the study, 55% of whom were male. The median age of the subjects was 9 months. The researchers developed approaches to determining the causative pathogen(s) of pneumonia in children using common techniques (culture, molecular assays, and serology) on routinely collected specimens (blood, sputum, induced sputum, and nasopharyngeal swab). Using those approaches, they found 48 (26%) subjects had a bacterial pathogen, 31 (16%) had a viral pathogen, 76 (40%) had both confirmed bacterial and viral pathogens, while in 33 (18%) subjects, the etiological agent could not be determined.

The researchers then analyzed blood biomarkers to help to differentiate bacterial and viral infections. Using five simple laboratory markers (leukocyte count, neutrophil to lymphocyte ratio, absolute neutrophil count, C-reactive protein (CRP), and procalcitonin), they found that procalcitonin has the best single predictor of bacterial status. A combination of leukocyte count with CRP yielded the best predictor of bacterial status overall. They also used biomarkers and characteristics of enrolled subjects, determining several factors as a proxy to predict worse outcomes, which can help to reduce mortality in hospitalized pediatrics pneumonia. In addition to publishing their work in scientific journals, Dr. Kosasih and his group shared their findings with the U.S. Centers for Disease Control and Prevention and the Indonesian National Institute of Health Research and Development (NIHRD). The PI reports that NIHRD has used the results of this study to develop pneumococcal vaccination policy for Indonesia.

PUBLICATIONS

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INDONESIA - PROJECT 5-395: INCORPORATING CLIMATE CHANGE INDUCED SEA LEVEL RISE INFORMATION INTO COASTAL CITIES' PREPAREDNESS TOWARD COASTAL HAZARDS

PI: Syamsidik, Tsunami and Disaster Mitigation Research Center, Syiah Kuala University
U.S. Partner: Louise K. Comfort, University of Pittsburgh (Funded by the National Science Foundation)
Dates: December 2016 - March 2022

PROJECT OVERVIEW

Research has not yet identified all the impacts of climate changes on island nations like Indonesia. One of the challenges is the complexity of the available data in Indonesia. This project aimed at combining two sets of processes—climate change-induced sea level rise and coastal hazards (coastal erosion, tsunami, and coastal flooding)—using three projected periods (30, 50, and 100 years). Climate change-induced sea level rise coupled with coastal hazards is a rarely studied topic in Indonesia. Dr. Syamsidik and his team expected that the project would produce newly developed scenarios for assessing impacts of climate change-induced sea level rise in Indonesia's coastal cities, combining information on sea level rise (a slow process) and coastal hazards (a relatively fast process). Their work also incorporated scientifically based policy analysis of urban development planning to increase the preparedness of cities in the region. In addition, this research compared the projected impacts of sea level rise coupled with coastal hazards between two coastal cities representing the northern hemisphere and southern hemisphere of Indonesia. The impact comparisons highlighted variations resulting from geographical differences. This research also offered examples for incorporating scientific evidence on climate change and coastal hazard impacts with techno-social approaches for disaster mitigation and climate change adaptation.

U.S. partner Dr. Comfort assisted this research team with her expertise in analyzing development planning policies. Her techno-social approach was a valuable resource for the Indonesian team. To gather input and disseminate their findings, Dr. Syamsidik and his colleagues organized several forums for stakeholders from the national and local levels. Two policy briefings were made to address the issue of climate change impacts and their incorporation into development planning for coastal cities in Indonesia. This research team also produced inputs for improving university-level instruction in courses involving climate change and disaster management. Lessons learned from this research process were used in revising the relevant course curricula at Syiah Kuala University in Banda Aceh and Mataram University in Mataram.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Syamsidik reports that his team's research results have made positive impacts from both the scientific and policy standpoints. The team members have also gained many opportunities to enhance their capacity in performing spatial analysis and numerical simulations and their ability to communicate and advocate for their research results. This in turn has also contributed to their university's performance at the national and international levels. Recently, their research center (TDMRC) also received important grants from Ministry of Education, Culture, Research and Technology of Indonesia, which will enable them to purchase advanced research equipment. Their two PEER grants (the other in Cycle 3) allowed the PI and his team to prove their abilities and competence to conduct high-quality tsunami-related research.

At the local level, the researchers expect to maintain long-term collaboration with the municipal governments in Banda Aceh, Mataram, and Ambo, their study sites for the current project. Preparedness of coastal cities towards impacts of climate change induced sea level rise is indeed a challenging issue in the context of Indonesia. During this research, Dr. Syamsidik and his colleagues have proposed ways of increasing the cities' preparedness by providing science-based information that can be integrated into the city's policies. Although they also identified some potential obstacles during the integration, they are confident that these obstacles can be eliminated or minimized through continuous collaboration with the municipal authorities. In addition to these local impacts, the team has also delivered outcomes at the national and international level by conducting a series of activities as part of the South-South and Triangular Cooperation coordinated by Ministry of Foreign Affairs of Indonesia. Two PEER grant supplements provided them with the opportunity to work with the Timor-Leste government as part of this effort.

Following are several other key achievements as of the summer of 2022 to be highlighted from this five-year project:

- 21 publications, including 19 papers in international journals and conference proceedings and two book chapters
- Creation of a new mandatory course on Knowledge of Disaster and Environment, which is taken by about 3,500 students per semester at Syiah Kuala University
- Five new research grants totaling $150,000 (four from Indonesian sponsors and one from the government of Japan)
- Promotion of the PI Dr. Syamsidik to full professor based on his research accomplishments
- Awards from the Indonesian National Disaster Agency to two team members for their work as tsunami mitigation and numerical simulation researchers

Although PEER funding has ended, at the time of the final report in July 2022 Dr. Syamsidik had plans for several follow-on activities. In September 2022, he expected to resume working with the Ambon Development and Planning Agency on integrating information on historical tsunamis into the city’s spatial planning efforts. In Banda Aceh, the team planned to continue developing probabilistic tsunami hazard maps and probable loss estimations for building damages due to tsunamis. The activities in Banda Aceh and Ambon are expected to run at least through 2024. At the national level, the team will work closely with units of the Ministry of Finance to formulate models for disaster risk financing and insurance, in which information from their tsunami models and experience developed during the two PEER grants will be very useful. As of the summer of 2022, the PI and his group were already working on another important study funded by the Ministry of Finance of Indonesia on providing strategies for disaster risk financing and insurance in Indonesia. Part of the research involves providing tsunami hazard information and analysis to compose the strategies. This project will also run through 2024. Furthermore, another study on the tsunami topic is under way in Banda Aceh and Ambon with funding from the Japanese program SATREPS. Research completed during the two PEER projects will provide a strong foundation for all of these ongoing efforts.

POLICY DOCUMENTS

“Management of Coastlines of Mataram as Parts of Adaptation and Mitigation of Coastal Hazards and Sea Level Rise" (download PDF)

[“Strategies of Tsunami and Coastal Flooding for Banda Aceh Exacerbating by Impacts of Climate Change Induced Sea Level Rise”](#) (download PDF)

PUBLICATIONS AND OTHER USEFUL LINKS

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Oktari, R.S., Louise K. Comfort, Syamsidik, and Putra Dwitama. 2020. Measuring coastal cities' resilience toward coastal hazards: Instrument development and validation. *Progress in Disaster Science* 5, 100057, 2590-0617. https://www.sciencedirect.com/science/article/pii/S2590061719300572

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Fauzia, A., Syamsidik, and S. Syahreza. 2020. “Spatio-temporal shoreline changes analysis based on

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Al’ala, M., Syamsidik, and S. Kato. 2017. “Predicting impact of SLR on coastal flooding in Banda Aceh coastal defences.” *AIP Conf. Proc*. 1892, 100004. https://doi.org/10.1063/1.5005736

The team's brief reports on the Sunda Strait Tsunami of December 2018 are available through the links below:

http://tdmrc.unsyiah.ac.id/the-latest-update-from-post-sunda-strait-tsunami-survey/
http://tdmrc.unsyiah.ac.id/the-2018-sunda-strait-tsunami-impacts-assessment/

OPEN DATA REPOSITORIES

2018 Mount Anak Krakatau Tsunami: https://doi.org/10.17632/yyyvmxh8vg.1
2018 Palu-Central Sulawesi Tsunami: https://doi.org/10.17632/vd8yk9crdn.1

INDONESIA - PROJECT 5-215: ENHANCING RESEARCH CAPACITY THROUGH A BIOTECHNOLOGY-DRIVEN INVESTIGATION OF NOVEL GRAM-NEGATIVE BACTERIA FROM INDONESIAN SPONGES

PI: Ocky Radjasa, Diponegoro University

U.S. Partner: Phillip Crews, University of California Santa Cruz (Funded by the National Institutes of Health)

Dates: December 2016 - May 2020

PROJECT OVERVIEW

This team hypothesized that an experimental design based on "integrative chemical biology" would provide new insights into life processes in Oceana. Leveraging an existing Indonesian-U.S. collaboration, the project aimed to advance marine microorganism biology, stimulate chemistry discoveries, and engage STEM students. The focus was on using biodiverse Indonesian sponges as a source of new halotolerant Gram-negative bacteria. The project, based at Diponegoro University (UNDIP) and led by Prof. Radjasa in cooperation with Prof. Crews' natural products lab team, aimed to merge marine-derived natural products with experimental therapeutics. The goals were: (1) to create a marine sponge-inspired initiative between UNDIP and UCSC; (2) to isolate, characterize, and culture at least 30 strains of Gram-negative bacteria from Indonesian marine sponges; (3) to discover at least 10 novel secondary metabolite scaffolds; (4) to establish a productive research partnership through exchange visits; and (5) to contribute to USAID/Indonesia higher education objectives by providing training for at least five UNDIP students and curriculum development.

The exploitation of symbiotic bacteria as a source for novel secondary metabolites is still in its infancy, but the discovery rate of novel active metabolites from marine Gram-negative bacteria could surpass that of their terrestrial counterparts. Sponges are an unusual niche for novel microbes, hosting hundreds of different bacterial groups and diverse symbionts. However, marine environments remain largely unexplored and understudied. The urgent need for novel substances to treat severe human diseases, combined with the rich potential of marine organisms, supports intensive exploration of new substances from these sources. This project aimed to overcome existing bottlenecks by using halotolerant Gram-negative bacteria, which can be grown on a large scale in the laboratory and are potent producers of bioactive compounds.

FINAL SUMMARY OF PROJECT ACTIVITIES

Indonesia is the global epicenter of marine biodiversity and one of the megadiverse countries harboring the majority of the Earth's species. Marine biotechnology aims to develop products and other benefits from marine biodiversity through biological knowledge and advanced techniques. However, the field is in its infancy in Indonesia, with fewer than 40 universities having faculties of fisheries and marine sciences and fewer than 10 focusing on marine biotechnology research. This results in a lack of human resources and research capacity. This project addressed these issues and the bottleneck in developing natural products from marine sources due to insufficient biomass and optimized cultivation conditions for pre-clinical and clinical studies. The PI and his team focused on collecting, culturing, and testing bacteria from sponges, utilizing gram-negative bacteria known for their unique bioactive molecules rarely produced by other bacteria, actinomycetes, or fungi.

In his final report, Dr. Radjasa indicated that he and his team achieved all five project aims. They collaborated with U.S. partner Dr. Philip Crews and his group at the University of California, Santa Cruz, who provided training, mentorship, and collaboration. The team isolated, characterized, and cultured halotolerant bacteria from Indonesian marine sponges and used techniques from Dr. Crews's group to estimate the genetic diversity of these bacteria. They discovered new secondary metabolite scaffolds from sponge-derived halophilic bacteria using various analytical techniques. The project facilitated exchange visits, joint sample collection voyages, co-taught training courses, and collaborative lab work between scientists at Diponegoro University and UCSC. Additionally, the project contributed to USAID/Indonesia higher education objectives by training a majority of female undergraduate students and young scientists from eastern Indonesia, with special attention to gender equality and social inclusion.

Significant outputs of the project included six peer-reviewed articles, one co-authored with their U.S. partner, and a book chapter. They submitted two Indonesian patent applications for different Gram-negative bacteria and uploaded bacterial sequence data to the National Center for Biotechnology Information database. The project also provided training, internships, workshops, and short training visits at UCSC, upgraded curricula for three courses benefiting 91 students, and supported six students in obtaining their PhDs. The UNDIP team received recognition from the Indonesian Minister of Research and Technology, with Prof. Radjasa and key team members ranked among the top 500 Indonesian researchers. The team received six competitive research grants from the Indonesian Ministry of Research and Technology and two international joint research grants, with additional proposals submitted for future funding.

The project established contacts with NGOs working in the marine environment sector, including the World Wildlife Fund and The Nature Conservancy, and built a relationship with the MERO Foundation in Bali to expand research capacity for bioprospecting marine microbial symbionts. Prof. Radjasa emphasized that the PEER project provided much-needed human and lab infrastructure capital, strengthening research capacity. With support from PEER and UNDIP, the team now has an established tropical marine biotechnology laboratory capable of carrying out world-class research. Although the PEER grant has ended, the young research team created will continue to coordinate projects from 2020 to 2022, leveraging their network of international research counterparts.

PUBLICATIONS AS OF JUNE 2020

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INDONESIA - PROJECT 5-125: STRENGTHENING RESILIENCE TO EXTREME WEATHER RELATED EVENTS IN INDONESIA THROUGH IMPROVING THE PREDICTABILITY OF DROUGHT RISK WITHIN DROUGHT CYCLE MANAGEMENT MODEL

PI: Heri Kuswanto, Institut Teknologi Sepuluh Nopember

U.S. Partner: Justin Sheffield, Princeton University (Funded by the National Science Foundation)

Dates: December 2016 - August 2020

PROJECT OVERVIEW

This PEER project aimed to improve the predictability of drought events in Indonesia as part of disaster risk reduction within the framework of the Drought Cycle Management (DCM) model. The DCM has proven to be a robust and practical approach for drought management in Africa for more than 30 years, but it has never been implemented in Indonesia. The Meteorological Office Indonesia (BMKG) issues drought information from a simple monitoring system but with very low predictive capacity and hence drought forecasts have never been made properly. Moreover, the provided drought information is difficult for smallholders and communities to access directly, which has led to lack of actions to reduce the risk. Dr. Kuswanto and his team therefore aimed to create a DCM model to frame decisions currently made at the smallholder and community levels in response to drought and determine whether decisions can be made (based on forecast information) to reduce drought risk.

This project developed a Drought Monitoring and Forecasting System (DMFS) and formulated scenarios to reduce drought risk. The DMFS was developed by drawing from methods developed by the Terrestrial Hydrology Group of Princeton University, integrated with seasonal drought forecasting derived from downscaled climate forecasts from the North America Multi-Model Ensemble (NMME)-II for predicting drought events in Indonesia. The goals of this project were to improve the predictability of drought by developing a reliable monitoring and forecasting system, to formulate a best framework for implementing a DCM model in Indonesia that incorporates local drought characteristics and community profiles; and to test the effectiveness of the DCM model to reduce drought risk.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and his team collected historical climate and hydrology data to characterize drought and develop a drought prediction model. They also identified vulnerable districts for the pilot study for implementation of the DCM: Probolinggo, East Java, and Lombok Utara, Nusa Tenggara Barat. The researchers undertook household surveys in the target districts to gather information on drought cycle management, focusing especially on drought knowledge and perceived impacts among smallholders.

The team compared several models for drought prediction (such as Bayesian Model Averaging (BMA), Ensemble Model Output Statistic (EMOS), etc.) to find the best model representing the Indonesian case. They made the DMFS publicly available, sharing it with government agencies, and aim to develop it into a more easily shareable format for the wider community. A module of the system operation is available in Bahasa Indonesia.

The team members held a variety of workshops and outreach activities, including workshops on climate change for primary school students, teachers, and local officials; a workshop on climate change and extreme events; and a local car-free day, in collaboration with the Directorate of Environment (KLH) of East Java Province. They also communicated findings and recommendations on developing a resilient village with village officials in East Java. A team study on the effectiveness of the car-free day in Surabaya resulted in a policy recommendation to the local government.

Dr. Kuswanto and his group shared their findings and policy recommendations with local government officials and in several published papers. The collaboration with the Indonesian state meteorological agency BMKG was especially intensive. Staff from that agency visited ITS in February 2020 to discuss further cooperation after the PEER project and decided to send staff members to study at ITS. Moreover, two ITS students were selected to conduct internships at BMKG. That same month, Dr. Kuswanto was invited by the PTPN (government company producing sugar) to give a training on data analysis. He shared information about the correlation between sugar cane output and the weather situation and explained the usefulness of applying mid-range forecast information. The PTPN staff expressed interest, stating that the predictions from the system the PI and his group are developing could help support their work, especially for the planting and production planning calendar.

On the educational side, two undergraduate students (bachelor’s degree program) and one research assistant (Master’s degree program) working on the project completed and defended their final projects in January 2020. All of them graduated in March 2020, just a day before the university was shut down due to Covid-19. During the project phase, the PI learned a great deal about the U.S. education system from his U.S. partners, which gave rise to his idea of adopting the “Master by Research” and “PhD by Research” program as applied in many U.S. universities. With Dr. Kuswanto now serving as the director of postgraduate programs and academic development at ITS, he was in an appropriate position to propose the idea to be implemented at ITS. After much discussion, the ITS Academic Senate approved the idea, and the programs were launched in late May 2020.

The PI received $26,000 in additional grants during the project period, including one from UNESCO, and was nominated as a member of Indonesian Young Science Academy.

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INDONESIA - PROJECT 4-393: INTEGRATED WATERSHED MANAGEMENT FOR ENHANCING LOCAL LIVELIHOODS AND BIODIVERSITY CONSERVATION IN INDONESIA

Pi: Ani Adiwinata Nawir, Center for International Forestry Research (CIFOR), former PI Terence Sunderland, Through December 2017

U.S. Partner: Jefferson Fox, East-West Center (Funded by the National Aeronautics and Space Agency)

Dates: November 2015 - October 2018

PROJECT OVERVIEW

This project sought to promote effective implementation of integrated watershed management (IWMA), thereby enhancing local livelihoods, biodiversity conservation, and the research capacity of the partners involved. The project aimed to overcome several resource management problems, biodiversity threats, and conflicting policy and regulation frameworks. Its specific objectives included (1) assessing a variety of institutional arrangements for more effective IWMA; (2) developing approaches for implementing landscape-level biodiversity conservation in remaining natural ecosystems that are key habitats of endemic endangered plant and animal species; and (3) promoting IWMA for enhancing local livelihoods supported by policy and regulation frameworks at national and local levels, based on good governance principles.

Activities in Year 1 included a review of policy and regulatory frameworks that hindered integrated watershed management, landscape-based biodiversity conservation approaches in identified areas, and existing institutional arrangements, as well as an analysis of stakeholders and their divergent needs and capabilities. In Year 2, the project team developed follow-up activities in collaboration with their U.S.-based partners based on data collected to develop scenarios for integrating the above three aspects. In Year 3, the project focused primarily on capacity building for local stakeholders.

By the time the project was completed, NGO partners in Indonesia had better capacity to conduct relevant research and apply research results to management on the ground. Government agencies and communities had a better understanding of effective IWMA and landscape-based biodiversity conservation and how it is applied in the three research sites included in the project (Bantaeng and Bulukumba districts in South Sulawesi and Sumbawa District in West Nusa Tenggara). Experiences were also shared with the other project site in West Kalimantan (Kapuas Hulu District), especially in developing community-based conservation approaches. Skills gained gave these key stakeholders the approaches and experience to continue implementing key project recommendations, ensuring that IWMA was applied after the project ended. It also built capacity among these stakeholders to participate in research and monitoring in future conservation and/or REDD+ activities. Triangular cooperation with the U.S. Government-supported partner at the East-West Center enhanced the scientific research capacity of project members and partners by sharing local and global knowledge on the issue of IWMA.

FINAL SUMMARY OF PROJECT ACTIVITIES

This three-year project sought to improve a number of facets of the local communities through an integrated watershed management approach. One of the main successes of the project was the developed capacity of the implementing organizations including CIFOR and the East West Center, as well as local counterparts. A series of trainings were conducted through which NGO partners and their local government counterparts gained relevant expertise and experience in IWMA and resulted in key project recommendations. Additionally, a number of practical-based trainings at the community level enabled community members to engage in similar community-relevant participatory research which spread the dissemination of project results beyond those who are directly involved and the initial scope envisioned by the project team.

Research activities were conducted at four project sites to ensure the evidence-based policy recommendations could be formulated and customized for local government systems at the village, district, and provincial levels. This developed as an exit strategies towards the end of project and was implemented by working collaboratively and involving a range of stakeholders. Outputs included several letters of decree confirming the membership of each NGO partner in the task force. The scientific knowledge generated in this project was shared to contribute towards addressing the problem of deforestation along the watersheds that have been hampered by the conflicting problems between agriculture and forestry activities. Wider outreach beyond research sites was conducted, and will be continued, by publishing key research finding through various media. Noted challenges included the long-processes and dynamic changes in the local government systems and bureaucracy, so the team constantly worked to re-strategize the policy advocacy.

INDONESIA - PROJECT 4-309: A BETTER UNDERSTANDING OF FUTURE SEISMIC AND TSUNAMI HAZARDS DUE TO THE MENTAWAI SEISMIC GAP, WEST SUMATRA, INDONESIA THROUGH DENSE GEODETIC NETWORKS AND CAPACITY BUILDING EFFORTS

PI: Ashar Muda Lubis, Bengkulu University

U.S. Partner: Louise Comfort, University of Pittsburgh (Funded by the National Science Foundation)

Dates: November 2015 - September 2019

PROJECT OVERVIEW

The Mentawai patch of the Sumatra subduction zone is locked and likely to produce a large earthquake in the near future (Chlieh et al., 2008). The potential for this patch to rupture made it very important to estimate future seismic and tsunami hazards that may ensue as a result. To get a better idea of future hazards, a better understanding of historical earthquakes on this patch was needed. To this end, the project team used the earthquake cycle model to estimate the historical slip distributions through inversion of the paleogeodetic data. To better understand future tsunami hazards, it was necessary to know how the patch would rupture in the future. The low-lying coastal Sumatran city of Padang has been the object of many research and outreach efforts, especially since the tsunami of 2004. However, significant barriers remained to linking science to risk reduction: hazard information was sometimes contradictory or confusing for non-scientists, and critical misunderstandings persisted.

This three-year project aimed to investigate and re-locate the source of earthquakes of the Mentawai seismic gap by densifying the GPS network in West Sumatra. This included training students from Bengkulu University in collecting and processing GPS data to model historical earthquakes in this region and simulate crustal deformation for earthquake cycles. They also investigated tsunami height based on various models. To help prepare for potential future disasters, they built partnerships among scientists, outreach workers, NGOs, and government officials in order to link science to risk-reduction practice. They leveraged the experience of their U.S. Government-supported partner, who had experience in developing community resilience to disaster and policies for earthquake and tsunami hazard mitigation.

These researchers also integrated earthquake education and curriculum development into their Global Positioning System (GPS) field surveys. Most of the GPS stations they installed were in schoolyards. Undergraduate faculty-in-training from Bengkulu University joined the GPS field teams to develop, test, and refine lessons about earthquakes and ways to reduce risk. The project team supervised undergraduate students in designing and implementing “go school” efforts and also provided science and teaching examples for an NGO-led program to integrate disaster-risk reduction into the Padang city schools’ curriculum. This provided an excellent opportunity for educating local communities about earthquakes because the undergraduates served as effective role models for the younger school students, inspiring them to stay in school and encouraging them to study science. The project team worked with the Padang government to present and explain their results, including tsunami and hazard maps, as well as an assessment of potential impacts at the district and city levels. This helped local governments in at-risk communities to prepare for natural earthquake and tsunami hazards and contributed to redefining the science of community resilience.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the third year, the project team installed low-cost seismometers co-located with GPS sites around West Sumatra, Indonesia. By mid-2018, they re-surveyed the GPS monuments installed in the second year to estimate crustal deformation due to Indo-Australian plate tectonic motion. Their findings indicated that the deformations were consistent with tectonic motion, showing stress accumulation on the Mentawai segment of the Sumatra subduction zone. They also conducted a tsunami simulation for Padang, predicting a potential tsunami height of up to 12 meters with an arrival time of less than 20 minutes.

The team presented their work on earthquake and tsunami mitigation at the SEA Studies Symposium 2018 held at the University of Indonesia. In early May 2018, they attended the Sumatra Scientist Meeting in Medan, where they discussed potential tsunamis related to the Sunda Megathrust and presented a system for calibrating a low-cost seismometer. From November 30 to December 16, 2018, they visited the University of California, Berkeley, and attended the 2018 AGU Fall Meeting in Washington, D.C. During this visit, they discussed their project, prepared a manuscript for publication, and gained new insights from other scientists. At the AGU meeting, they presented the PEER project, demonstrating how the 30 installed low-cost GPS sites in West Sumatra could improve the understanding of seismic risk in the region.

In July 2018, the team held a workshop on earthquake and tsunami mitigation in Padang, collaborating with SMA N 6 Padang and other local organizations. They trained 45 senior high school teachers and over 100 students on disaster preparedness and evacuation procedures. In mid-July 2019, they conducted a workshop to disseminate the PEER project findings to local government and stakeholders in Padang, emphasizing the importance of infrastructure resilience and building codes.

The team highlighted the importance of understanding hazards and vulnerabilities for better decision-making and resource allocation. They recommended ongoing collaboration with the Meteorology, Climatology, and Geophysical Agency of Indonesia (BMKG) for updated information. They emphasized the need for infrastructural preparedness, adequate water storage, and operational building design following an earthquake. Additionally, they distributed 1000 pocketbooks to students in Padang, containing information on actions during natural disasters and updates on potential earthquakes.

INDONESIA - PROJECT 4-260: ONE FITS ALL: DEVELOPING DECAPODS BIODIVERSITY RESEARCH FOR EDUCATION, CONSERVATION, AND RESEARCH BENEFITS

Pi: Ambariyanto, Indonesian Biodiversity Research and Diponegoro University
U.S. Partner: Christopher Meyer, Smithsonian National Museum of Natural History
(Funded by the National Science Foundation)
Dates: January 2016 - June 2021

PROJECT OVERVIEW

Biodiversity is defined as the variety of organisms within a given area. The Convention on Biological Diversity indicates that the richer the diversity of life, the greater the opportunity for economic growth. However, despite having the highest marine biodiversity in the world, Indonesia frequently faced significant economic challenges and poor development due to unsustainable exploitation of its natural resources. Efforts to quantify biodiversity have traditionally relied on easily observed parameters like coral cover and fish biomass, while smaller invertebrates that significantly contribute to reef diversity were often ignored due to difficulties in identification, potentially resulting in inaccurate assessment of biodiversity and reef health. Although Indonesia is home to seas featuring more than half of all known marine species, not all taxa of these species had been assessed and quantified, and local expertise to support biodiversity research was small in relation to Indonesia's size and biodiversity.

This project focused on quantifying the biodiversity of decapods (an order of crustaceans that includes crayfish, crabs, lobsters, prawns, and shrimp) across Indonesia while also nurturing international collaboration and improving local taxonomic expertise. The research team implemented an integrated research and education program using autonomous reef monitoring structures (ARMS) and dead coral heads (DCH) as artificial and natural collection platforms for reef-associated decapods. Decapod diversity was then assessed using both traditional taxonomy and cutting-edge genetic approaches. The results of this project provided the first insights into the magnitude of marine biodiversity in one of the most diverse groups of marine metazoans in Indonesia, while also assessing how this diversity was distributed throughout the archipelago. Results helped inform local researchers and managers regarding the health of reef ecosystems across Indonesia, facilitating the development of conservation strategies based on current biodiversity assessments.

The data collected was helpful in designing management strategies to preserve biodiversity hotspots within Indonesia and in focusing conservation efforts on particularly threatened areas. Trainings and workshops organized through this project increased local capacity to develop high-quality biodiversity research and nurtured the growth of local taxonomists. In addition, smartphone applications (www.dnabarcodingassistant.org) and an online database produced through this project, for the first time, made biodiversity research accessible to people beyond the scientific community, which was critical for mobilizing grassroots support for marine conservation.

Through joint research and educational programs with the Smithsonian Institution, the team trained dozens of Indonesian students and researchers through experiential learning in research-intensive courses. By using research as a platform for education, the project simultaneously improved understanding of Indonesian marine biodiversity and developed the next generation of biodiversity scientists.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the course of this project, which ran for five and a half years, Prof. Ambariyanto and his team trained almost 300 students, involved around 20 institutions, and collected more than 10,000 decapod samples. Ten graduate and undergraduate students wrote their theses based on data from the project and graduated successfully. As of August 2021, the project team had published three journal articles, three proceedings abstracts, and one book chapter based on their work on the project, with at least two more research papers in preparation. By working closely with universities across Indonesia, particularly in areas where the samples were collected, the team also developed capacity building programs and incorporated their dead coral head analysis methodology into the curriculum at the partner universities. Besides universities, they also collaborated with three local NGOs (Yayasan ReefCheck Indonesia, Yayasan Misool Basetfin, and Yayasan TAKA) to develop educational and awareness programs on environmental and coastal education in both central Java and the Savu seas, Eastern Indonesia.

The decapod samples collected under the project have been identified and catalogued in a database, with the original samples being stored at Universitas Diponegoro, where they will be made accessible and become assets for future research. The data and biodiversity information associated with it have also been shared and communicated with local stakeholders to ensure the information can be used for conservation and management use. In addition, most of the data generated through this project are accessible through the Smithsonian's Genomic Observatories MetaDatabase (GEOME) (https://geome-db.org/workbench/project-overview?projectId=78) and can be downloaded free of charge.

Although at the time the project ended in June 2021, there had not yet been any policy impacts from the project, the PI reports that the data have informed stakeholders on the importance of incorporating diversity parameters into biodiversity management and conservation practices. Among others, TAKA (an NGO in central Java) has used the data for educational activities around coastal areas in their region. Given the success of these activities, more frequent educational events are expected to be held in the area.

Meanwhile, Prof. Ambariyanto reports that he has received approximately $104,000 in research grants (one international and six Indonesian) to continue and expand on the work begun under the PEER project. Universitas Diponegoro also has a small grant scheme to facilitate research activities for students and lecturers. The PI will encourage all his lab members to apply for funding to do further work on the existing species database and expand sampling and new research activities. The institutional linkages built and cohort of students and junior researchers trained during the years of the PEER project also represent a wonderful resource that has strengthened the marine biodiversity research community in Indonesia. Prof. Ambariyanto points out that PEER has provided him and his team with the flexibility to do research that can combine data generation and exploration with capacity building. PEER support has also made it possible to add valuable and previously unavailable biodiversity data from Indonesia to a globally accessible database while simultaneously nurturing the research capacity and interests of the rising generation of marine scientists across Indonesia. The PI also notes that PEER has provided an immense opportunity to collaborate with a leading U.S. researcher, broadening his team's research network and facilitating intensive knowledge exchange between the two countries. He and his group expect to continue the collaboration and produce further joint publications based on the large amount of data they have collected.

PUBLICATIONS

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INDONESIA - PROJECT 4-146: DEVELOPING A BIOECONOMY IN INDONESIA: IDENTIFICATION OF NOVEL MICROORGANISMS AND MICROBIAL ENZYMES FROM INDONESIAN PEATLAND AND BUFFALOES TO IMPROVE BIOCONVERSION OF OIL PALM RESIDUES

PI: Amadeus Pribowo and Co-Pi Irnayuli Sitepu, Indonesia International Institute for Life Sciences

U.S. Partner: Kyria Boundy-Mills, University of California, Davis (Funded by the National Science Foundation)

Dates: November 2015 - December 2017

PROJECT OVERVIEW

The overarching goal of this project was to explore Indonesia's rich biodiversity in two different ecosystems, namely peat swamp forests and buffalo manure, to find new enzymes and microbes that could improve the efficiency of converting Indonesia's abundant biomass residues into energy and other value-added products. Indonesia is one of the world's top biodiversity hotspots, and its microbial diversity had the potential to be a rich source for various biological products such as novel pharmaceuticals or industrial enzymes. Unfortunately, much of this microbial biodiversity remained unknown to science due to insufficient research funding and capabilities in Indonesia.

The project aimed to build technical capabilities in metagenomics research to explore the microbial diversity of Indonesia and create a culture collection to facilitate ex-situ conservation of this microbial diversity. The research focused on identifying novel enzymes to improve the bioconversion process. Microbial communities living in peat swamp forests and buffalo manure were likely sources of novel enzymes that could break down lignocellulose, the fibrous material in plants. The high proportion of lignin in peat naturally promoted the selection of microbial communities that could degrade or modify lignin. Similarly, a recent study had discovered vast arrays of enzymes active on lignocellulosic biomass from buffalo rumen. Since buffaloes could thrive on low-quality feeds that were hard to digest, the microflora in the buffalo rumen were a likely source of enzymes that could effectively break down hard-to-digest biomass materials. To date, no studies had thoroughly explored the potential of microbial enzymes from these two ecosystems for improving the efficiency of the bioconversion process. As a third objective, the researchers worked to identify yeasts that could convert lignocellulosic sugars to oil for biofuels.

The development benefits of this project included promoting the conservation of Indonesia's biodiversity, strengthening education and research capacities, facilitating climate change mitigation, and supporting green economic development. As an agricultural country, Indonesia had enormous biomass resources, but most of these biomass residues currently went to waste. On the other hand, Indonesia was highly dependent on fossil fuels, which accounted for more than 95% of Indonesia's total primary energy mix. Biorefinery technologies could turn biomass residues into products such as biofuels, biochemicals, and electricity. Hence, developing biorefineries to create value-added products from Indonesia's biomass resources could help reduce the country's dependence on fossil fuels, reduce greenhouse gas emissions, create jobs, and promote rural development.

Efforts to build biorefineries had been hampered by the high cost of enzymes. This project aimed to overcome this challenge by utilizing local biodiversity to find novel enzymes and microbes that could lower the cost of the bioconversion process or facilitate the production of new products.

FINAL SUMMARY OF PROJECT ACTIVITIES

In his final report on this project, when ended as of December 31, 2017, the PI Dr. Pribowo notes that this PEER award represented his institution's first foreign funding and its biggest grant overall since i3L was founded about five years ago. He also notes that the project has helped i3L internally to become more confident in leveraging research and development activities as part of the university's mission. It has also facilitated the involvement of students in a real research setting beyond what the students received in class, and it contributed to the educational process especially in the laboratory practice. Several students were funded to attend professional and academic conferences, where they presented their results from the project, giving them the opportunity to develop their soft skills as young scientists.

On the research side, the project has helped in implementing and improving techniques and methods that otherwise might be impossible without the PEER support. The instruments purchased during this project will continue to be utilized by i3L and others. For example, the thresher that was used to thresh biomass is now being used for processing organic waste as part of the waste management initiative at i3L. The PEER support also helped create a microbial culture collection at i3L. Building a culture collection was not part of the initial activity plan, and the PI and his team originally planned to collaborate with a local microbial culture collection to jump start the process of enzymatic screening while gradually collecting microbes from the environment of interest. However, we could not secure any collaboration, mostly due to restricted use of the other collection for internal research. Buying microbial strains was not an option due to the expense. Therefore, the team focused their first efforts on collecting microbes. As a result, PEER funding was crucial in the establishment of a collection with more than 1,200 strains as of January 2018. The researchers are in the process of uploading a set of 231 microbial strains into the Global Catalogue of Microorganisms. This open catalogue allows global communities to access the team's selected microbial database and communicate with them if there is any interest in the microbes. This Global Catalogue of Microorganisms is managed by the Chinese Academy of Sciences and can be accessed from http://gcm.wfcc.info/ and http://www.wfcc.info/ccinfo/index.php/collection/by_id/1137/. The registration ID is i3LCC WDCM1137 - i3L Microbial Culture Collection Indonesia International Institute for Life Sciences (i3L).

Although the project ended about a year early due to job changes by the PI and co-PI, Dr. Pribowo reports that he and his colleagues plan to continue their research on potential microbes and enzymes with elevated levels of lignocellulosic enzymatic activities. They also intend the continue exploring possible utilization of i3L's microbial culture collection and its team's capacity in metagenomics for other applications (for example, in healthcare or food science). They university is able to provide a small grant to continue the research project even now that PEER funding has ended, and the team is also actively looking for other research grants. They remain in collaboration with their U.S. partner Dr. Kyria Boundy-Mills in preparing manuscripts for publication.

One-minute video on the project on YouTube

INDONESIA - PROJECT 4-125: DEVELOPING SCIENCE AND LEARNING RESEARCH CAPACITY OF BENGKULU UNIVERSITY IN EX SITU CONSERVATION OF SUMATRAN FRESHWATER AND TERRESTRIAL TURTLES

PI: Aceng Ruyani, Bengkulu University

U.S. Partner: Catherine Matthews, University of North Carolina, Greensboro (Funded by the National Science Foundation)

Dates: December 2015 - January 2019

PROJECT OVERVIEW

Science education at the K-12 levels in Bengkulu did not focus on biodiversity. Fieldwork was rarely included as an instructional technique at any educational level, and there was little emphasis on local conservation issues. Bengkulu University (Unib) recently started a graduate program for teachers with the theme of “Natural Conservation Education for A Better Life.” In conjunction with this graduate program, Unib also launched a pioneering conservation effort, "Unib Campus, A Safe Home for Turtles,” with educational components at the K-12 level and at the university as part of the Science Teacher Education curriculum track. Meanwhile, the U.S. Government-supported partner from North Carolina engaged equal numbers of high school students, girls and boys, with a focus on rural minority students, in summer residential programs that taught the students about herpetology by involving them in research on native species. Teachers were included as participants in the summer programs, and graduate students were able to earn university credit by participating.

The main goal of this PEER project was to develop both science and learning research capacity through cooperation between UNC Greensboro and Unib, using the field of herpetology as a venue to improve conservation education and, indeed, conservation itself. The cooperation aimed to achieve the following goals: (1) identify some safe habitats for five species of turtles, (2) increase science and learning research capacity through the thesis research of nine graduate students, (3) develop teaching modules, (4) develop both indoor and outdoor learning resources, and (5) establish a new teacher training center in herpetology and environmental education on the green campus of Unib.

This project supported the spirit of the program “Unib Campus, A Safe Home for Turtles,” which was a novelty for Indonesia. The presence of turtles on the Unib campus served as a learning resource for conservation education for young people in Bengkulu. This model of conservation efforts through educational approaches was designed to be completed over three years, as an attempt to improve the competence of biology teachers in Bengkulu and other provinces of Indonesia. The project aimed to change some paradigms of science education to approach the criteria of “teaching green.” It fostered a personal connection with nature, connections with other people and other species, and helped participants move from awareness to knowledge to action.

Furthermore, the project aimed to move science education in Bengkulu from a very formal model to a more culturally appropriate effort for increasing young people's knowledge, appreciation, attitudes, environmental awareness, and involvement in nature conservation in Bengkulu. There was a clear distinction between scientists and science teachers in Indonesian universities, with scientists focusing on pure biology (science) and science teachers focusing on learning biology (pedagogy). Some educational institutions in Indonesia still emphasized this dichotomy between content and learning, which had been noted as a classical problem in science education. This project developed both science and learning research capacity to show that these two identities could co-exist in a single individual and that this could be very beneficial.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main goal of this research was to develop both science and learning research capacity using the field of herpetology as a venue to improve conservation education and, indeed, conservation itself. It was designed to achieve the following targets: (1) identify some safe habitats for three species of turtles; (2) increase science and learning research capacity through the thesis research of nine graduate and undergraduate students; (3) develop nine teaching modules; (4) develop five indoor and outdoor learning resources; and (5) establish nine new teacher training centers in herpetology and environmental education. During the period from December 2015 through January 2019, the PI and his team established three new ex situ conservation areas, bringing to five the total number of areas on campus for Cyclemys oldhamii, Cuora amboinensis, Siebenrockiella crassicollis, Heosemys spinosa, and Manouria emys. The living collections of the five species are also available at the Unib Turtle Learning Center to be used as a learning resource for turtle conservation. Over the course of the project, 20 undergraduate and graduate students participated in research about ex situ turtle conservation. The data they collected and experience gained were incorporated into the compilation of nine validated teaching modules, which the team implemented in the new teacher training center at Unib. The modules served a varied range of student groups from preschoolers through postgraduates, as well as professional teachers. This PEER project also resulted in the organization of three research workshops, 40 training sessions, and three seminars, involving a total of 1,870 participants (1,003 female and 867 male). Overall, the five output targets were all achieved according to plan. Although the team still faces some challenges and limitations regarding the ex situ conservation aspects of their work, they have applied the interim results they achieved (in terms of both data and research capacity) to enhance their baseline for future sustainable conservation efforts. The PI Dr. Ruyani believes that the Sumatran freshwater and terrestrial turtle study center will serve as a flagship unit at Unib. The government of Indonesia has provided around $35,000 in funding from 2018 through 2021, but the PI and his team continue to seek further support from national and international conservation institutions.

INDONESIA - PROJECT 4-29: IMPLEMENTATION OF A RANDOMIZATION-BASED CURRICULUM FOR INTRODUCTORY STATISTICS AT UPH AND ACROSS INDONESIA

PI: Kie Van Ivanky Saputra, Universitas Pelita Harapan
U.S. Partner: Nathan Tintle, Dordt University (Funded by the National Science Foundation)
Dates: November 2015 - October 2021

Project Website: http://statistikasimulasi.com
Project Blog: https://statisticsreform.wordpress.com
YouTube Channel

PROJECT OVERVIEW

Statistics education reform has been spreading around the globe but had yet to reach Indonesia. In this project, Dr. Saputra and his colleagues exposed many Indonesian teachers of introductory statistics to the reformed content and pedagogy of simulation-based methods for teaching introductory statistics. These methods have been growing in popularity at both the high school and college levels worldwide. The team demonstrated that the simulation-based approaches to teaching introductory statistics, developed by their U.S. Government-supported partner Dr. Tintle and his colleagues, were a viable and effective alternative for teaching statistics to Indonesian university and high school students. As part of this project, the UPH group provided helpful training to many statistics educators in Indonesia, impacting thousands of students in one of the world's fastest-growing disciplines. Documenting student learning gains and improved attitudes when using the new curriculum was an important element of the project, with statistics teachers around Indonesia participating in an assessment project to document these gains. They disseminated the results of their workshops and the assessment project through peer-reviewed papers and conference presentations.

This new statistics curriculum reformed statistics education on a national level, changing traditional teaching methods to an active learning, student-focused approach, engaging students to use more technology in learning something new, and initiating changes in statistical education through professional development. The sustained online learning community and faculty development materials included in this project reached more than 200 statistics teachers and ultimately more than 3,000 Indonesian students. With a diverse range of professions in which statistics plays a role, the project had the potential for effecting substantial change in many sectors in the nation. Initially, it impacted hundreds of statistics educators and thousands of students in the classroom, and later on, indirectly, it should improve overall statistical literacy in the country.

The broader impacts of this project were envisioned in enhancements to the quality of statistical education, the quality of statistical research, and the application of statistics throughout Indonesia. By reforming the statistics curriculum and providing extensive training and resources to educators, the project aimed to foster a new generation of statistically literate individuals capable of contributing to various professional fields. The project also aimed to create a lasting change in the educational landscape of Indonesia by promoting active learning and the use of technology in the classroom, ultimately leading to a more informed and capable workforce.

FINAL SUMMARY OF PROJECT ACTIVITIES

One objective of this project, which ended on October 31, 2021, was to share information with statistics lecturers around Indonesia regarding the statistics curriculum with simulation-based inference that the PEER team created. In total, Mr. Saputra and his colleagues conducted 11 in-person workshops between March 2017 and March 2020, including four at their own university, two elsewhere in Jakarta, and one each in Bandung, Yogyakarta, Palembang, Surabaya, and Makassar. Each one-day workshop discussed the contents of the team's new statistics curriculum, possible challenges, required and supported textbooks, examples of exams, technological applications, and many other important points.

The team also created a website http://statistikasimulasi.com, which presents an online course for those interested in learning and in teaching statistics with simulation-based inference. Visitors to the site can log in and create their own accounts. Student users can access every course and every assessment free of charge. Secondary school teachers and university lecturers can get support from the PEER team if they wish to adapt this curriculum for use in their classes. The team can also provide books, exams, lecture slides, and many other instructional materials. Additional follow-up is still needed with all the lecturers who attended workshops under the project, but as of the date of the final report, six university faculty members had received individualized consultation and materials.

Another important activity under this project was a study comparing implementation of statistics instruction using a simulation-based inference curriculum in Indonesia versus implementation using the traditional curriculum. The PI and his group conducted pre- and post-surveys each semester with students who took their courses to gauge their statistics aptitude and knowledge. The researchers have published articles in conference proceedings and have another one in preparation as of December 2021 with the aim of submitting it to Indonesia's leading journal in the field of mathematics education.

The project also aimed to improve students' attitudes and knowledge toward statistics in Indonesia. To this end, besides their work with university students, the team conducted webinars with high school students and teachers to introduce their curriculum in an engaging, easy-to-understand, and non-threatening way. This is important, as many students are afraid to major in Science, Technology, Engineering and Math fields due to the need to master statistics. The team also succeeded in developing an Android application to help students in understanding the concept of simulation. In addition, they also created a new problem book for students taking their statistics course, addressing the challenge that most examples and problem sets in textbooks are not relevant to the Indonesian context.

On the program's final goal, making statistics available for everyone, the PI and his team have worked since June 2021 on developing a website to serve as a learning management system for those who want to learn statistics and as a documentary of their project, including blogs on their activities and sources of information about simulation-based inference methods. A series of video lecturers will be embedded in the website eventually but is currently available on YouTube.

Although the PEER project has ended, Dr. Saputra and his colleagues plan to continue their efforts, including finishing their website, revising one paper and preparing at least one more, and continue outreach to other Indonesian statistics professors who are interested in implementing their curriculum. They also plan to organize another workshop for statistics lecturers who have not yet heard about their curriculum. This will be a start of work towards their goal of creating a community for improving statistics education in Indonesia. Last but not least, the team has been invited by Indonesian Cyber Education, a consortium of 12 Indonesian universities, to make their statistics course available online to all students at those universities.

PUBLICATIONS

Saputra, K. V. I., and O. Couch. 2018. Implementing a simulation-based inference curriculum in Indonesia: A preliminary report. In Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS-10), Kyoto, Japan. Voorburg, The Netherlands: International Statistical Institute.

Saputra, K. V. I., L. Cahyadi, and U.A. Sembiring. 2018. Assessment of statistical education in Indonesia: Preliminary results and initiation to simulation-based inference. In Journal of Physics: Conference Series (Vol. 948, No. 1, p. 012033). IOP Publishing.

INDONESIA - PROJECT 4-12: CORAL VULNERABILITY ASSESSMENT TO TEMPERATURE STRESS (BLEACHING) AND OCEAN ACIDIFICATION IN THE SPERMONDE ARCHIPELAGO: CONSERVATION STRATEGIES FOR CLIMATE RESILIENCE

PI: Nita Rukminasari, Universitas Hasanuddin

U.S. Partner: Brian Hopkinson, University of Georgia (Funded by the National Science Foundation)

Dates: December 2015 - November 2018

PROJECT OVERVIEW

The focus of this project was the categorization of coral species based on their ability to withstand stress events. The research aimed to provide science-based metrics and approaches essential for planning and managing future marine protected areas designed to protect reef biodiversity, reef productivity, and the socioeconomic welfare of communities dependent on them. In the Spermonde Archipelago, a group of small islands off the west coast of South Sulawesi, coral reefs served as invaluable resources both as a food source and as island protection. Over the last decade, ocean temperatures in the region increased, causing more frequent coral bleaching and losses of entire coral colonies in the Spermonde Archipelago. This trend was predicted to continue with climate change. Increasing carbon dioxide concentrations in seawater led to ocean acidification, further stressing corals and the ecosystem. The Spermonde Archipelago is part of the Coral Triangle region, known as the "Amazon of the seas," which is the center of global coral reef diversity. However, despite its significance, the region remained dramatically understudied, with poor documentation of coral bleaching and the impact of increasing carbon dioxide on coral.

The research team conducted field research at six islands in the Spermonde Archipelago to identify thermal- and acidity-tolerant coral species, map their distribution, and characterize habitats that buffer coral species from thermal anomalies. They examined environmental conditions such as depth, temperature regimes, light attenuation, geomorphology, and prevailing currents. They also conducted laboratory experiments to study coral symbiotic zooxanthellae clades and determine their resistance to heat and acid stress. Existing management strategies were reevaluated based on this detailed physiological information and spatial mapping to incorporate tolerance and environmental refuges into new Marine Protected Area (MPA) management strategies within the Spermonde Archipelago.

The project aimed to improve the management of coral reef ecosystems facing climate change by providing comprehensive information about the ecology and physiological characteristics of corals in the Spermonde Archipelago. It contributed to the management of Coral Triangle Marine Protected Areas with a focus on climate change resilience. The development of sustainable alternative livelihoods, such as marine fish aquaculture, was a key to reducing destructive fishing practices. Through educational and outreach efforts in local communities, Dr. Rukminasari and her colleagues on the project aimed to produce a long-term impact on the sustainable human use of coral reef resources in the region. To this end, they developed an easy-to-use monitoring protocol for assessing coral reef conditions and water quality changes that could be used by non-scientists to monitor the condition of their coral reef.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the final year of the project, which ended on November 30, 2018, Dr. Rukminasari and her team completed their ocean acidification experiment using a CO2 system that ran smoothly. From April through August 2018, they analyzed their data and prepared two manuscripts from September through November, to be published in March 2019. Throughout the three-year project, the PI updated curriculum materials for several courses at Universitas Hasanuddin (Unhas), incorporating project results related to climate change and coral resilience. The team also conducted community service training workshops for residents of six islands in the Spermonde Archipelago, teaching them about coral reef ecosystem health and alternative livelihoods like raising lobsters in floating cages.

As of early February 2019, Dr. Rukminasari and her team were still analyzing the results from their ocean acidification experiment and coral bleaching field data. Although final analysis was pending, they reported gaining a better understanding of coral bleaching and ocean acidification impacts on coral around the Spermonde Islands. They planned to submit a technical report to the Marine and Fisheries Agency at South Sulawesi Province by mid-2019, identifying coral species resistant to bleaching and acidification and developing tools and strategies for coral reef conservation.

In terms of outreach, the team met with officials from the Marine and Fisheries Ministry of Indonesia to discuss implementing their research results, especially for monitoring and managing coral bleaching in the Coral Triangle. They built a network for coral bleaching monitoring and data sharing and initiated collaborations with the Center of Excellence for Development and Utilization of Seaweed and Tadulako University to extend their research. Dr. Rukminasari also aimed to continue her collaboration with U.S. partner Dr. Brian Hopkinson, securing funding for a new project on the effects of increasing CO2 concentration on microalgae and cyanobacteria in shrimp pond waste.

The project significantly contributed to better understanding and managing coral reef ecosystems facing climate change, enriched educational curricula, and empowered local communities with new knowledge and livelihoods. The sustained efforts in research and community outreach promise long-term benefits for coral conservation and resilience in the Spermonde Archipelago.

INDONESIA - PROJECT 3-212: STUDY OF CLIMATE CHANGE AND AIR QUALITY IMPACT FROM SHORT-LIVED CLIMATE FORCERS (SLCFS) REDUCTION IN INDONESIA

PI: Asep Sofyan with Co-Pi Ayu Purwarianti, Institut Teknologi Bandung
U.S. Partner: Gregory R. Carmichael, University of Iowa (Funded by the National Science Foundation)
Dates: September 2014 to May 2016

PROJECT OVERVIEW

Short-lived climate forcers (SLCFs) such as black carbon and ozone play a major role in global warming, and Indonesia is one of the dominant emitters of these pollutants in Asia. No comprehensive studies had been carried out to explore quantitative links between Indonesia's source emission intensity and its effects on air quality, as well as climate impacts within the region and beyond. This project aimed to support Indonesia's target for a 26% reduction in greenhouse gas emissions below the "business-as-usual" level by 2020 based on unilateral actions, with further reductions of up to 41% with adequate international support. The study was expected to enhance understanding of climate processes, especially the interaction with air quality through SLCFs, and to promote the integration of air quality improvement and climate forcing mitigation policies.

To meet this need, the research project brought together leading Indonesian and U.S. research groups to conduct joint research on air pollution and climate interactions. The project aimed to assess the impacts of various mitigation measures of important SLCFs in the Indonesian region on air quality and climate by using a co-benefit approach, and to generate a scientific basis for policy recommendations to integrate air quality and climate policies. The study developed realistic emission reduction scenarios and analyzed them using a modeling tool provided by the U.S. partner. The project shed light on interactions between emissions in Indonesia and local air quality and climate. Other outcomes included capacity building of Indonesian researchers and policymakers in SLCF emission reduction and integration of air quality and climate forcing mitigation policies. The results were disseminated through national workshops, scientific conferences, and scientific publications.

FINAL SUMMARY OF PROJECT ACTIVITIES

During this project, which was completed at the end of September 2015, Dr. Sofyan and his team at ITB completed their five planned research components. The first was assessment of the status of SLCFs. ITB PhD student Ms. Hafidawati assessed the status and trends of surface ozone in Jakarta for 2010-2014 using data collected from automatic monitoring stations of the local environmental protection agency. Moreover, the researchers have also tracked ambient levels of other pollutants, such as PM10, SO2, NO2, NO, and CO. Black carbon (BC) data in Jakarta have been collected from many secondary data sources, including BATAN (National Nuclear Energy Agency). ITB continued collecting ozone and BC data for other large cities in Indonesia, such as Bandung, Semarang, and Surabaya, and continued updating maps of the spatial distribution of PM, BC, and ozone levels over selected cities (Jakarta and Bandung). Their second research component was development of emissions inventory (EI) data. ITB continued updating to produce a comprehensive EI database of key air pollutants and climate forcers for major emission sources of Indonesia for the base year 2010. The researchers improved the emissions inventory, and Ms. Hafidawati converted the data to a 0.050 x 0.050 (about 5.5km x 5.5km) grid for air quality-climate model applications. In addition, four Master's students updated the EI for the three largest cities in Indonesia, namely Jakarta, Bandung, and Tangerang, for the base year 2013 with a resolution of 1km x 1km grid size. Ms. Lailatus Siami and Mr. Qiyam worked on traffic EI for Jakarta, Ms. Grace on the industrial sector for Jakarta, Mr. Ferry on all sectors for Bandung, and Mr. Nurdiansyah and Adi on all sectors for Tangerang. For all sectors, the EI includes major anthropogenic sources such as residential, on-road transport, crop residue open burning, etc.

The third research component in this project focused on air quality and climate modeling. ITB Master's student Ms. Amalia developed a computer server for these modeling purposes, and the team set up and ran the air quality-climate modeling systems using WRF/Chem for Jakarta and Bandung. For the case of Jakarta, ITB has collaborated with BPLHD Jakarta (Environmental Management Agency for Jakarta Province) to implement the WRF/Chem model for supporting the agency's work on developing the air quality control strategy for Jakarta. The fourth research component was emissions reduction for target sources. Master's student Mr. Qiyam developed action plans for BC emissions reduction from vehicles in Jakarta. In particular, he and the team focused on BC emissions reduction from implementation of Bus Rapid Transport (BRT) in Jakarta.

The fifth and final research component was networking, capacity building, and dissemination. In this regard, Dr. Sofyan and his team facilitated data sharing and knowledge transfer through the research network and disseminated their information to policy makers and the public through various forums. For example, several meetings were organized between the ITB researchers and the Ministry of Environment of Indonesia, the environmental protection agencies of Jakarta and Bandung, NGOs, and interested members of the public to discuss the most feasible emissions reduction scenarios in Indonesia. For dissemination within the academic community, Dr. Sofyan presented some of his team’s research results at the International Joint Seminar of Japan and Indonesia "Environmental Sustainability and Disaster Prevention (ESDP-2015)" in Bali March 22-24, 2015. Although his PEER grant has now been completed, he will also present a paper entitled “Emission Reduction From Implementation of Bus Rapid Transit Corridor 13th in Jakarta” at the 5th Environmental Technology and Management Conference “Green Technology towards Sustainable Environment,” November 23 - 24, 2015, in Bandung. To continue his research. Dr. Sofyan has received a grant from the Ministry of Higher Education of Indonesia.

INDONESIA - PROJECT 3-195: SUSTAINABLE CONVERSION OF OIL PALM LIGNOCELLULOSIC WASTE INTO PENTANOL USING METABOLICALLY ENGINEERED MICROBES

PI: Fransiskus X. Ivan, Surya University, With Co-Pi Yalun Arifin (Former Pi, now at Curtin University, Malaysia)

U.S. Partner: Brian Pfleger, University of Wisconsin, Madison (Funded by the National Science Foundation)

Dates: January 2015 - February 2017

PROJECT OVERVIEW

Indonesia has the largest oil palm plantations in the world, and together with Malaysia, it accounts for roughly 85% of the world's palm oil production. However, serious environmental problems are caused by the oil palm plantations and industry. With only 10% of the oil palm plant producing oil, as much as 90% of the total plant mass becomes lignocellulosic waste, and the disposal of such abundant lignocellulosic waste is problematic. Conversion of oil palm lignocellulosic biomass into valuable chemicals can solve environmental problems related to their disposal while generating profit. The goal of this research project was to convert oil palm lignocellulosic waste into liquid fuels or high-value chemicals.

To achieve this goal, the research team aimed to metabolically engineer microbes using synthetic biology tools to efficiently convert levulinic acid into pentanol. They developed a bacterial strain capable of converting levulinic acid into pentanol in industrially relevant titer, rate (productivity), and yield using metabolic engineering and synthetic biology. This strain could be used to convert oil palm plantation waste into pentanol sustainably. The conversion of oil palm lignocellulosic waste into pentanol could potentially reduce environmental problems stemming from waste disposal and produce bio-gasoline (pentanol) economically and sustainably, significantly reducing consumers' dependence on petroleum.

If the strain-mediated production of pentanol proves profitable, it could influence the oil palm industry's intent to expand plantations through tropical forest destruction, thus protecting wildlife and biodiversity. Additionally, since all lignocellulosic materials can be converted into levulinic acid, this strain should be applicable for valorizing other agricultural or forest residues. This may inform policymakers to create new regulations on how to treat such residues. In the long term, the strain could potentially prevent further destruction of tropical forests and wildlife, and reduce the levels of water, pesticides, and herbicides needed for oil palm plantation maintenance.

FINAL SUMMARY OF PROJECT ACTIVITIES

The major component of this project, which was completed at the end of March 2017, was a visit of almost two years by Surya University researcher Wasti Nurani to the laboratory of U.S. partner Dr. Brian Pfleger at the University of Wisconsin. Initially Wasti's work focused on trying to engineer the bacterium Pseudomonas putida so that it can consume a particular lignocellulose-waste derived chemical named gamma-valerolactone (GVL) and later convert it into other chemicals of interest. She attempted to express several potential GVL-breaking enzymes from other organisms in P. putida with the hope that one of them would allow P. putida to grow solely on GVL to an appreciable extent. Not all questions pertaining to the use of GVL by the engineered organism could be answered, perhaps because the gene expression tools being used, which were developed for work with E. coli, did not work as well with P. putida. Therefore, in the second year of Wasti's visit, she and her colleagues turned their attention to constructing a series of synthetic gene expression tools specifically tailored for P. putida, testing some constitutive and inducible gene promoters. Some of challenges have been resolved, but questions still remain for further study. The initial findings were publicized at the 2016 annual meeting of the Society for Industrial Microbiology and Biotechnology in New Orleans, and two other manuscripts were in preparation as of April 2017. Meanwhile, the team published two other papers in journals during 2016 and team members delivered several technical presentations.

Despite the research challenges, the PI Dr. Ivan reports several benefits in terms of capacity building for the institutions and individuals involved. This project has contributed to the development of a start-up research group in biotechnology, with research projects on algal bioprocessing and biorefinery technology. Wasti Nurani has received a scholarship to pursue her PhD at the Technical University of Denmark, where she will study yeast metabolic engineering. Laurancia Vina Steifa, a more junior student who spent 10 weeks in Wisconsin working in Dr. Pfleger's lab in the summer of 2015, is now taking courses toward her Master's degree in biotechnology at the University of Queensland, Australia. The original PI on the project, Dr. Yalun Arifin, was appointed as chair of the Department of Food Business Technology at Prasetiya Mulya University in Indonesia, having returned from a year and a half on the faculty at Curtin University in Malaysia. Dr. Ivan at Surya University is working closely with the bioinformatics group at Nanyang Technological University in Singapore on a systems biology project, and besides his research he is also active in promoting STEM education focusing on biotechnology to young scholars in Indonesia.

Thanks to the commitment of Dr. Ivan, Dr. Arifin, and their team members, this project had an unexpectedly large outreach component. They delivered several seminars, a two-day STEM workshop, and a presentation to the public aimed at improving awareness of the importance of biotechnology. They are also preparing a book about 21st century biotechnology that is intended for general readers. It is expected to be published by the end of 2017.

INDONESIA - PROJECT 3-148: STRENGTHENING RESEARCH AND TEACHING CAPACITY OF BRAWIJAYA UNIVERSITY IN MONITORING AND EXPLORING OF VOLCANOES (PILOT STUDY: IJEN VOLCANO COMPLEX, EAST JAVA)

PI: Sukir Maryanto, Brawijaya University

U.S. Partner: James Foster, University of Hawaii (Funded by the National Science Foundation)

Dates: November 2014 - January 2017

PROJECT OVERVIEW

Around 13% of the world's volcanoes are located in Indonesia; however, few studies had been conducted and there was minimal community education on volcano eruptions. To mitigate the hazard, a volcano monitoring system was initiated after Kelud's eruption in 1919, which killed more than 5,000 people in East Java. Since then, monitoring, education, and research in the field remained minimal. East Java, one of the places most prone to volcanic eruptions in Indonesia, had the most victims affected by volcano eruptions during the 20th century. One of its most active volcanoes, Ijen Volcano, known for its large hyperacidic crater lake, posed significant volcanic and environmental hazards to its immediate surroundings. Despite its threats, the volcano provided benefits to the surrounding communities due to its sulfur mining, tourism, and geothermal energy potential. In this research project, Ijen Volcano became a natural laboratory for volcano education and research in all aspects of monitoring and exploration with anticipated social, economic, and environmental impact.

This project aimed to develop sustainable and integrated Geophysical Volcano Monitoring and Exploration (GVME) in East Java Province through cooperation between the University of Hawaii and Brawijaya University in research and teaching capacity building by integrating geophysical approaches. Collaboration between the Indonesian and U.S. partners promoted knowledge transfer, training, and advancements for Indonesian researchers and staff. The expertise of the U.S. partner strengthened the Indonesian capacity to monitor and explore volcanoes in Indonesia, minimizing the loss and risks caused by such events. The research team established a collaboration with the Indonesian Center for Volcanology and Geological Hazard Mitigation (CVGHM), and much of the capacity building involved CVGHM staff and student training through workshops and seminars.

Through this project, a new research group on volcanology and geothermal research was established at Brawijaya University, affiliated with the Research Center for Geosciences and Disaster Mitigation. This unique research center will conduct volcanology and geothermal research in the future, contributing significantly to the scientific understanding and practical management of volcanic hazards and geothermal resources in Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

During this PEER project, which was completed as of the end of January 2017, Dr. Sukir Maryanto and his team conducted a wide range of activities to achieve their goals of improving research and teaching in the field of volcano geothermal studies at their university and beyond. The PI launched his project in November 2014 by creating the Research Group BRAVO ENERGEOBHAS at Brawijaya University. Through this group, he and his students and fellow researchers conducted three major workshops (two onsite at the Cangar-Arjunos Welirang Volcano complex) in 2014 alone. The group also organized two annual Indonesian Conferences on Geothermal and Volcanology in 2015 and 2016 and sent the PI and other participants to present their work at other international and domestic conferences, including the 2016 Annual Meeting of the American Geophysical Union. The team engaged in frequent field work, including geophysical surveys in both volcanic and geothermal areas. They used geophysical methods (magnetotelluric, gravity, magnetic, self potential, and seismic–microtremor) to identify subsurface conditions around the Blawan – Ijen complex and the Arjuno – Welirang volcano. So far, the project has resulted in seven published journal articles, a book authored by the PI, and several technical presentations at conferences and other events.

On the education side, in each of the two years of the project, four students received scholarships. The PEER project also contributed significantly in the establishment of a new doctoral program in the Department of Physics beginning in 2016. The existing curriculum in the department was also enhanced by the addition of field work, especially for the subjects of Physical Volcanology and Geothermal Exploration, with the activities being conducted in the university's new Field Laboratory of Volcano and Geothermal Studies that was built in 2016. The PI also reports that his work on the PEER project contributed to the development of the new Brawijaya Volcanology and Geothermal Research Center, which had its pre-opening event in December 2016.

The project also facilitated the creation and strengthening of new collaborations between the Brawijaya team and various Indonesian and foreign universities and government agencies in order to share and increase knowledge regarding volcano and geothermal-related issues. At the national scale, Dr. Maryanto and his group have collaborated with the government of the Indonesian city of Batu to sustain geothermal and volcano education in Cangar and also with the Center for Volcanology and Geological Hazard Mitigation. They are also involved in a proposal to USAID's Sustainable Higher Education Research Alliance (SHERA) program that involves nine other Indonesian universities in an effort to build research capacity in their field. Internationally, the PI collaborates with colleagues at the National Central University Taiwan, National Cheng Khung University Taiwan, University of Neuchatel, and University of Hawaii at Manoa (home institution of his U.S. partner on this PEER project). Thanks to funding provided in 2016 by the Indonesian Ministry of Research, Technology, and Higher Education and the Brawijaya University Research Management Program, the PI and his group are continuing their efforts even though this PEER award has ended, and they are active seeking additional support in 2017 and beyond.

INDONESIA - PROJECT 3-147: TSUNAMI WAVES IMPACTS ON COASTAL MORPHOLOGICAL CHANGES BASED ON SEDIMENT TRANSPORT NUMERICAL SIMULATIONS

PI: Syamsidik, Tsunami and Disaster Mitigation Research Center, Syiah Kuala University
U.S. Partner: Philip L-F. Liu, Cornell University (Funded by the National Science Foundation)
Dates: September 2014 - September 2016

PROJECT OVERVIEW

Since its initial development, numerical tsunami simulation was expected to provide explanations for the hydraulics regime as it relates to tsunami wave propagation and inundation. However, limited models had been developed and tested for investigating the impacts of tsunami waves on coastal morphological changes, and even fewer research studies had been conducted in tsunami-affected areas to estimate tsunami wave impacts. This research team focused on coupling sediment transport modules inside the tsunami wave propagation model to estimate coastal morphological changes caused by wave forces. The research concentrated on the Banda Aceh Coast of Indonesia, an area severely damaged by the Indian Ocean Tsunami in 2004, with most coastal areas recovering through natural processes or hard coastal structures.

The project aimed to (1) investigate the impacts of tsunami wave forces on eroding coastal morphology by developing numerical simulations; (2) locate the origins of sediment transported and deposited around the coastal plain and affected areas; and (3) simulate the coastal morphology recovery process by incorporating recent coastal processes around the selected tsunami-affected coast and provide recommendations for better reconstruction processes around tsunami-affected coasts. This research project extended the well-known model of tsunami wave propagation, COMCOT, and incorporated the bouncing process of the tsunami wave-affected coasts to recover the eroded coasts. The coastal morphology recovery model, Delft3D, was used to simulate mid-term and long-term coastal morphological changes.

The results of this research provided a clearer understanding of sediment sources during the tsunami, deposition mechanisms, and the role of sediment transport during the coastal recovery process. The findings of this project equipped scientists and disaster responders with knowledge on managing coastal areas to mitigate the impacts of tsunami waves more effectively and suggested alternative measures to accelerate coastal morphology recovery processes.

FINAL SUMMARY OF PROJECT ACTIVITIES

The study areas for this project were at two locations in Aceh Besar District of Indonesia. Site 1 was on the Ujong Pancu Coast of Aceh Besar, located at the western part of Banda Aceh, and Site 2 was around Lhoong Sub-District of Aceh Besar, located about 40 km west of Banda Aceh. Dr. Syamsidik and his team collected bathymetry data from Ujong Pancu, topography data from Site 2, and sediment property data from both sites. They also measured the current profiles at Site 1 to understand the hydrodynamic regime around this area that might contributed to the recovery of the coastal area at the site after it was severely eroded by the 2004 tsunami. At Site 2, a number of trench tests were made to investigate tsunami sediment deposits in order to validate the results of numerical simulations. They found that their GIS analysis proved that the recovery process in this study area was good in the areas used for housing but the land did not recover so well where there were ponds, mangroves, and paddy fields. Although the coastal profile of this area has recovered to a great extent, the environmental recovery of this coastal area has yet to support the return of productive aquaculture activities and mangrove areas around the study area. Therefore, the researchers identified needs for a sustainable environmental recovery in this area more than ten years after the Indian Ocean tsunami.

In order to enhance local capacity to understand recent advances in tsunami-related studies, the team conducted one five-day training course in Aceh for young researchers and students. The training was delivered specifically to train the participants to understand numerical modelling for tsunami wave propagation. The participants were introduced to basic numerical schemes and were trained to run the Cornell Multi-Grid Coupled Tsunami model (COMCOT). At the last stage of the training, the participants learned methods for visualizing results and presenting simulation results as clearly as possible. In addition, the PI Dr. Syamsidik attended an OpenFOAM training in London, where he learned methods for simulating Reynold Average Navier Stokes cases (RANS) for hydro-dynamic modeling. OpenFoam could be useful for researchers at TDMRC to develop more detailed simulations of the impacts of tsunami waves on specific coastal and harbor structures.

Thanks to PEER funding, the team has purchased an acoustic Doppler current profiler and a conductivity, temperature, and depth (CTD) profiler. These instruments enabled them to observe hydrodynamic conditions and map suspended sediment distribution around the study site. The equipment has also been used by undergraduate and graduate students at Syiah Kuala University during field work.

As of the end of the project in September 2016, the team has published four papers in journals, two conference papers, and one book chapter, all of them peer reviewed. They still have two more papers to be submitted to international journals by the end of 2016. The team has also presented their activities in two documentary videos, one on the National Symposium on Tsunami Mitigation (December 2015) and another on their research activities and findings. This PEER project also contributed to the designation of the Tsunami and Disaster Mitigation Research Center (TDMRC) of Syiah Kuala University as a provisional Center of Excellence (CoE) in Tsunami Mitigation by the Indonesian Ministry of Research Technology and Higher Education (RISTEKDIKTI). Dr. Syamsidik and TDMRC have been selected to receive a new PEER award in Cycle 5 of the program to continue and expand on their work.

INDONESIA - PROJECT 3-103: INTEGRATED LOCAL EMERGENCY RESPONSE POLICY IMPROVEMENT AND CAPACITY BUILDING FOR ADVANCE-EARLY WARNING SYSTEM IN THE FACE OF NEAR-FIELD TSUNAMI RISK

PI: Harkunti Pertiwi Rahayu, Institut Teknologi Bandung

U.S. Partner: Louise K. Comfort, University of Pittsburgh (Funded by the National Science Foundation)

Dates: September 2014 - October 2018

PROJECT OVERVIEW

This research project focused on the utilization and integration of a logic model and new public management and network theories to improve the near-shore tsunami early warning system and enhance local emergency response policy. The use of the logic model and new public management provided tools for assessing and mapping the cognitive behavior of people during tsunami evacuations, which helped improve tsunami emergency response policy. Additionally, the utilization of network theory offered real-time assessment of the early warning system's performance and its subsequent emergency response to disasters. This real-time monitoring was used to improve evacuation performance and provide support to disaster victims. The research team investigated how multiple parties and organizations with a disaster response-related mandate coordinated and cooperated effectively. The use of Social Network Analysis (SNA) advanced the scientific understanding of emergency response operations and evacuation.

The results of this research project were expected to influence and enhance emergency response policy in the study area and contribute to the development of the disaster management sector in Indonesia. The outcomes improved the capacity of government officials, non-governmental organizations, and local communities to prepare for and respond to disasters, particularly in terms of emergency operation and response, through a combination of technocratic and participatory approaches. Findings and lessons learned from this research were anticipated to be applicable to both the U.S. and global contexts, serving as a model for developing an integrated early disaster warning and emergency response system.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project achieved significant results and impact in four case study cities (Padang, Pariaman, Agam, and Pesisir Selatan) including updated risk assessment and evacuation plans, revised disaster management plans, and capacity building on preparedness and early warning systems for tsunamis. The team developed Social Network Analysis and Logic Model of People’s Cognitive Behavior models to improve downstream warning chains and provide policy briefs on tsunami disaster risk reduction. Results from the Social Network Analysis model showed that some policies and initial response capacities of each city/regency negatively affected the network structure. For example, the quality of networks in Padang City, which follows its Mayor Regulation 14/2010 requiring public-private cooperation with a media company, differed significantly from Agam Regency, which lacked such regulation or cooperation. The research suggested a common disconnect between formal tsunami early warning systems and local organizations like schools, mosques, and Community-based Disaster Preparedness Groups (KSBs) across cities/regencies, impacting tsunami response. The main recommendation was to include these organizations in city/regency-level policy on tsunami early warning and enhance their capacity to deliver warning information.

The People's Cognitive Behavior model was developed to improve downstream warning chains and provide policy briefs on tsunami disaster risk reduction (DRR). Findings indicated that 35.10% of people preferred immediate evacuation, while 34.86% opted for delayed evacuation, and 30.04% did not want to evacuate. Key factors influencing evacuation decisions included the planned evacuation order and method (36.65%) versus vulnerability and chaos of unplanned evacuation (23.11%). Combining Natural Warning and TEW logic models, the team found that knowledge was crucial in immediate evacuation decisions (30.34%), while the decision to never evacuate was driven by reason (34.50%). The model assessed city preparedness for tsunamis and supported policy development to enhance tsunami preparedness.

The ITB PEER team used these research results to improve the Padang City Mayor Decree on Tsunami Early Warning Systems (Perwako No. 14/2010), receiving high praise from PEER's partners. Key success components included innovative and holistic research approaches, participatory stakeholder engagement, and utilizing the Indian Ocean Wave Tsunami Exercise '16 (IOWave'16) to test the improved SOP for tsunami early warning and emergency response in Padang City.

The team's work led to two MoUs for disaster mitigation and education between the Padang city mayor and ITB rector, one in December 2016 and the other in January 2015. The research process and lessons were documented as technical guidelines and videos for dissemination, making it easier to replicate in other tsunami-prone cities. This documentation aims to increase national and regional impact, demonstrating the importance of scientific research and data in developing disaster risk reduction policies. Replicating this approach in other tsunami-prone areas will enhance Indonesia's overall disaster resilience. The multimedia product showcases how science addresses local challenges, secures stakeholder commitment, and raises global awareness of DRR research, benefiting both Indonesia and the US in disaster management.

Link to news article on the PEER team's field work in West Sumatra in August 2015 (in Bahasa Indonesia)

Link to news article about the team's participation in IOWave'16 and preparatory activities in September 2016 (in English)

INDONESIA - PROJECT 3-82: SEDIMENT TRANSPORT EVALUATION ON THE BENGAWAN SOLO RIVER (DOWNSTREAM AND ESTUARY) TO MINIMIZE SEDIMENTATION AND FLOOD COMBINING EFFECT ON NEARBY INFRASTRUCTURE

PI: Ria Asih Aryani Soemitro, Institut Teknologi Sepuluh Nopember

U.S. Partner: Gangfeng Ma, Old Dominion University (Funded by the National Science Foundation)

Dates: November 2014 - November 2018

PROJECT OVERVIEW

Excessive upstream to downstream land-use and deforestation, along with downstream local sand mining along Indonesian rivers that started in the 1990s, triggered significant river surface runoff and flow increases, unbalanced sedimentation, aggradations, and degradation. These interacting effects resulted in unpredictable changes in river morphology, leading to flooding and infrastructure instability in most Indonesian rivers. Considering the serious impact of flooding and infrastructure damage, research on river sedimentation problems was necessary to provide preliminary assessment guidance for river channel capacity normalization and estuary management to prevent estuary aggradations. The novelty of this research was to develop a more accurate river discharge flow calculation and estuary sedimentation prediction and analysis, taking into account river morphology changes based on thorough and meticulous sedimentation process investigation.

Without comprehensive detailed knowledge of sediment transport and seawater tidal processes, analyzing downstream river and estuary morphology changes accurately would have been impossible. The research team focused on the Bengawan Solo River, considering its river morphology. Collaboration with the U.S. partner strengthened the Indonesian team's ability to better predict and analyze estuary sedimentation problems and analytically predict downstream and estuary flooding, infrastructure failure, and channel port aggradation due to changes in river morphology. The research project results were disseminated to the East Java Ministry of Public Works to provide preliminary assessment guidance for river channel capacity normalization and estuary management to prevent estuary aggradations. Collaboration between the Indonesian team and the U.S. partner promoted knowledge transfer, training, and advancement for Indonesian researchers.

FINAL SUMMARY OF PROJECT ACTIVITIES

After a preliminary site survey of the upstream section and an investigation into the river and embankment characteristics of the downstream section, the research team investigated the water depth. They then undertook field and lab-based geotechnical investigations of the estuary area, as well as analyzed nearby infrastructure (bridge and river dike) conditions and hydraulic characteristics of the river estuary. PEER funds also allowed Dr. Soemitro and her team to purchase a Strata Box HD to investigate the sub-bottom profile of the river.

The PI and a fellow researcher took part in the International Conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation in Kyoto, Japan, early in the grant period. Researchers also collaborated with Universitas Teknologi Sumbawa and presented a guest lecture on the findings to Kumamoto University in Japan.

The research team shared project results with the East Java Ministry of Public Works to provide preliminary guidance for river channel capacity normalization and estuary management. The research team also disseminated its findings to fellow scientists and to government stakeholders, including the Ministry of Public Works and Housing at Bandung and the Development Planning Agency of the Sumbawa District, receiving feedback on the results and suggestions for further research. At a follow-up workshop in 2018, officials at the Coastal Research Center of the Ministry of Public Works and Public Housing were particularly interested in collaborating on future work on estuary sedimentation and high sea waves.

Dr. Soemitro also visited three universities in the United Kingdom to collaborate with colleagues and present lectures. The team's collaboration with the U.S. partner, whom they visited near the end of the project term, strengthened their ability to better predict and analyze the estuary sedimentation problems and predict downstream and estuary flooding.

PUBLICATIONS

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INDONESIA - PROJECT 3-40: DIVERSIFICATION AND INVENTORY OF THE THREATENED LOWLAND HERPETOFAUNA OF JAVA AND SUMATRA

PI: Nia Kurniawan, Brawijaya University

U.S. Partner: Eric Nelson Smith, University Of Texas At Arlington (Funded By The National Science Foundation)

Dates: November 2014 to April 2017

Project Website: http://nkresearch.ub.ac.id/

PROJECT OVERVIEW

Wildlife harvesting is a global issue, particularly relevant to the herpetofauna of Southeast Asia. The research team aimed to establish baseline population genetic data for lowland reptiles and amphibians in Sumatra and Java prevalent in the wild animal trade. Using molecular techniques, they sought to delimit population boundaries, determine the origin of traded animals, assess the trade's impact on populations, and establish a molecular laboratory at the University of Brawijaya. This facilitated genetic monitoring of wildlife trade and complemented Dr. Eric Smith's inventory of highland herpetofauna by focusing on lowland taxa. The project aimed to inform wildlife management practices and policies, ensuring long-term sustainability.

The project was intended to provide valuable data for selecting and prioritizing harvestable species, creating large DNA reference collections, and public databases of allele frequencies from harvested populations. Indonesian stakeholders, including students, museum technicians, researchers, government officials, and local wildlife traders, benefited from training in fieldwork, museum work, computational and molecular biology, and participation in outreach programs, publications, and scientific presentations.

FINAL SUMMARY OF PROJECT ACTIVITIES

During field research trips to various locations in Java and Sumatra, the team held discussions with traders and local residents about herpetofauna, changing mindsets about killing snakes by explaining their ecological role, handling techniques, and snakebite first aid. Workshops on herpetofauna diversity and sustainable harvest were conducted at senior high schools, reaching hundreds of students and residents. The team presented findings at other universities and two symposiums on Asian vertebrate species diversity.

Two team members traveled to the University of Texas at Arlington to meet the project's U.S. partner, learn new DNA extraction and analysis methods, specimen preservation techniques, anti-venom production, and discuss an ongoing paper.

During the PEER grant period, the PI and colleagues established a new Herpetology course for undergraduates at Brawijaya University and received a $21,000 grant for a related proposal. The team published nine peer-reviewed papers as a result of the grant.

The research team collaborated with various organizations, including Remote Envenomation Consultancy Services, providing data on snake diversity and distribution to assist healthcare providers with snakebite management. Relationships were developed with Museum Zoologicum Bogoriense at the Indonesian Institute of Sciences, the Indonesian Department of Environment and Forestry, Paru Dungus Hospital in Madiun, and Meru Betiri National Park. This project also led to initial planning for a Herpetofauna conservation center at Brawijaya University and increased student interest in herpetology as a thesis topic.

PUBLICATIONS

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Harvey, M.B., O'Connell, K.A., Wostl, E., Riyanto, A., Kurniawan, N., Smith, E.N., & Grismer, L.L. 2016. Redescription Crytodactylus lateralis (Werner) (Squamata: Gekkonidaei) and Phylogeny of the Prehensile-tailed Cyrtodactylus. Zootaxa 4107 (4): 517-540.

Kurniawan, N., Fahmi, M., Priambodo, B. 2015. Phylogenetic relationship of the Genus Limnonectes (Amphibia, Anura) in Sundaland and surrounding areas as revealed by 12s rRNA, tRNA val and 16s rRNA sequence analysis. Proceeding of JSPS-Core-to-Core Program: The 5th International Symposium on Asian Vertebrate Species Diversity. Chulalongkorn University, Bangkok. December 14-19, 2015.

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Sidik, I., Sarker, G., Smith, E.N., Kurniawan, N. 2015. Biogeography and pattern variation of Linnaeus's reed snake Calamaria linnaei Boie, 1827 (Collubridae: Calamarinae), in Java. Proceeding of JSPS Core-to-Core Program: The 5th International Symposium on Asian Vertebrate Species Diversity. Chulalongkorn University, Bangkok. December 14-19, 2015.

Streicher, J.W., Hamidy, A., Harvey, M.B., Anders, B., Shaney, K.J., Kurniawan, N. & Smith, E.N. 2014. Mitochondrial DNA reveals a new species of parachuting frog (Rhacophoridae: Rhacophorus) from Sumatra. Zootaxa 3878 (4): 351-365.

Wostl, E., Sidik, I., Trilaksono, W., Shaney, K.J., Kurniawan, N. & Smith, E.N. 2016. Taxonomic status of the Sumatran Pitviper Trimeresurus (Popeia) toba David, Petri, Vogel & Doria, 2009 (Squamata: Viperidae) and other Sunda Shelf species of the subgenus Popeia. Journal of Herpetology 50(4): 633-641.

INDONESIA - PROJECT 3-21: CLEAN PROJECT: CONVERTING MUNICIPAL SOLID WASTE LEACHATE INTO ENERGY

PI: Wiratni Budhijanto, Universitas Gadjah Mada

U.S. Partner: Largus T. Angenent, Cornell University (Funded by the National Science Foundation)

Dates: October 2014 - April 2018

PROJECT OVERVIEW

In the Bantar Gebang Landfill Site, which handles the municipal solid waste (MSW) from Jakarta, the total emitted volume of MSW was 5000-6000 tons/day, with leachate volume reaching 100-1000 m^3/day. If treated appropriately, the MSW and leachate had the potential to produce 500,000 Nm^3 of biogas per day, equivalent to 200 MWh of electricity per day. Leachate remained one of the largest environmental problems in Indonesian landfill sites, which were closely surrounded by inhabitants. This research project aimed to overcome the leachate problem by transforming the Bantar Gebang Landfill Site into an environmentally friendly renewable energy plant. The energy plant included an anaerobic reactor system that converted MSW to biogas, and the leachate treatment produced additional biogas and fresh inoculums to accelerate the conversion. The long-term goal was converting problematic MSW landfill sites into integrated industries to produce energy and other side products beneficial for the surrounding community.

The project activities included laboratory experiments, mathematical model-based computer simulation, year-long operation of the pilot project, and outreach programs involving graduate students, workshops for stakeholders, and training of junior staff and technicians. Collaboration with the U.S. partner, who provided technical and scientific advice, opened more possibilities for the acceleration of clean energy initiatives in Indonesia. The project developed within a low-carbon energy system framework addressed one of USAID's focus areas in support of low-carbon development in Indonesia. The clean energy research project aimed to minimize leachate emission, which had been hazardous for residents in the surrounding area. Developmental impacts expected from this project included strengthening institutional capacity for implementing Indonesia's clean energy vision, enhancing international collaboration in academic activities, promoting environmental cleanup using appropriate technology at an affordable budget, triggering new industries to produce start-up kits for stabilizing the up-flow anaerobic sludge (UASB) reactor, promoting the establishment of an energy extraction complex, and presenting a method of technology development appropriate for the Indonesian situation, community, and stakeholders.

FINAL SUMMARY OF PROJECT ACTIVITIES

By the time the project ended on April 30, 2018, Dr. Wiratni Budhijanto reported that the pilot plant at the Piyungan Landfill Site, including the aerobic treatment section and the anaerobic fluidized bed reactor, had been operating since September 2017. The treated leachate's pollutant elimination level stabilized around 70-80%, satisfying the site's management.

The PI and her team collaborated with other groups at UGM on a comprehensive monograph about Indonesian municipal solid waste. The book covered various perspectives, including the current waste management situation, regulations, best practices, technology, leachate treatment, economic aspects, and a life cycle analysis. The book was in final editing, and nine peer-reviewed publications resulted from their project work.

Training for undergraduate and graduate students, including five international students and 25 Indonesians, was an important aspect of the project. The PI launched a new bioprocess engineering course and concentration at UGM. Several students who graduated during the project have become faculty members at various universities, extending the project's vision. Some received small grants to continue their research. Even though PEER funding ended, educational efforts continued. In April 2018, the PI applied for a grant from the Indonesian government to conduct a summer course in water sustainability, including wastewater treatment. The request was granted, and the team collaborated with Dr. Samir Kumar Khanal of the University of Hawaii to conduct the course in August, involving 20 Indonesian and 20 U.S. students.

Networking and building linkages with key stakeholders from the government and private sectors were crucial for the project's sustainability. Dr. Wiratni's team organized workshops, focus group sessions, and hosted site visits from industry and government officials. They collaborated with the Indonesian Institute of Sciences (LIPI) and UGM to submit a joint proposal for methane production from bioethanol plant waste in Yogyakarta. The team conducted a feasibility study for methane production from Kramatjati Market's organic waste and explored biogas production with PT. Pertamina. In May 2018, the team was involved in consultancy work with local government for a feasibility study on public-private partnerships in municipal solid waste management, including leachate treatment and biogas production at landfill sites.

A PEER Evidence to Action Supplement awarded in January 2016 allowed Dr. Wiratni and her colleagues to focus on private sector connections, complementing their scientific approach with business coaching and new economic perspectives. They invited industrial practitioners to help find their niche in the industrial community. Through additional workshops, focus groups, and consultations, the PI noted that while scientists cannot be converted into businesspeople, they can learn to present their research results as actual benefits for the private sector. For instance, researchers can conduct feasibility studies on technologies, research the applicability of new technologies, help businesses determine the most appropriate technical options, and develop technologies to fit their needs. Dr. Wiratni emphasized the importance of collaborating with industry from the beginning of the research to ensure the product is in their best interest. The team continued their efforts with follow-on funding secured from non-PEER sources.

A YouTube video on the leachate problem at the Piyungan Landfill Site and the introduction of the CLEAN Column Anaerobic Fluidized Bed Reactor is available at https://www.youtube.com/watch?v=9oPUOXAMJwQ.

INDONESIA - PROJECT 2-457: CITIZEN SCIENCE SOLUTIONS FOR NATIONAL BIODIVERSITY DATA NEEDS: DEVELOPING A PLANT CHECKLIST FOR WEST KALIMANTAN, INDONESIA

PI: I Made Wiryana, Universitas Gunadarma

U.S. Partner: Campbell Webb, Arnold Arboretum of Harvard University (Funded by the National Science Foundation)

Dates: September 2013 - March 2016

PROJECT OVERVIEW

Better data are needed on the plant biodiversity resources of Indonesia, especially given the major land use changes under way in the country. But there are simply not enough professional botanists with the time and funds to visit the many under-collected places in Indonesia. However, there exists a very enthusiastic group of students, park rangers, and professional environmental consultants who frequently travel to the field and make informal observations of plants, which they share via social digital media. During this PEER project, the PI and his team developed a comprehensive digital reference library for these citizen-scientist parataxonomists, including many thousands of plant images, as well as a checklist and training materials to facilitate the accurate identification of plant species and the sharing of observations. A key portion of this project was an intensive training course for 12 parataxonomists in West Kalimantan, an area of very high plant diversity but facing serious biodiversity threats. The course was designed to build rigor in data and metadata collection and share plant knowledge.

Beyond its value in contributing to the management of Indonesia's plants at the provincial level, the project was intended to serve as a data source for several national and international initiatives related to biodiversity, plant conservation, and taxonomy. Including citizen scientists as parataxonomists also helped improve the ability of local communities to manage biodiversity sustainably and equitably, including factors based on local knowledge and wisdom.

FINAL SUMMARY OF PROJECT ACTIVITIES

After completing their two-day initial training course in Pontianak in late January 2014, 12 parataxonomists from different educational and employment backgrounds took part in a series of multi-day field workshops over the following eight months. Equipped with tablets pre-installed with a digital library, digital cameras, and netbooks for image storage and curation, the participants took part in a 15-day expedition to an under-explored area of West Kalimantan, where they put their skills to work, photographing and identifying plants. The data collected were uploaded and integrated into the project platform, and photographs of some plants were matched by technicians at the national herbarium. Although most of the plants encountered were common, as was expected, the teams collected 1,693 plant samples plus associated metadata, as well as more than 20,000 images (50 Gigabytes). The U.S. partner developed metadata structure for the platform. A total of 907 unique species were found, 786 of which were identified as common.

The portal's inventory of specimens provided some learning and reference material to be used by specialists, students, or the general public. The system has automatically incorporated new data into a dynamically generated checklist for identification that is accessible and downloadable in various formats.

Three of the parataxonomists later became trainers themselves as part of a three-day workshop for biology undergraduates at Tanjung Pura University in August 2014. The PEER team also held a week-long workshop in Jakarta in October 2014 for parataxonomists who already had extensive field survey experience throughout Indonesia, as well as a three-day biodiversity training course in March 2015 and other workshops and seminars to share their results and the portal.

The project team has presented the new system to the Municipal Government in Jakarta, which manages the Thousand Islands National Park, as the team plans to deploy a similar system for conducting a biodiversity inventory in Pulau Seribu. They also introduced the use of the platform for Biodiversity Warriors Group from the NGO KEHATI and presented their results to the Ministry of Research Technology and Higher Education. Finally, they have also presented the system to the Ministry of Research Technology and Higher Education as an example relevant to the Ministry's current Science and Technology Information System (SIIN) project.

In terms of human capacity building, this research led to the creation of a new special course on web semantics and the addition of a new research theme to the doctoral degree program in information technology at Gunadarma University. It has resulted in conference proceedings publications (one international, one Indonesian), three Master's theses, and two bachelor's theses.

PUBLICATIONS

Pulu, O. S., Nurjannah, F., & Dwintaputri, K. (2016). Manual Book-Aplikasi Flora-indonesia.id.

Siregar, K. D., Wiryana, I. M., Triono, T., & Webb, C. O. (2015). Flora-Indonesia.id, A Citizen Science Approach for Biodiversity Informatics Portal. In Proceedings of the 5th Uzbekistan-Indonesia International Joint Conference on Globalization, Economic Development, and Nation Character Building.

Nurjannah, F., Dwintaputri, K. D., & Longpradit, P. (2013). Social Network for Citizen Scientist to Support the Development of Wise Management and Policy in Biodiversity. In Proceedings of the 3rd Uzbekistan-Indonesia International Joint Conference on Economic Development and Nation Character Building to Meet the Global Economic Challenges.

INDONESIA - PROJECT 2-409: TREE ISOTOPE RECORDS OF PAST RAINFALL VARIABILITY IN THE INDONESIAN MARITIME REGION

PI: Sri Yudawati Cahyarini with Co-Pi Intan Suci Nurhati, Indonesian Institute of Science (Lembaga Ilmu Pengetahuan Indonesia)
U.S. Partner: Mike Evans, University of Maryland (Funded by the National Science Foundation)
Dates: August 2013 - May 2018

PROJECT OVERVIEW

This project focused on applying techniques for tree isotope analysis to Indonesian trees to generate rainfall records over the past 300 years, with the ultimate goal being to advance scientific understanding of the evolution of the El Niño-Southern Oscillation (ENSO). ENSO modulates monsoonal rainfall variability in Indonesia, causing climate-related disasters. The effects of global warming on ENSO characteristics are still uncertain, and a 300-year high-resolution rainfall record from Indonesia, a region of strong ENSO impacts, is a key to better understanding. The project research also focused on tropical dendroclimatology, as the inference of past rainfall variability via tree-ring widths has been hampered in the region due to indistinct annual growth rings in tropical trees.

This project added to the scientific knowledge base shared by researchers worldwide but also improved the infrastructure at Indonesian institutions and built skills for the project participants. New lab equipment was purchased and installed at the Indonesian Institute of Science (LIPI) to allow the researchers and their students to conduct sample preparation work and basic analysis on the tree samples collected. As a state research institution, LIPI also expanded its outreach activities on tropical dendrochronology during the project.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Cahyarini and her co-PI Dr. Intan Suci Nurhati, formerly of Surya University, worked with counterparts at Mulawarman University in East Kalimantan to organize a capacity building workshop on dendroclimatology, which was held at Mulawarman May 24 to June 2, 2014. One day of lectures and one day of technical training in the university's forest were followed by a week of field work for selected participants to collect tree samples for further tree ring analysis. The goals of the event were (1) to build linkages among Indonesian paleoclimatologists and stakeholders in the local forestry sector to initiate dendroclimate studies at the university and (2) to create interest in paleoclimate studies among forestry undergraduates. As a follow up to this workshop, a Memorandum of Understanding between the Indonesian Institute of Science (LIPI) and Mulawarman University was signed on September 10, 2014, with the aim of facilitating expanded collaboration in educational and research activities. The PI Dr. Cahyarini presented a lecture on the use of trees and corals for paleoclimate studies during the visit. Later that year, they sent some tree core samples to the University of Maryland for chemical analysis, and Dr. Nurhati continued supervising her students as they prepared other samples for analysis.

Although they were hampered by various technical and communications difficulties, the researchers undertook analysis of carbon and oxygen isotopic data from 25 years of ring-dated samples from three replicate increment cores from Muna, Sulawesi, Indonesia. The team sent some tree core samples to the University of Maryland for chemical analysis, and a joint paper on their initial findings was presented at the European Geosciences Union annual meeting in 2018. The researchers also presented their work and results at meetings of the Asia Dendrochronological Association and the Asia Oceania Geosciences Society, as well as the the Small Islands Research in Tropical Regions conference. The PI Dr. Cahyarini has also presented lectures on paleoclimate using geological archives (such as trees, coral, and sediments) at the Department of Oceanography at the Institut Teknologi Bandung. The team also received a new $30,000 grant from the National Geographic Society to support their further research. Their latest paper on their work appeared in 2024.

PUBLICATIONS

Nurhati, I. S., Evans, M. N., Cahyarini, S. Y., D'Arrigo, R. D., Yoshimura, K., & Herho, S. H. S. (2024). $\delta^{18}O$ of marine influenced Tectona grandis L. f. from equatorial Indonesia: A local rainfall amount and remote ENSO indicator. Paleoceanography and Paleoclimatology, 39, e2023PA004758. https://doi.org/10.1029/2023PA004758

Evans, M., Nurhati, I., Cahyarini, S. Y., & D'Arrigo, R. (2018). Pilot study: stable isotopes in teak from marine-influenced equatorial Indonesia as local rainfall amount and remote ENSO indicators. Geophysical Research Abstracts, 20, EGU2018-18659. https://ui.adsabs.harvard.edu/abs/2018EGUGA..2018659E/abstract

INDONESIA - PROJECT 2-324: CONNECTING SCIENCE AND MANAGEMENT THROUGH BIODIVERSITY RESEARCH AND COLLABORATION

PI: Made Pharmawati, Universitas Udayana

U.S. Partners: Forest Rohwer, San Diego State University, and Paul H. Barber, University of California, Los Angeles (Funded by the National Science Foundation)

Dates: August 2013 to March 2018

PROJECT OVERVIEW

Indonesia has almost 80,000 km of coastline surrounded by human development, and almost 50 percent of Indonesia's 240 million inhabitants rely heavily on coastal areas for their food security and livelihoods. Despite an increasing conservation focus throughout Indonesia, coastal environmental degradation is still growing exponentially and fisheries are still not properly managed. Addressing degradation of key coastal habitats and achieving proper fisheries management are essential in reducing pressures on marine ecosystems and threats to coral reef fish. This project focused on coastal seagrass, a coastal ecosystem that receives little attention but provides a critical nursery ground for economically important coastal fisheries, including for humphead wrasse, an extremely valuable reef fish that is being rapidly depleted throughout Indonesia and the Coral Triangle.

Dr. Pharmawati and her colleagues used genetic methods to describe seagrass diversity throughout Indonesia and identify those regions of the country most susceptible to environmental threats, including climate change. The researchers hope this will help marine managers determine which areas need to be prioritized for conservation efforts. The scientists also investigated humphead wrasse fisheries in western Indonesia, supplementing fisheries data with information on habitat community connectivity and parentage analysis. This information is particularly important in assuring that the fisheries activities are sustainable while at the same time assuring a reliable basis for livelihoods in this area. This project sought to build Indonesian research capacity in genetic techniques, both through the project and through training opportunities for the broader Indonesian scientific community by involving more than 10 universities across the country.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers undertook four seagrass monitoring campaigns. The PI and her team conducted the first activity at Dowora Beach, Tidore, Ambon, in collaboration with academic staff from the Faculty of Fisheries and Marine Science at Universitas Khairun, Ternate. The second monitoring campaign was conducted at Serangan Beach, Bali, with students from the Biology Department of Udayana University. Students learned about seagrass species, identification, and function as well as seagrass monitoring techniques. Additional field research campaigns took place in Kondang Merak Beach and Waru-waru Beach, in Malang, East Java, as well as at Alor Island.

Among their findings was a low diversity of seagrass at Kondang Merak Beach, with only a single species, Syringodium isoetiolium, and Waru Waru Beach, with two species identified, Halodule uninervis and Halophila ovalis. At Deere Beach on Alor, the diversity of seagrass was higher with coverage areas reaching 100%. The researchers identified five species: Enhalus acoroides, Syringodium isoetifolilum, Cymodocea rotundata, Cumodocea serrulata, and Halodule uninervis. In Tidore, researchers found six seagrass species, and eight species at Serangan Beach in Bali. The team also worked to analyze DNA sequence data of Enhalus acoroides from the Lesser Sunda region (Bali, Lombok, Flores, Kupang) and eastern Indonesia. The PI published the results in an academic article and presented the findings at an international conference on global resource conservation.

During the PEER project, the team conducted workshops on seagrass for high school and university students in Bali. About 40 high school students and 60 university students learned to identify seagrass species and conduct seagrass population monitoring. The PEER group also offered a DNA extraction and RAPD analysis workshop to students and staff of partner universities, and they revised the content of undergraduate and graduate courses at Udayana University, including incorporating a special lecture of plant DNA analysis. As a result of the project, the team received a $7,000 grant from the Indonesian Ministry of Research, Technology and Higher Education to conduct a related study on genetic and environmental aspects of production of tocopherol (Vitamin E) from Enhalus acoroides.

PUBLICATIONS

Putra, I. N. G., Syamsuni, Y. F., Subhan, B., Pharmawati, M., & Madduppa, H. (2018). Strong genetic differentiation in tropical seagrass Enhalus acoroides (Hydrocharitaceae) at the Indo-Malay Archipelago revealed by microsatellite DNA. PeerJ, 6, e4315. http://dx.doi.org/10.7717/peerj.4315

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Pharmawati, M., Nurkamila, U. S., & Stevanus. (2016). Short Communication: RAPD fingerprinting key and phylogenetic of nine seagrass species from Sanur coastal water, Bali, Indonesia using matK sequences. Biodiversitas, 17(2), 687-693. https://doi.org/10.13057/biodiv/d170243

Pharmawati, M., & Imaniar, E. F. (2016). PCR-RFLP and sequencing of trn S/trn fM fragment of Enhalus acoroides from Sanur coastal waters, Bali, Indonesia: A preliminary study. The Journal of Tropical Life Science, 6(2), 118-122. https://doi.org/10.11594/jtls.06.02.10

Pharmawati, M., Putra, I. N. G., Syamsuni, Y. F., & Mahardika, I. G. N. K. (2015). Genetic diversity of Enhalus acoroides (L.) Royle from coastal waters of Pramuka Island, Lembongan Island, and Waigeo Island, Indonesia, based on microsatellite DNA. Advanced Science Letters, 21, 199–202. https://doi.org/10.1166/asl.2015.5861

Kurnia, M., Pharmawati, M., & Yusup, D. S. (2015). Jenis-jenis lamun di Pantai Lembongan, Nusa Lambongan dan analisisnya dengan PCR ruas rbcL [Seagrass species at Lambongan Beach, Nusa Lembongan and their analysis using PCR of rbcL fragment] [in Bahasa]. Jurnal Simbiosis, III(1), 330-333.

INDONESIA - PROJECT 2-319: COMBATING SEAGRASS DECLINE: DEVELOPING A RESTORATION MANUAL FOR INDONESIA AND THE CORAL TRIANGLE

PI: Rohani Ambo-Rappe, Universitas Hasanuddin
U.S. Partners: John J. Stachowicz and Susan L. Williams, University of California, Davis
(Funded by the National Science Foundation)
Dates: September 2013 - January 2017

PROJECT OVERVIEW

Seagrasses are marine flowering plants forming large, undersea meadows that stabilize shorelines, link habitats, and trap atmospheric carbon dioxide. However, seagrass meadows are declining rapidly. Indonesia, a hot spot for global seagrass diversity, lacks sufficient research and documentation. This PEER project aimed to advance ecological understanding of seagrass restoration to reverse damage and loss of ecosystem functions, such as food provision, habitat, and nursery areas for diverse marine organisms, including commercially valuable or endangered species like sea cucumbers, snappers, groupers, dugongs, and sea turtles. Dr. Rohani Ambo-Rappe and her team created a pilot seagrass restoration project by transplanting different combinations of seagrass species to determine the best combinations for growth, persistence, and the diversity and abundance of associated animals. They also measured the performance of commercially valuable sea cucumber juveniles in different seagrass mixtures.

This research was the first to address the role of different seagrass species in restoration within the Coral Triangle. The gained knowledge guided restoration practices and provided new data on the relationship between species diversity and ecosystem function.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Ambo-Rappe and her team developed seagrass transplantation experimental plots at two project sites in Pulau Badi and Barranglompo. They collected data on different conditions for cultivating seagrass plants and the effect of macroalgae coverage on natural and transplanted seagrass beds. The researchers regularly monitored the plots monthly, recording data on survival rate, density, and coverage from each treatment, as well as water quality measurements (light, pH, dissolved oxygen, temperature, salinity, and water current). Results showed a positive relationship between seagrass species richness and the survivorship and coverage change of seagrass transplants. Seagrass cover increased only when at least four species were planted together, with better results at five species. Halodule uninervis showed the highest survivorship and fastest expansion rate, suggesting a mixed-species approach holds promise for enhanced restoration in the Indo-Pacific.

The team also conducted experiments on seeding seagrass in different substrates, the density of plants providing protection for seedlings, and the effect of macroalgae coverage. They organized a twice-yearly Marine Debris Census, training students to collect, identify, group, and measure debris. Data from the census were used to produce a manuscript comparing debris between Indonesia and the United States. Two stakeholder workshops were held on the importance of seagrass to marine life and the threats they face in Indonesia.

The project contributed to the research of three Master's degree students and helped create a new Master's program in Integrated Coastal Resources Management. The researchers received two smaller grants, totaling about $20,000, from the Directorate of Higher Degree of Indonesia to continue their work, and they presented their results at two international conferences. Dr. Ambo-Rappe also communicated with staff from the Indonesian National Conservation Agency for Sea and Coastal Areas, which showed interest in implementing the seagrass restoration method developed under her project. After the PEER project ended, she planned to develop an action document to guide this collaboration with the agency.

PUBLICATIONS

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Asriani, N., Ambo-Rappe, R., Lanuru, M., & Williams, S. L. (2018). Botanica Marina, 61(3), 205-211. https://doi.org/10.1515/bot-2017-0127

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Sur, C., Abbott, J. M., Ambo-Rappe, R., Asriani, N., Hameed, S. O., Jellison, B. M., Lestari, H. A., Limbong, S. R., Mandasari, M., Ng, G., Satterthwaite, E. V., Syahid, S., Trockel, D., Umar, W., & Williams, S. L. (2018). Marine debris on small islands: Insights from an educational outreach program in the Spermonde Archipelago, Indonesia. Frontiers in Marine Science, 5, 35. https://doi.org/10.3389/fmars.2018.00035

Williams, S. L., Ambo-Rappe, R., Sur, C., & Limbong, S. R. (2017). Species richness accelerates marine ecosystem restoration in the Coral Triangle. Proceedings of the National Academy of Sciences, 114(45), 11986-11991. https://doi.org/10.1073/pnas.1707962114

Tasabaramo, I. A., Kawaroe, M., & Ambo-Rappe, R. (2015). Laju pertumbuhan, penutupan, dan tingkat kelangsungan hidup Enhalus acoroides yang ditransplantasi secara monospesies dan multispesies [Growth rate, cover, and survival rate (Enhalus acoroides) transplanted in monospecies and multispecies]. Jurnal Ilmu dan Teknologi Kelautan Tropis, 7(2), 757-770. https://doi.org/10.28930/jitkt.v7i2.11169

Williams, S. L., Abbott, J., Ha, G., & Ambo-Rappe, R. (2014). Juvenile batfish hidden in seagrass. Coral Reefs, 33, 909. https://doi.org/10.1007/s00338-014-1194-6

INDONESIA - PROJECT 2-232: EXPLORING THE DYNAMIC OF EXTREME WEATHER EVENTS IN INDONESIA USING LARGE SCALE METEOROLOGICAL PATTERN AS THE FORECAST GUIDANCE (PILOT STUDY: INDRAMAYU, WEST JAVA)

PI: Heri Kuswanto, Institut Teknologi Sepuluh Nopember

U.S. Partner: Richard Grotjahn, University of California, Davis (Funded by the National Science Foundation)

Dates: August 2013 - January 2016

PROJECT OVERVIEW

Extreme Weather Events (EWEs) cause negative impacts socially, economically, and environmentally, as well as influence planning and management decisions by utilities and governments. Indonesia has been identified as being among the countries most vulnerable to the risk of natural disasters, such as floods, heat waves, and droughts. Considering these facts, forecasting EWEs is crucial work. This PEER project focused on heavy rain and heat waves, two dominant EWEs for countries like Indonesia, examining EWEs in Indonesia's Indramayu District as a pilot study. In particular, the project developed a supporting tool for forecasting EWEs based on the corresponding large-scale meteorological pattern (LSMP). The previously used forecast model often misses local details of the tropical meteorological climate system, which reduces forecast reliability. LSMPs are composite weather maps linked to each type of EWE. Finding and using such LSMP maps has improved the reliability of EWEs forecast in the United States.

The PI Dr. Kuswanto and his team collaborated with the Meteorology, Climatology, and Geophysics Agency (BMKG) Indonesia, an institution with official authority to set policy regarding EWEs. The main outcome of this project was composite maps and a technical report which can be used by BMKG Indonesia to predict extreme events. BMKG plans to apply these maps as part of their early warning systems to predict extreme weather events. The maps were intended to be useful for other stakeholders, including the National Agency for Disaster Management (BNPB) and Ministry of Agriculture.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Kuswanto and his group investigated data availability for several sites across Java Island, confirming their findings with BMKG. They decided to first develop composite maps for extreme high temperatures in Surabaya, identifying the thresholds in temperature and duration. A temperature exceeding 36.2 degrees Celsius for more than 3 days has a significant impact on society, and it is also a preliminary indication of a drought event. The researchers performed statistical tests on their sample and developed computer code to build the maps, analyzing their work as they went. Team members presented their results at a variety of events, including Global Engineer Asia 2015, Euro-Asia Civil Engineering Forum (EACEF) and a workshop of climate change and disaster organized by Research Center for Earth, Disaster and Climate Change at ITS. The researchers installed and are maintaining a rain gauge to generate a time series dataset to support future studies.

The PEER team also organized a “Young Forecaster” workshop, to increase students’ interest in working as weather forecasters and provide them with knowledge about extreme weather events. The team received more applications for the workshop than there were spots, so they opened it up to an additional 10 students. Workshop participants attended a class as well as laboratory sessions. Several participants joined the team’s Extreme Weather and Climate Research (Extreme WeCaRe) Group. This group, developed during the PEER project, is for young and early career researchers in Indonesia interested in multiple aspects of extreme weather and climate. Under this research group, two new related research projects have received grants, and the PI Dr. Kuswanto also went on to win a second PEER award in Cycle 5 (2016-2020). PEER project support was also key in helping several students involved in the research finish their theses for Master’s and Bachelor’s programs.

The team wrote and delivered a technical report to BMKG as their key project deliverable. It consists of a detailed procedure for developing composite maps. The researchers expect that BMKG forecasters will be easily able to replicate the procedure to develop similar maps for other regions in Indonesia, and they are also developing a mentoring program with BMKG researchers to support ongoing efforts on map development and validation.

PUBLICATIONS

Kuswanto, H., Andari, S., & Permatasari, E. O. (2015). Identification of extreme events in climate data from multiple sites. Procedia Engineering, 125, 304-310. https://doi.org/10.1016/j.proeng.2015.11.067

Kuswanto, H., Andari, S., Permatasari, E. O., Ferawati, K., Armanda, N. N., Supriyanto, E., & Hidayati, S. (2015). Laporan Teknis: Peta Komposit (Composite Maps) untuk prediksi hujan ekstrim di Indramayu, Jawa Barat [Technical Report: Composite Maps for predicting extreme rain in Indramayu, West Java].

INDONESIA - PROJECT 2-42: IMPROVING PROCESS-SKILLS OF STEM UNDERGRADUATE STUDENTS IN INDONESIA THROUGH PROBLEM-BASED LEARNING (PBL): FACULTY MEMBER DEVELOPMENT, STUDENT ASSESSMENT, AND CURRICULUM ADJUSTMENT

PI: Kamarza Mulia, Universitas Indonesia

U.S. Partner: Lisa Hunter, University of California, Santa Cruz (Funded by the National Science Foundation)

Dates: August 2013 - August 2016

PROJECT WEBSITE: https://pblkamarzaelsa.wordpress.com/

PROJECT OVERVIEW

This PEER project assessed the effectiveness of problem-based learning (PBL) in improving the process skills of chemical engineering students at Universitas Indonesia (ChE UI) while satisfying curriculum requirements. Skills assessed included problem solving, working in groups, lifetime learning, and critical thinking. The project also provided training to more than 1,100 university faculty members from throughout Indonesia over three years, by extension affecting thousands more of their students and making it possible to carry out longitudinal assessment studies of PBL effectiveness in improving students' process skills. The main objective of the project was a paradigm shift of STEM faculty members from teacher-centered to student-centered learning (SCL), PBL in particular.

FINAL SUMMARY OF PROJECT ACTIVITIES

Invitations were sent to faculty members of selected campuses throughout Indonesia to attend an introductory workshop on SCL and PBL. In the workshops, participants discussed the SCL paradigm in teaching and learning, process skills required for a successful PBL implementation, and ways of converting a lecture-based course into the PBL format. Participants with strong motivation to implement PBL were invited to attend a facilitator workshop consisting of more practical topics such as how to conduct mini process skill workshops for students and PBL problems or case studies. These participants were then invited to apply for teaching grants and continuing support from the project leaders, and if necessary, a visit to their institutions, and eight were selected for this honor.

In total, the PEER team conducted 29 workshops attended by 1,173 faculty members from higher institutions across Indonesia (far more than the originally planned 6 workshops for 200 participants). In general, workshop participants responded well to the workshops, as indicated by their responses to some key questions in the post-event evaluation survey. Most had not learned the workshop materials previously (86%), and almost all (97%) were inspired and motivated to continue developing student-centered learning methods such as PBL. The survey also found that 81 workshop participants switched courses they teach over to a PBL model, three times as much as the target of 25 stated in the original grant proposal. The project is particularly relevant since the Ministry of Research and Higher Education requires Indonesian universities to implement more student-centered teaching-learning methods such as PBL.

To help their workshop participants in their ongoing teaching activities, the PEER team created several PBL implementation resources, most of which are available on the website https://pblkamarzaelsa.wordpress.com/. The website features articles on PBL and the implementation of this student-centered teaching-learning method, trigger problems, and links to relevant sites including an online discussion board and Yahoo group.

In addition to offering the capacity building workshops, the PI and co-PI also worked with their colleagues at ChE-UA to integrate skills development modules into eleven PBL-based courses spread over the curriculum, to facilitate improvement of process skills of students in all the study programs (chemical engineering—regular program, chemical engineering—international program, and bioprocess engineering), while learning fundamentals in their chosen disciplines. These process skills improvement modules include teaching-learning and assessment activities linked to specific intended learning outcomes of the courses. During the project, the modules were implemented in courses involving more than 900 ChE-UI students from the incoming classes in the years 2010-2015.

PEER funds also supported the creation of a specially designed PBL classroom at the Faculty of Engineering - Universitas Indonesia in July 2015. The room accommodates 80 students learning in a group setting (PBL mode), equivalent 100 students in the lecture format. The renovation included 80 new chairs, two new projectors (one wireless), a new document camera, 15 new computer monitors for group discussion, a new motorized screen, and a new sound system. This classroom features a flexible seating arrangement conducive to small-group discussion, and each group has access to a computer monitor with a high-speed Internet access. The popular new classroom has a very high occupancy rate and is used by all teaching staff in the UI Faculty of Engineering.

PUBLICATIONS

Krisanti, E., & Mulia, K. (2016). Penerapan Metode Problem-Based Learning (PBL) [Application of the Problem-Based Learning (PBL) Method]. Leutikaprio. ISBN: 978-602-371-264-9.

Mulia, K., & Krisanti, E. (2014). Communication skills course: Enhancing presentation and proposal writing skills of chemical engineering students. In Proceedings of the 121st ASEE Conference, Indianapolis, June 15-18, 2014.

INDONESIA - PROJECT 1-235: CORAL HEALTH SURVEYS IN COREMAP: BUILDING RESILIENCE IN CLIMATE-IMPACTED CORAL REEFS OF INDONESIA

PI: Jamaluddin Jompa, Universitas Hasanuddin

U.S. Partner: C. Drew Harvell, Cornell University (Funded by the National Science Foundation)

Dates: June 2012 - April 2015

PROJECT OVERVIEW

Marine protected areas (no-fish reserves) are the primary mechanism to preserve coral-reef ecosystems and the ecosystem services they provide to coastal communities. However, the ability for marine protected areas to reduce one of the most detrimental impacts to coral reefs, coral disease, is unknown. Coral diseases are often related to colony density and therefore may be more common in protected areas that have high coral cover. Reduced fishing practices within protected areas leads to a more functionally diverse fish community. Herbivorous fishes may reduce algal cover, a potential vector for coral disease transmission, while piscivorous fishes may reduce the populations of corallivores that may spread diseases to corals. This project aims to test the hypothesis that marine protected areas will improve resilience of coral communities and, in particular, reduce the prevalence of coral disease.

Since it began in 1998, the Indonesian Coral Reef Rehabilitation and Management Program (COREMAP), has created different marine protected areas within the country. COREMAP is a long-term program aimed at protecting, rehabilitating, and achieving sustainable use of the Indonesian coral reefs. COREMAP's efforts include training for scientists to properly identify coral diseases.

The PEER-supported project surveyed three locations within selected COREMAP protected areas as well as adjacent unprotected areas that are ecologically similar to its paired site. Each site was surveyed using a nested approach to account for spatial variations and differences in depth profile. By bringing the complementary skills and expertise of the Indonesian and U.S. researchers to bear, this project evaluated the impact of coral diseases throughout Indonesia, the most coral-diverse region in the world, and helped quantify the efficacy of marine protected areas in reducing coral disease outbreaks.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI and his team conducted coral disease survey work, including sample collection (mucus) and water quality sampling off Badi, Bonetambung, and Barranglompo Islands; turf algae growth rate monitoring in the Spermonde Archipelago; and surveys of coral diseases and coral cover at Mentawai Sumatra. The research team produced two videos highlighting their project and its impacts. One video is intended for general audiences and the other includes additional lecture footage appropriate for students. Findings and photographs from their research have been included in the materials of several courses such as Coralogy, Microbiology, and Marine at the Faculty of Marine Science and Fisheries.

The PEER grantees created the Coral Diseases Working Group (CDWG), established to exchange ideas and distribute information with all scientists who have interest or experiences on coral diseases. During the PEER project, researchers met with USAID staff and took them to the field to witness the coral diseases under water. They also presented the results to governmental and community groups at workshops and have communicated with the tourism industry in Bali to encourage them to avoid further degradation of coral reefs around the island, which is one of the most important destinations for international tourists.

Leaflets and posters on coral diseases and actions to prevent them were distributed to COREMAP sites nationwide, and the PEER researchers presented their results at conferences, including the Annual Meeting of Indonesian Association of Oceanologists, World Coral Reef Conference, and the National Symposium on Marine Science and Fisheries.

PUBLICATIONS

Rahmi, B. Hamdani, Arniati, and J. Jompa. 2014. Identifikasi Penyakit pada Karang Keras (Scleractinia) di Pulau Barrang Lompo. Edt. Kartono D.T.,Surata, S.P.K., Arnawa, K.
Prosiding SEMNAS 2014 Hasil-Hasil Penelitian. UNMAS Press. ISBN 978-602-18622-4-7.483-489p.

Erinn M. Muller, Laurie J. Raymondo, Bette L. Willis, Jessica Haapkyla, Syafyudin Yusuf, Joanne R. Wilson, Drew C. Harvell. 2012. Coral Health and Diseases in Spermonde Archipelago and Wakatobi, Sulawesi. Journal of Indonesia Coral Reefs 1(3): 147-159.

USAID blog post, August 19, 2013

Article on the project published by the New York Times, January 29, 2013

INDONESIA - PROJECT 1-208: ASSESSING DEGRADATION OF TROPICAL PEAT DOMES AND DISSOLVED ORGANIC CARBON (DOC) EXPORT FROM THE BELAIT, MEMPAWAH, AND LOWER KAPUAS RIVERS IN BORNEO

PI: Gusti Z. Anshari, Universitas Tanjungpura

U.S. Partner: Charles F. Harvey, Massachusetts Institute of Technology (Funded by the National Science Foundation)

Dates: June 2012 - April 2016

PROJECT OVERVIEW

The tropical peatlands of Borneo and the rivers that flow through these landscapes are important for supplying natural goods, maintaining livelihoods, conserving biodiversity, and affecting climate. Peat forests and associated rivers provide timber, freshwater fish, and other natural products. Because tropical peats are only stable under water-logged environments, the climate must be sufficiently wet for peat to accumulate. Biodiversity also flourishes under a wet climate. Therefore, there is a strong link among the sustainability of livelihoods, biodiversity, and climate stability. Increasing uses and disturbances of these peat forests and rivers induce degradation of tropical peat domes (including drainage), leading to an increase in carbon dioxide emissions through the atmosphere and lateral export through rivers to the ocean. As a result, peat degradation not only depletes natural resources but also affects climate stability.

This project aimed to link lateral carbon exports by rivers to the characterization of peat degradation from satellite data and field measurements. The researchers contrasted rivers in North and South Borneo (i.e., the Belait River in Brunei Darussalam and the Mempawah and the Lower Kapuas Kecil River in West Kalimantan Province, Indonesia). Outputs of this joint research project included thematic maps of peat dome degradation and DOC fluxes from the studied rivers. Although recognized as important, the fluvial export of carbon from tropical peatlands had rarely been assessed. In this project, sensors were developed to evaluate DOC fluxes from these rivers to the South China Sea, providing the first accurate measurement of fluvial carbon fluxes from tropical peatlands. The project also aimed to increase awareness and knowledge of tropical peatlands, their role, and the impact of their degradation. For this purpose, a reference book and extension materials were developed and disseminated in both English and Bahasa Indonesia. A multi-stakeholder workshop on the relationship between tropical peatlands and climate change was organized, and a website on climates and tropical peatlands was constructed.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team's field activities included gathering water and peat samples in situ, measuring peat depth, pH, and conductivity of water in the target rivers. Thanks to PEER funding, they were also able to acquire a portable gas analyzer to measure CO2 emissions from peat soils, as well as other gases. Multiple graduate and undergraduate students have developed their ongoing research and completed their theses during this project as part of their studies. One of the researchers on the team, Dr. Evi Gusmayanti, was awarded an additional research grant from the Indonesian Ministry of Research, Technology and Higher Education to continue and expand her study of carbon flux from oil palm on peats, a three-year project that involved undergraduates and one research assistant. During the PEER project, Dr. Anshari and his colleagues also developed and introduced a new course on peatland ecosystems and conversation, designed to introduce students to local and global perspectives on how to manage tropical peatlands and give them hands-on research experience.

Dr. Anshari and other team members presented their findings to the American Geophysical Union Joint Assembly conference, a seminar on tropical peatlands at the Oregon State University, and a local conference in Indonesia. The team also communicated results of the PEER findings to NGOs and governments, in particular on peat distribution and peat properties in West Kalimantan Province to Badan Restorasi Gambut (Peatland Restoration Agency), allowing the institution to generate a map for a peat restoration program. The researchers also conducted peat training for two companies that operate oil palm plantations, PT Agrolestari Mandiri, and PT Paramita Internusa Pratama.

PUBLICATIONS

Anshari, G. Z., Gusmayanti, E., Afifudin, M., Ruwaimana, M., Hendricks, L., & Gavin, D. G. (2022). Carbon loss from a deforested and drained tropical peatland over four years as assessed from peat stratigraphy. Catena, 208, 105719. https://doi.org/10.1016/j.catena.2021.105719

Putri, T. T. A., Syaufina, L., & Anshari, G. (2016). Emisi Karbon Dioksida (CO2) Rizosfer dan Non Rizosfer dari Perkebunan Kelapa Sawit (Elaeis guineensis) pada Lahan Gambut Dangkal [Rhizospheric and Non-rhizospheric Carbon Dioxide (CO2) Emissions from Oil Palm (Elaeis guineensis) Plantation on Shallow Peat]. Jurnal Tanah dan Iklim, 40(1), 43-50.

Nuriman, M., Djajakirana, G., Darmawan, & Anshari, G. Z. (2015). Metode Alternatif Memperkirakan Konsentrasi Karbon Organik Terlarut dalam Air Saluran Drainase dan Tanah Gambut [An Alternative Method for Estimating Dissolved Organic Carbon (DOC) Concentration in Drainage Canal and Peat Pore Water]. Jurnal Tanah dan Iklim, 39(1), 1-8.

Gusmayanti, E., Anshari, G. Z., & Afifudin, M. (2014). Estimasi stok dan emisi karbon serta strategi penggunaan lahan dalam mitigasi perubahan iklim di kubah gambut Rasau Jaya, Kalimantan Barat [Estimation of carbon stock and emission, and land-use strategy for climate change mitigation in Rasau Jaya Peatdome, West Kalimantan]. Presented at the Seminar Nasional dan Rapat Tahunan Bidang MIPA 2014 | SEMIRATA.

INDONESIA - PROJECT 1-205: MARINE BIODIVERSITY OF RAJA AMPAT ISLANDS: THE ARMS, MORPHOLOGY, AND GENETIC APPROACHES FOR INVENTORYING AND MONITORING PATTERNS OF MARINE BIODIVERSITY

PI: Abdul-Hamid Toha, State University Of Papua

U.S. Partner: Kent Carpenter, Old Dominion University (Funded by the National Science Foundation)

Dates: June 2012 - November 2016

PROJECT OVERVIEW

Raja Ampat, a remote Indonesian archipelago of small islands and cays off New Guinea, has gained international scientific attention due to its high marine biodiversity and the discovery of multiple new species of corals and fish. The high levels of marine biodiversity in this region are an important part of Indonesia's natural heritage and global biodiversity. However, our understanding of the processes responsible for shaping biodiversity patterns in this region are still lacking. Dr. Toha and his fellow researchers on this project aimed to describe the richness, study the status, and explain the spatial and temporal patterns in the biodiversity of Raja Ampat. Interest in these goals has gained momentum due to escalating anthropogenic impacts and the need to conserve resources in important hotspots of endemic species.

This study employed a novel tool, Automated Reef Monitoring Structures (ARMS), to monitor marine biodiversity gradients across the Raja Ampat Islands in a standardized, highly efficient, and statistically robust way. Researched undertook analyses based on DNA barcoding and metagenomics to show whether visual surveys of conspicuous groups like fish and corals (the subjects of traditional surveys) can reliably capture biodiversity patterns for the inconspicuous groups (smaller invertebrates, algae, and microbes) that actually comprise the vast majority of marine biodiversity. They also sought to understand whether marine biodiversity varies predictably as a function of conservation management strategy (e.g., Marine Protected Areas).

The goal of the project was to improve our understanding of the contemporary processes shaping the distribution of marine biodiversity in the Raja Ampat, providing a scientific foundation to support the sustainability goals of Papua and Indonesia in general. The study built on strong partnerships with UCLA developed as part of a previous National Science Foundation (NSF) Partnerships for International Research and Education (PIRE) award.

FINAL SUMMARY OF PROJECT ACTIVITIES

Researchers deployed 48 ARMS, collecting more than 200 individuals of 63 invertebrate species and published data on these specimens on their website. The PEER team presented their work at national and international conferences, published regular newsletters to share results, and have published more than 20 academic papers and a book, Diversity and Conservation of Sea Urchin.

The PI and his colleagues presented a workshop entitled Genetic Analysis and Bioinformatics for the research group on marine resource exploration and management of fisheries and marine sciences of Brawijaya University. They also held several training sessions on genetic data analysis for PhD students from Brawijaya and the State University of Malang, provided training in proposal writing for high school students to apply to the Indonesian Institute of Sciences, and shared their results with all lecturers within the University of Papua.

The PEER project supported students' thesis research and the PI's lab hosted undergraduates and fishery students to study laboratory work practices and genetic approaches. Indonesia's State Ministry of Research and Technology awarded the PEER team an additional research grant to continue their work. The researchers are also part of a consortium that won a new NSF PIRE award to continue collaborative biodiversity research across Indonesia.

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PUBLICATIONS

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INDONESIA - PROJECT 1-152: ENHANCEMENTS OF RESEARCH FOR ADAPTATION OF WETLANDS IN INDONESIA TO PROJECTED IMPACTS OF SEA LEVEL RISE

PI: Frida Sidik, Institute for Marine Research and Observation, Ministry of Marine Affairs and Fisheries

U.S. Partner: Ilka Feller, Smithsonian Institution

Dates: August 2018 - August 2019

PROJECT OVERVIEW

Mangroves are key ecosystems for protecting the coasts and fishery resources in Indonesia, serving as a primary coastal barrier important for adapting to sea level rise. Despite Indonesia having the world's largest areas of mangroves, understanding of mangrove responses to sea level rise in this region is lacking. This project aimed to establish a greater understanding of wetland adaptation to sea level rise in Indonesia and to improve the capacity of Indonesian researchers in monitoring coastal systems.

Dr. Sidik and her team established a mangrove monitoring station to gather information on wetland stability, aiming to serve as a model for similar marine monitoring sites in other parts of Indonesia. The project involved data collection and model development to increase knowledge of how mangrove wetlands will respond to sea level changes and promoted training and technical expertise development for Indonesian researchers. At the completion of the initial PEER grant, the team was awarded an Evidence to Action (EtoA) supplement to produce guidelines on mangrove adaptation to sea level rise and distribute their results to relevant stakeholders.

FINAL SUMMARY OF PROJECT ACTIVITIES

These researchers established a mangrove monitoring station in Bali and collected data for two years, studying wetland vulnerability to sea level rise and the capacity of mangroves to store carbon. They established a regional mangrove network with universities in five other countries (the United States, Australia, Singapore, Malaysia, and the Philippines) that used the same protocol for monitoring mangrove adaptation to sea level rise.

The PI and her colleagues published two papers on mangrove carbon sequestration and sedimentation and mangrove growth rates, based on data collection undertaken as part of the PEER project. They also presented their results at several scientific meetings, both within Indonesia and internationally. The team made two videos about mangroves and sea level rise, one aimed at a general audience and one for researchers, academics, and stakeholders. They published a book of guidelines for creating a mangrove monitoring station, including a research summary of their work, and an illustrated guide to the Perancak Estuary in Bali.

During the project period, the team held a collaborative program to build mangrove research capacity, attended by 20 Indonesian researchers and academics from governmental institutions, NGOs, and universities. This event, part of their Evidence to Action Supplement, aimed to build awareness among policymakers and coastal managers regarding the importance of mangroves for mitigating and adapting to climate change.

The team convened other workshops and discussions to build the capacity of researchers, practitioners, and academics on mangrove research and monitoring. The PI delivered lectures on mangroves and sea level rise to marine science students at Udayana University (Bali), Gadjah Mada University (Yogyakarta), and Brawijaya University (Malang). Another team member presented on mangrove remote sensing, exposing academics to new techniques for mangrove monitoring.

To engage the local community in protecting and valuing the mangrove ecosystem, Dr. Sidik and her team held a mangrove product training workshop in partnership with a local entrepreneur and the Mangrove Institute, highlighting the sustainable use of mangrove products for food and handicrafts (batik). This workshop helped identify alternative conservation activities that align with the PEER research. The grantees held a small group discussion on their results and recommendations with national policymakers focused on planning and climate adaptation, paired with a site visit to the mangrove monitoring station. They also consulted with community organizations, Clungup Mangrove Conservation, Demang Gedi Mangrove Conservation, and the Mangrove Institute for supporting information for their mangrove-related videos and policy recommendations. The team created a final working paper from this series of workshops.

Another outreach strategy involved using Instagram as a knowledge hub to provide mangrove-related information and activity updates. The PI and her team organized a Mangrove Vlog Competition for high school students in Jembrana Regency, Bali. This activity aimed to gain followers for the Instagram hub and increase students' awareness regarding mangrove conservation. All videos were uploaded to the team's Instagram account "MangroveNet Bali," attracting more than 1,000 people who voted for their favorite video.

The team and PI have been invited to be part of several international and national research proposals to further build knowledge around mangrove conservation and climate change adaptation.

PUBLICATIONS

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INDONESIA - PROJECT 1-102: BUILDING INDONESIAN RESEARCH CAPACITY THROUGH GENETIC ASSESSMENT OF COMMERCIAL FISH SPECIES

PI: I Gusti Ngurah Kade Mahardika, Universitas Udayana
U.S. Partner: Kent Carpenter, Old Dominion University (Funded by the National Science Foundation)
Dates: June 2012 - December 2014

PROJECT OVERVIEW

The Coral Triangle is a region of Southeast Asia defined by the presence of 500 or more coral species. This region is the global epicenter of marine biodiversity, and its importance as an economic and natural resource for the six Coral Triangle countries resulted in the 2009 Coral Triangle Initiative, which is aimed at responding to the increasing natural stresses and overexploitation of marine environments in the region. Of particular concern is the intensifying pressure on two key Indonesian fisheries, namely tuna and shark.

Realizing the importance of subsistence tuna fishing in Indonesia and the high value of tuna exports, the Indonesian government initiated conservation efforts in 2000 in cooperation with various worldwide tuna commissions, which presently regulate tuna as single fishery stock. However, recent genetic data suggests that there are multiple tuna stocks within the Indian Ocean alone. Managing tuna as a single stock fishery when there are multiple distinct subpopulations could result in inappropriate conservation planning, resulting in ineffective management actions that could result in depleted tuna stocks in the future. In addition to tuna, Indonesia has also been an area of intense shark fishing, which is driven by high demand for shark fins in markets of Hong Kong and China. As of the project start date in 2012, there were no Indonesia-wide management policies to promote shark conservation. One major obstacle was the lack of reliable data on the current status of Indonesian shark fisheries. Obtaining these data is especially challenging because most body parts by which species identification can be made have been removed at the time of landing. However, DNA barcoding can identify samples to species based only on a tissue sample, offering an alternative way to identify sharks.

This project studied genetic differentiation in Big Eye Tuna (Thunnus obesus) populations across Indonesia to test whether there are different stocks requiring separate management plans, with the aim of influencing how tuna resources are managed by different tuna commissions. In addition, the researchers sampled shark fins from fishmongers across Indonesia to determine species identity via barcoding, providing detailed shark catch data. The broader aim of the project was to build Indonesian research capacity in performing genetics research.

FINAL SUMMARY OF PROJECT ACTIVITIES

The publication of the research's team investigation into shark genetics has brought insight into what species are still targeted by fishermen and what provinces are the major areas for shark fisheries, as well as their conservation status. The team built a long-lasting collaboration with major institutions working in tuna conservation, including LOKA TUNA Indonesia (LTI) and Yayasan Masyarakat dan Perikanan Tuna Indonesia (YMDPI). LTI has agreed to extend an existing memorandum of understanding with the PI's Mahardika's center for another two years to focus more on studying population genetics of Southern Pacific Bluefin Tuna.

The PEER grantee team successfully organized summer courses at Karimunjawa National Park, Jepara, Central Java. focused on studying marine decapod biodiversity. Students were exposed to dead coral head methods, a rapid and reliable means of sample collection, participated in fieldwork, and took part in an intensive one-week molecular ecology class complete with lab work experience.

Seven workshops led by the researchers included research methods that could provide quick estimates of unseen biodiversity in a coral reef ecosystem and were successful in promoting phylogenetic science to wider research networks in Indonesia. The IBRC has also successfully assisted more than a dozen undergraduate students to complete internships in various research projects and provided advanced training opportunities (including in the United States) for three Master's students.

Through its Ministry of Marine and Fisheries (MMF), the Indonesian Government has also devoted a significant amount of effort to protecting sharks from unsustainable fisheries and over exploitation. Dr. Mahardika and his colleagues have developed initial communications with the ministry to use their results as policy input.

Team members presented the result of the research at the Third Asia Pacific Coral Reef Symposium, the International Conference on Science and Technology Application on Climate Change, Enhancing Marine Biodiversity Research in Indonesia, and the National Symposium on Sustainable Tuna Fisheries in December 2014.

During its final months with PEER support, the center successfully secured a $250,000 grant from the Alice Tyler Perpetual Trust, which will be used to build a marine research station in Pemuteran, Western Bali, to develop and facilitate interest in marine science research and education.

PUBLICATIONS

Sembiring, A., Pertiwi, N. P. D., Mahardini, A., Wulandari, R., Kurniasih, E. M., Kuncoro, A. W., Cahyani, N. K. D., Anggoro, A. W., Ulfa, M., Madduppa, H., Carpenter, K. E., Barber, P. H., & Mahardika, G. N. (2015). DNA barcoding reveals targeted fisheries for endangered sharks in Indonesia. Fisheries Research, 164, 130-134. https://doi.org/10.1016/j.fishres.2014.11.003

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INDONESIA - PROJECT 1-90: STRENGTHENING RESEARCH AND TEACHING CAPACITY OF THE ANDALAS UNIVERSITY IN CLIMATE CHANGE AND NATURAL RESOURCES MANAGEMENT

PI: Rudi Febriamansyah, Andalas University
U.S. Partner: Brendan Buckley, Lamont-Doherty Earth Observatory, Columbia University (Funded by the National Science Foundation)
Dates: June 2012 - August 2017

PROJECT OVERVIEW

Climate change has resulted in significant impacts on the environment, water availability, and safety. Millions of people are affected by droughts and floods annually, with widespread effects on various regions. In West Sumatra specifically, climate change has caused sea level rise along the coast, impacting the livelihoods of small-scale fisheries. Additionally, the altered rainy season has influenced cropping patterns, decreased land productivity, and affected the stability of the water supply for three electric power plants.

Given the importance of these impacts for Indonesia, upgrading the capacity of Andalas University faculty and research staff to understand the linkages among the natural systems involved was crucial for creating better solutions and recommendations for local government or community action. Exploring climate variability over a longer period and its connection with the characteristics of ecology, environments, and human activities was an essential element in understanding these linkages. The advanced techniques and technologies for tree-ring analysis developed by experts at Lamont-Doherty Earth Observatory (LDEO) of Columbia University were deemed appropriate for application in West Sumatra province.

The overall goal of this project was to develop a sustainable and adaptive natural resources management system in West Sumatra through cooperation between Columbia University and Andalas University, integrating natural and social sciences approaches. Activities to achieve this goal included: (1) joint research between Andalas staff and LDEO experts on reconstructing climate variability in West Sumatra through tree-ring analysis, (2) support for two PhD students and four M.Sc. students on climate change, watershed management, water supply studies, and agriculture system studies, (3) development of the tree-ring research laboratory at Andalas, (4) organization of seminars and conferences for disseminating the results of the studies, (5) provision of training for Andalas staff, research students, and laboratory technicians, and (6) organization of a workshop for teaching module development.

FINAL SUMMARY OF PROJECT ACTIVITIES

In collaboration with Dr. Kamarza Mulia and Dr. Elsa Krisanti (PEER grantees from Universitas Indonesia), the PI organized a workshop focusing on development of the Problem-Based Learning (PBL) method, as a result, encouraging development of a PBL course at his university. USAID awarded supplemental funding for Andalas University to conduct the International Conference on International Conference on Green Development in the Tropical Region, which took place in October 2015. As for infrastructure development, the laboratory equipment bought with PEER funds has been used not only for this project but also for other training and course delivery at Andalas University. International collaborative ties were also strengthened. The PI visited his U.S. partner Dr. Buckley at LDEO and learned two important methods in tree ring studies, specifically, (1) using matrix paper for cross-dating the ring width before measuring the width with instruments and (2) using MATLAB software to analyze the correlation of the ring width with climatic data to develop the climate reconstruction model. At the LDEO library, the PI obtained journal articles and data sources otherwise not accessible in Indonesia. During the visit, Dr. Febriamansyah made a presentation about his research, which led to his receiving valuable suggestions on how to focus his further work both geographically and in terms of tree species.

A no-cost extension through August 2017 was granted to the PEER team in order to allow Dr. Febriamansyah complete his publications and dissemination of research results. A PhD student of another PEER PI, Dr. Nguyen van Kien from An Giang University in Vietnam, enrolled to complete her PhD study at Andalas University in Padang, and Dr. Febriamansyah expressed interest in supporting her PhD research, in collaboration with Dr. Kien. As of the time the project ended, the student was in the process of completing her comparative research studies at Andalas University.

INDONESIA - PROJECT 1-21: INCORPORATING BALI'S SUBAK HERITAGE INTO PRIMARY AND SECONDARY EDUCATION: CURRICULUM DEVELOPMENT, TEACHER TRAINING, AND ACTION RESEARCH

Pi: Sang Putu Kaler Surata, Mahasaraswati University
U.S. Partner: John Stephen Lansing, University of Arizona Tucson (Funded by the National Science Foundation)
Dates: June 2012 - November 2014

PROJECT OVERVIEW

Researchers developed course materials to teach primary and secondary students about the agroecology of Bali, with an emphasis on the ancient institutions that manage Bali's celebrated rice terraces: subaks and water temples. Balinese subaks are traditional, community-level religious institutions that manage irrigation water, which is regarded as a gift from the Goddess of the Lakes, and as such, a shared resource.

Generations ago, nearly all Balinese children had direct experience of subaks and the agroecology of terraced rice, but today the majority of Balinese are no longer farmers, and knowledge of both the ecological and spiritual role of the subaks and water temples is much less accessible. The subak system is also experiencing threats from both land conversion and loss of soil fertility. The subaks and water temples are more than functional institutions; they are widely regarded as a cultural achievement of the Balinese people, and their vulnerability is a frequent topic in Balinese newspapers, television, and seminars.

As part of this project, both printed and Web-based instructional materials were created by teams of future teachers, who will received training in the formal evaluation of the pedagogical effectiveness of these materials and methods. The project team included U.S. researchers who were conducting a National Science Foundation-funded investigation of the resilience of Balinese subaks.

The development and assessment of the teaching materials was carried out by college students at Mahasaraswati University who were seeking certification as primary and secondary school teachers. This part of the project was organized as a series of projects embedded within the teacher training curriculum at Mahasaraswati. Students participated in data collection in the field, gaining firsthand awareness of the concerns and perceived vulnerabilities of the farmers and temple priests, working in teams to collect historical data, photographs, and oral histories that provided the raw materials for teaching modules.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER research team produced learning modules, several undergraduate action research proposal projects, and 3,000 copies of student books. The PI held three workshops with 120 teachers and undergraduates to evaluate the student books' effectiveness as an educational resource and discuss methods of adding it to the existing curriculum, and gave a presentation to the Environmental Education Center Bali on methods to integrate subak culture into school curriculums.

Kuliah Kerja Nyata (KKN) or Students Field Work is one of the three pillars of higher education in Bali. As a direct result of the PEER project, approximately 1,800 community members, youth groups, teachers, and students participated in the community service outreach over the course of 35 days in a fully immersive Subak cultural experience focused on heritage and sustainability, the first in KKN history. Participants trained on how to teach primary school students sustainability based on their environment and shared heritage.

The project was presented by the PI at the Asia Engage Conference. A second edition of the student book will be produced and printed by the Deputy of Cultural Affairs to be used as a resource for primary and secondary school students in Indonesia. The research team also received several grants from the Indonesian Ministry of Technology, Research, and Higher Education.

PUBLICATIONS

Surata, S.P.K., I.G.A.G.S. Jayantini, J.S. Lansing. 2015. Engaging Student Teachers in Designing Ecopedagogy Learning Modules for Bali's Subak Cultural Landscape. NACTA Journal 59(2): 139-143 (June 2015). https://www.jstor.org/stable/10.2307/nactajournal.59.2.139

Surata, S.P.K., I.G.A.G.S. Jayantini, and J.S. Lansing. 2014. Exploring Community Capital of the Balinese Subak Cultural Heritage: A Content Analysis of Participatory Maps.
International Journal of Technical Research and Applications 2(7): 28/34. e-ISSN: 2320-8163

Surata, S.P.K., N.G.A.G.E Martiningsih, and I.G.A.G.S. Jayantini. 2014. Participatory Mapping: Developing Collaborative Learning for Educating Youth to Understanding Their Cultural Landscape Heritage. Proceedings of the 2nd Asia Engage Regional Conference, Bali, 17-20 November 2014.

Surata, S.P.K. et al. 2013. "Ngayah" Pelibatan Mahasiswa Calon Guru dalam Ipteks bagi Wilayah berbasis Pendidikan untuk Pembangunan Berkelanjutan dan Pariwisata Budaya. (Involving The Student Teachers in an Education for Sustainable and Cultural Tourism based Science and Technology for a Region Application) Aplikasi Ipteks, 4(1): 84-100 (Ngayah, A Journal of Science and Technology Application).

INDONESIA – PROJECT H2-3: EFFECTS OF AIR POLLUTION IN EARLY LIFE ON INFANT AND MATERNAL HEALTH

PI: Nikmah Salamia Idris, University of Indonesia - Cipto Mangunkusumo National General Hospital

U.S. Partner: Kerstin Klipstein-Grobusch, University Medical Center Utrecht (Funded by the National Institutes of Health)

Dates: February 2015 - August 2020

In Memoriam: On August 6, 2019, PEER received word that Dr. Nikmah Salamia Idris had passed away after a two-year illness. The staff of the PEER Program and its sponsors at the U.S. Agency for International Development offer their deepest condolences to her family, friends, and co-workers. She was a dedicated researcher whose work has helped many women and children, and its impacts will continue to be felt in the future despite her untimely passing. Dr. Nikmah will be remembered as a treasured friend and colleague--may she rest in peace.

PROJECT OVERVIEW

Maternal and neonatal morbidity and mortality appear to be an intractable problem worldwide. One of the underlying reasons may be that reductions in mortality and morbidity depend not only on care access and quality of care but also on adverse effects of air pollution on communities. In Indonesia, air pollution levels are high, particularly in major cities. This PEER team aimed to assess if prenatal exposure to air pollution increases the risk for pregnancy complications and the risk for adverse maternal and neonatal health. The researchers studied this question in healthy pregnant women living in and around Jakarta being recruited for an ongoing breastfeeding behavior intervention trial (BRAVO). Jakarta is arguably one of the most polluted cities in the world, with large exposure contrasts between many residential areas, making it an ideal setting for such a study.

The researchers took long-term measurements of particulate matter and the major gaseous pollutant NO2 in individual homes to obtain pollution exposure levels. Women and offspring were followed until six months after birth to record pregnancy complications, maternal lung function, neonatal indicators of fetal health, infant function, structural measurements of the respiratory and circulatory tracts, and infant diseases, particularly infections. The PEER team sought to establish relationships between pollutant exposure in pregnancy and maternal and neonatal health indicators.

The project also aimed to put air pollution and health more prominently on the agenda of Indonesian policy makers, offering a more comprehensive insight into the health consequences provided by local research, and build research capacity in Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team undertook several types of air pollution measurements, including installing devices to measure particulate matter and NO2 at multiple sites in Jakarta city. The sampling mechanisms included one reference site, which will measure air pollution level throughout the year; an electric scooter equipped with a measuring device to take measures around Jakarta, particularly in the area around mothers' residences; and passive nicotine samplers installed in a random subset of homes (50 pregnant women). The researchers surveyed pregnant women to investigate domestic smoking habits and sent the passive sampler papers to the Netherlands to be analyzed.

Among the health outcome measurements researchers collected were maternal obstetric data, pregnancy-induced hypertension, nutritional analysis, maternal lung function, fetal growth, hair and nail sampling, vaginal swab sampling, placental and blood cord sampling (only if mothers consented), and birth outcomes. Health outcome measurements for the infants included growth, infection episodes, lung function, and cardiovascular outcomes. The researchers followed up with mothers and infants over the course of several years.

The PEER team also presented workshops on air pollution measurements, use of a mobile app to measure infection episodes in infants, placental sampling, and spirometer training. The group developed both local and international collaborations with healthcare providers, researchers, and academic institutions and maintained a website on their research activities. The PI and team also received two additional grants, worth a total of $22,000, related to the work. Their 2023 paper (see citation below) presented their findings, including an association between maternal exposure to soot and NOx during pregnancy and reduced length of babies at birth.

PUBLICATION

Frida Soesanti, Cuno S.P.M. Uiterwaal, Kees Meliefste, Jie Chen, Bert Brunekreef, Nikmah S. Idris, Diederick E. Grobbee, Kerstin Klipstein-Grobusch, and Gerard Hoek. 2023. The effect of exposure to traffic related air pollutants in pregnancy on birth anthropometry: a cohort study in a heavily polluted low-middle income country. Environmental Health 22:22. https://doi.org/10.1186/s12940-023-00973-0

INDONESIA – PROJECT H2-4: DEVELOPMENT OF A REFERRAL SYSTEM USING KANGAROO MOTHER CARE FOR LOW BIRTH WEIGHT BABIES

Pi: Hadi Pratomo, Faculty of Public Health, Universitas Indonesia
U.S. Partner: Abdullah Baqui, Johns Hopkins University Bloomberg School of Public Health (Funded by the National Institutes of Health)
Dates: February 2015 – December 2018

PROJECT OVERVIEW

The project aimed to improve the survival of low-birth-weight infants (LBWI) using kangaroo mother care (KMC). The objectives were to address LBWI problems, improve the referral system from community to hospitals and vice versa, promote the sustainability of KMC for increasing survival, and reduce both mortality and morbidity. Although the Ministry of Health developed the referral health system, implementing these services, including LBWI, remained a significant challenge. Coordination and follow-up of referral services after hospital discharge were very weak. However, the current policy on Universal Coverage of health services (BPJS) provided an opportunity to devise and strengthen the referral health system, including cases of LBWI.

The study design was a before-and-after intervention carried out at the hospital and community levels. The primary target population was families with LBWI born in either the hospital or community setting. In each district, the expected number of mothers with LBWI was estimated at 200 in each hospital, 100 in primary health centers or private midwife clinics, and another 100 in home deliveries. The total sample was approximately 800 mothers with LBWI. The secondary target populations included family members, cadres, healthcare providers, and decision-makers.

Formative research was conducted to increase the possibility of an effective, acceptable, and sustainable intervention. This helped fine-tune the proposed intervention adjusted to existing conditions. A quantitative study followed to investigate LBWI survival and morbidity rates. Case fatality rates (CFR) due to major complications and neonatal mortality were studied retrospectively both at the hospital and community settings. However, both neonatal morbidity and CFR were studied only at the hospital level. The intervention consisted of Learning Organization and training for personnel involved in the care of LBWI for KMC and its referral system. An end-line study compared knowledge and perception about KMC services and referral for LBWI using KMC before and after the intervention.

The primary intended project outcome was improvements in LBWI outcomes, such as survival, presence of complications, CFR, and cause of death after receiving KMC service. The secondary outcome measures included improvements in knowledge, opinion, and perception of health personnel about KMC and LBWI referral using KMC. Several tools were developed to monitor implementation, such as KMC admission criteria both in hospital and community settings.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project ended as of December 2018. The major project achievement was policy change regarding Kangaroo Mother Care implementation in Koja Hospital. Koja Hospital is determined to become a center of excellence for KMC in Jakarta area; therefore, they have changed their Medium Plan Strategies to highlight the KMC practice. They also established a room designated for KMC for mothers and equipment needed to practice continued KMC in the hospital. In addition, the information technology system using a web-based application, si Kanguru (Kanguru means Kangaroo), was also established to ensure information on LBW babies and KMC practices are available for monitoring purposes in the Koja area. Si Kanguru contains information on LBW babies collected during follow up visits done by community health personnel and can be accessed by both hospital and community health personnel to ensure the continuous care and KMC practice for the LBW babies. While Karawang is still considering policy changes regarding the KMC practice, it has showed their willingness to practice KMC in the hospital and uses the referral mechanism for monitoring and follow up LBW babies.

To achieve the research objectives, the team conducted a baseline assessment through Knowledge, Attitude, and Practice (KAP) surveys of health personnel which showed that they lacked in knowledge on KMC practices. A pilot training of KMC using the updated modules (from previous KMC modules in Malawi and Nepal) was performed in a hospital in East Jakarta prior to implementation in the study sites of Karawang and Koja Hospitals. Modules for community health personnel training were also developed. Training for health personnel in both hospitals covered 210 participants consisting of doctors, nurses, and midwives, as well as 247 participants from primary health centers (PHC) in both areas. Post training activities, implementation of KMC practice in both areas began which aimed to increase KMC practices in the hospital and the community.

Data collection on newborn mortality and morbidity of low-birth-weight babies in both hospitals occurred using registers from wards and medical records. This activity was followed up with home visits to the LBW babies' houses and measured their growth and weight gain. Additionally, the team emphasized and supported North Jakarta and Karawang to set a referral mechanism from hospital to community for LBW babies discharged from the hospitals using KMC as means of transport and accompanied by community midwives during transfer from hospital to community. At the community, midwives also ensured that KMC was practiced by the family and monitored the babies' growth and weight gain. The referral mechanism is now used by both areas and uses group messaging to share information on discharged babies and follow up plans. Through the monitoring and evaluation activity, the research team found that both hospitals have standard operating procedures (SOP) for KMC implementation, but not for KMC counselling. In response, the team conducted a panel meeting which included experts on KMC and pediatricians, as well as management teams of both hospitals to develop the SOPs. As a result, both hospitals have SOPs for KMC counselling.

For outreach, the team produced KMC media in the form of flipcharts and booklets. The flipchart and booklet have been distributed to Koja and Karawang hospital, and to all PHC in North Jakarta and Karawang districts. The booklet and flipchart have received intellectual property rights from Indonesia as of November 2017. A national level dissemination meeting was also organized in Jakarta with aim to disseminate the research results and findings and to obtain commitment from invited stakeholders to implement KMC for LBW babies. Meeting participants were from the Ministry of Health, Jakarta and West Java PHO, DHOs (North Jakarta, East Jakarta, Karawang), Province Hospitals in Jakarta, Perina Medica, and other stakeholders. A focus on improvements of LBW baby care through KMC was agreed to be implemented and scaled up. The Director of Family Health actively participated in the meeting and expressed her willingness to support the KMC implementation in Indonesia.

INDONESIA – PROJECT H2-2: IMPROVING HOSPITAL CARE FOR BREASTFEEDING SUPPORT IN INDONESIA

Pi: Francisca Handy Agung, Center for Health Research, Universitas Indonesia
U.S. Partner: Valerie Flaherman, University of California, San Francisco School of Medicine (Funded by the National Institutes of Health)
Dates: February 2015 - June 2019

PROJECT OVERVIEW

Breastfeeding, especially exclusive breastfeeding, is one of the most effective preventive health measures to reduce infant morbidity and mortality. For all newborns, particularly the sick ones, breastfeeding is a simple, life-saving method. To improve global breastfeeding initiation and duration rates, WHO and UNICEF launched the Baby-Friendly Hospital Initiative (BFHI) in 1991. BFHI comprises the Ten Steps to Successful Breastfeeding and the WHO International Code of Marketing of Breast-milk Substitutes, serving as the gold standard for evidence-based breastfeeding care in hospitals. Data shows that adherence to the Ten Steps predicts breastfeeding duration and exclusivity long after hospital discharge. However, despite strong evidence for the Ten Steps, hospital compliance in Indonesia is poor. A national survey in 2011 found only 8% of state hospitals complying with 7 out of 10 steps of successful breastfeeding.

To improve hospital care for breastfeeding, the project aimed to identify the barriers and opportunities of BFHI implementation in Indonesia and obtain solid local evidence on implementing BFHI through a pilot project. The project consisted of two studies. Study 1 was a qualitative study exploring the barriers and facilitators of BFHI implementation in Indonesia, covering various stakeholders related to hospital support for breastfeeding, including the Ministry of Health, provincial and district health offices, related professional organizations, selected hospitals, and community mother support groups. The provinces involved were Jakarta, West Java, and Banten, with one district selected from each province and three hospitals chosen in each respective district.

Study 2 was a quasi-experimental study conducted in Banten Province, involving six hospitals with different types of services and ownership. These hospitals were randomly allocated to intervention and control groups, with three hospitals in each group. The intervention included WHO BFHI section 2 (training for hospital managers), WHO BFHI section 3 (training for maternity staff), and 12 months of technical assistance performed by the Indonesian Breastfeeding Center. The outcomes of the study included the performance of hospitals on BFHI implementation using the WHO module, breastfeeding self-efficacy scale, family breastfeeding support scale, LATCH score, and breastfeeding rates, measured for both healthy and sick newborns.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project was completed in June 2019. From the phase 1 study, five themes were identified as contributors to low rates of early exclusive breastfeeding in Indonesian hospitals: 1) quality and quantity of breastfeeding education; 2) marketing and influence of infant formula manufacturers; 3) hospital infrastructure; 4) policy, legislation and protocols; and 5) perceived need for infant formula supplementation. Participants noted that providers and mothers receive inadequate or incorrect education regarding breastfeeding; manufacturers promote infant formula use both inside and outside hospitals; constraints in physical space and hospital design interfere with early breastfeeding; legislation and protocols designed to promote breastfeeding are inconsistently enforced and implemented; and providers and mothers often believe infant formula is necessary to promote infant health. All participants identified numerous barriers to early exclusive breastfeeding that related to more than one identified theme.

Following the phase 1 study, the phase 2 study found that the Indonesian version of the WHO-BFHI module training with supportive supervision was the most beneficial intervention compared to only training and the control group. Step 7 (rooming in) was the most improved practice that increased the breastfeeding rate at discharge and step 10 was the most difficult step among others to be implemented. One of the hospitals in the full intervention group was a big public hospital serving serving districts with around 400 births each month. It approached the intervention enthusiastically during the whole process and saw the best performance and improvement with an increase in the breastfeeding rate from 2% to 98%. Following this, the hospital was selected by the Provincial Health Offices to serve as an example to other hospitals to develop a baby friendly service.

PUBLICATION

Flaherman, V. J., Chan, S., Desai, R., Agung, F. H., Hartati, H., & Yelda, F. (2018). Barriers to exclusive breast-feeding in Indonesian hospitals: a qualitative study of early infant feeding practices. Public Health Nutrition, 21(14), 2689–2697. https://doi.org/10.1017/s1368980018001453

INDONESIA – PROJECT H2-1: IMPACT OF REDUCED IN-HOME SECONDHAND SMOKE EXPOSURE ON LOW BIRTHWEIGHT PREVALENCE AND NEONATE HEALTH

PI: Yayi Suryo Prabandari, Center for Health Policy and Management, Faculty of Medicine, Gadjah Mada University

U.S. Partner: Donald Bailey, Research Triangle Institute International (Funded by the National Institutes of Health)

Dates: February 2015- May 2019

PROJECT OVERVIEW

Indonesia has made strides in improving public health and development indicators, but the rates of low birth weight (LBW) births, neonatal morbidity, and mortality remain higher than in other countries in the region. International evidence has clearly implicated secondhand smoke (SHS) exposure as a primary preventable risk factor for LBW and neonatal morbidity, with sufficient evidence to implicate SHS exposure as an independent cause of LBW. While smoking rates among women in Indonesia are relatively low, the percentage of men who smoke is among the highest in the world, and a majority of these men smoke within the home. Efforts to reduce LBW births and improve neonatal health must address male smoking in the home.

The proposed study, the first of its kind in Indonesia, aimed to demonstrate the potential impact of an innovative, multi-component intervention targeting pregnant women living in households where a male smokes. The community and household intervention directly targeted male smokers. Specifically, the study was a quasi-experimental, intervention/control study in two geographically distinct but demographically similar areas. The intervention area received three separate but interrelated intervention components: a Smoke-Free Home media campaign aimed at educating the public about the dangers of SHS during pregnancy and the benefits to child health by restricting smoking in homes; Smoke-Free Home community promotion leading to a community-level declaration of commitment to Smoke-Free Homes; and Smoke-Free Home family education leading to household-level Smoke-Free Home contracts. The study aimed to demonstrate the potential impact of this intervention to reduce SHS exposure in the home, reduce rates of LBW births, and improve neonatal health outcomes. If effective, the intervention could be efficiently scaled up throughout Indonesia with the potential to significantly improve neonatal health outcomes.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project was completed in May 2019. The researchers found some important results even though the study sites experienced severe flooding in December 2016 which displaced the study population and made it a challenging environment to conduct the research.

The study found that pregnant mothers in North Lombok living with household members who smoked more than 5 cigarettes per day at home in the first trimester are 1.29 times more likely to give birth to low birth weight (LBW) infants, adjusted for LBW history and maternal body mass index (BMI) before pregnancy. The researchers also found other factors associated with the risk of LBW. Primiparous women are 2.19 times more likely to give birth to LBW infants compared to women who have no history of LBW in the previous pregnancies. Women with a history of LBW are 3.92 times more likely to give birth to LBW infants than those without. LBW is associated with maternal BMI before pregnancy. Mothers who were malnourished before pregnancy (BMI <18.5 kg/m2) were 1.97 more likely to give birth to LBW infants. The team calculated scores for in-home SHS exposure which range from 0-16. A greater score indicates a greater exposure from in-home SHS. The study found a decrease in in-home SHS exposure both in the intervention area (North Lombok) and control (Bima). However, the score for SHS exposure in Bima remained higher than North Lombok at postnatal. The differences are significant at baseline, 6 months, and delivery. The average infant birth weight in Bima (3100 gram) is slightly higher than in North Lombok (3026 gram). The difference is not statistically significant and both still fall within the normal range (2500-4000 gram). The percentage of LBW decreased in Bima (8.23%) and North Lombok (7.42%); however, the decrease was not found statistically significant. The percentage of neonates with signs of illness was higher in Bima. There are significantly higher percentages of neonates experiencing respiratory distress (5.82%) and diarrhea (6.19%) in Bima compared to North Lombok (4.04% and 3.36%, respectively).

Through the project, one village community agreed to declare their village as a “Smoke-Free Home for Pregnant Women” village. The project team also had 80% of their participants (1334 people) sign onto a community declaration of a Smoke-Free Home. Health promotion media was created by the PEER project team to assist with communicating the importance of a smoke-free home and aimed to persuade smokers not to smoke around women and children. The promotion media consisted of stickers, leaflets, and calendars. Some leaflets are also distributed in posyandu during antenatal care. The researchers recommended that pregnant mothers and husbands need to be continually educated regarding harmful effects of SHS exposure on pregnancy and neonatal health, as well as other relevant information regarding child development.

The research results were disseminated to the local level as well as policy makers at public health offices.

PUBLICATIONS

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Padmawati, R. S., Prabandari, Y., & Malik, S. (2018). Challenges in developing a smokefree home initiative in Lombok Utara, Nusa Tenggara Barat. ICTOH-TCSC. Surabaya, Indonesia. http://ictoh-tcscindonesia.com/wp-content/uploads/2019/01/Proceeding-Book-5th-Final-include-cover.pdf

Prabandari, Y., Padmawati, R. S., Cranshaw, E., & Mellen, R. C. (2018). What factors contribute on the participation of Smoke Free Home Movement in Lombok Utara, Nusa Tenggara Barat? ICTOH-TCSC. Surabaya, Indonesia. http://ictoh-tcscindonesia.com/wp-content/uploads/2019/01/Proceeding-Book-5th-Final-include-cover.pdf

Prabandari, Y., Padmawati, R. S., & Suryo Bintoro, B. (2018). Multilevel intervention in reducing in-home secondhand smoke exposure among pregnant woman in North Lombok district, Indonesia. Tobacco Induced Diseases, 16(1), 709. https://doi.org/10.18332/tid/84590

INDONESIA PROJECT H1-163: EPIDEMIOLOGIC AND GENOTYPIC ANALYSIS OF ACTIVE M. TUBERCULOSIS CASES IN INDONESIA: UNDERSTANDING THE ACQUISITION AND TRANSMISSION OF DRUG-RESISTANT TUBERCULOSIS

PI: Andani Eka Putra, Andalas University

U.S. Partner: Megan Murray, Harvard Medical School (Funded by the National Institutes of Health)

Dates: October 2013 - April 2017

PROJECT OVERVIEW

Multidrug-resistant tuberculosis (MDR-TB) has hampered global efforts to control and manage tuberculosis infections. Indonesia ranks 8th globally among high MDR-TB burden countries, with WHO estimating about 2% of new and 17% of retreatment cases testing positive for multi-drug resistance. The US Global Health Initiative strategy for Indonesia aimed to diagnose one million TB patients and treat 5,100 MDR-TB patients by 2015. Despite progress made with the Indonesia National TB Program, significant gaps remain in understanding how and under what circumstances resistant Mtb emerges and is transmitted. This project aimed to elucidate the host, microbial, and environmental factors underlying the emergence and transmission of MDR and XDR-TB in Indonesia, obtain an unbiased prevalence of MDR, and describe the distribution and patterns of drug resistance mutations.

This observational prospective cohort study enrolled 2,400 incident cases of suspect pulmonary tuberculosis from government-operated community health centers, lung clinics, or hospitals within Padang, Pariaman Regency, and Pariaman City districts. Participants were followed up by healthcare professionals as per routine national protocol. Those testing positive for RIF-resistance had samples cultured, tested for antibiotic resistance, and sent for whole genome sequencing. The study results aimed to help the NTP and USAID accurately assess the burden of MDR and the need for new TB diagnostics and second-line drugs within Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team engaged extensively with various government levels to ensure the study aligned with the existing TB eradication program in West Sumatra. They obtained necessary permissions, conducted training sessions for TB officers, and procured essential equipment, including the GeneXpert machine. Field preparations involved training officers on study procedures, including obtaining participant consent, conducting interviews, collecting sputum samples, and managing data. Initially, the study focused on Padang, Padang Pariaman, and Pariaman City districts, but due to low initial sample collection, Pesisir Selatan District was added in 2015.

Throughout the study, 2,436 new sputum samples were collected, with 2,425 testing positive on GeneXpert. Among these, 32 cases were identified as rifampicin (RIF) resistant, accounting for 1.32% of the samples. The samples underwent laboratory procedures, including decontamination, DNA extraction, and whole genome sequencing using Illumina technology, with bioinformatics analysis conducted at Toyama University, Japan. The team maintained rigorous sample and data collection protocols, ensuring proper storage and transport. Results were submitted to the Department of Health for follow-up and treatment, providing updated information on TB patients and supporting the national TB program. Additionally, the team found a positive response to their training and engagement efforts, as demonstrated by the high-quality data collected and the support from local health offices.

The project faced challenges, particularly in collecting adequate samples and questionnaires, a common issue in community-based research. The team extended the research period to address these challenges and improve enumerator management. By October 2017, all procedures were completed. Moving forward, the team plans to publish their findings in international journals. This community-based study ensured rapid identification and treatment of MDR-TB, contributing valuable data for improving TB diagnosis and management in Indonesia. The study's results will be published in the Gene Bank, and the team continues to support TB health programs by providing updated information and recommendations for optimizing diagnostics and treatment strategies.

INDONESIA PROJECT H1-158: INTENSIFIED ANTIBIOTIC TREATMENT PLUS LOW DOSE ASPIRIN FOR TUBERCULOUS MENINGITIS: A RANDOMIZED CLINICAL TRIAL

PI: Rovina Ruslami, Universitas Padjadjaran
U.S. Partner: H. Clifford Lane, National Institute of Allergy and Infectious Diseases
(Funded by the National Institutes of Health)
Dates: October 2013 - October 2017

PROJECT OVERVIEW

TB meningitis (TBM) is the most severe manifestation of TB, leaving up to 50% of patients dead or neurologically disabled. Current treatment is similar to that of lung TB, although the penetration of some antibiotics into the brain is poor, and the immune-pathology of TB meningitis is very different from pulmonary TB. Current treatment regimens are not based on clinical trials. Rifampicin is a key drug for TBM, but its penetration into the brain is limited, suggesting that a higher dose may be more effective. Several highly relevant, outstanding questions related to the appropriate dose of rifampicin for TBM needed to be addressed before a multicenter phase III trial could be performed.

The overall aim was to establish the optimal dose of rifampicin for TBM, which could be evaluated in a follow-up multicenter phase III randomized controlled trial (RCT). The primary objective was to generate pharmacokinetic (PK) data for higher doses of rifampicin in patients with TBM. This study was designed as a double-blinded, 1:1:1 randomized, placebo-controlled, phase IIb trial. Approximately 60 adult TBM patients were randomized to one of three arms consisting of varying doses of rifampicin administered orally, as part of a standard 4-drug regimen for TBM. Pharmacokinetics data, safety/tolerability, and efficacy data were collected, and subjects were followed for 180 days. Finding the right dose of rifampicin could potentially alter the standard of care and reduce mortality and morbidity for this important and difficult-to-treat disease.

FINAL SUMMARY OF PROJECT ACTIVITIES

Initially, this PEER project aimed to conduct an explorative pharmacokinetic (PK) study, examining three different oral doses of rifampicin (450 mg, 900 mg, and 1350 mg) in TB meningitis patients. The result of this study was to be a validation of an improved treatment regimen for TB meningitis to overcome bad outcomes associated with the disease. The team also aimed to strengthen microbiological diagnosis of TB meningitis cases by performing various confirmation techniques including enhanced staining (cytospin), culture, and PCR-based (GeneXpert and in-house PCR) techniques. The team modified the objectives in the second year of the project focus on three objectives in the third year.

Overall impacts of the research:

- The results of the bacteriological confirmation have led the team to promote the use of GeneXpert and/or in-house PCR. The benefit of using cytospin was analyzed using data from three different countries.
- The result of the PK study using a higher dose of Rifampicin has encouraged physicians to use a higher than recommended dose of Rifampicin to treat TB meningitis patients. The Indonesian health policy maker also has approved the administration of higher dose of Rifampicin for extrapulmonary TB, especially TB meningitis.

- A multicenter, phase 3 trial for the higher dose of Rifampicin was discussed and the plan has been initiated by submitting a proposal to the MRC, UK, and possibly will be funded by NIH/NIAID.
- Data on PK of INH in plasma and CSF is also being used to design clinical trial using higher dose of INH.

PUBLICATIONS

van Laarhoven, A., Dian, S., Ruesen, C., Hayati, E., Damen, M. S. M. A., Annisa, J., Chaidir, L., Ruslami, R., Achmad, T. H., Netea, M. G., Alisjahbana, B., Ganiem, A. R., & van Crevel, R. (2017). Clinical parameters, routine inflammatory markers, and LTA4H genotype as predictors of mortality among 608 patients with tuberculous meningitis in Indonesia. The Journal of Infectious Diseases, 215(7), 1029-1039. https://doi.org/10.1093/infdis/jix051

INDONESIA PROJECT H1-115: DEVELOPMENT OF AN ANTIGEN-CAPTURE IMMUNOASSAY FOR THE RAPID DIAGNOSIS OF ACUTE LEPTOSPIROSIS

PI: Farida Handayani, Ministry of Health, Republic of Indonesia
U.S. Partner: David Aucoin, University of Nevada, Reno (Funded by the National Institutes of Health)
Dates: February 2016 - December 2022

PROJECT OVERVIEW

Leptospirosis (LPS) is a globally important zoonotic disease endemic in Southeast Asia, with human infection commonly reported throughout the region. It is classified as a neglected disease in Indonesia and has been an increasing public health issue in the country. A number of recent outbreaks of leptospirosis have occurred in several areas in Indonesia, with mortality rates as high as 35%. Diagnosis of leptospirosis is particularly difficult because its symptoms are so variable, ranging from a classical flu syndrome to Weil's disease. In addition, the availability of specific tests, including bacteria isolation, DNA testing, and serology using the microagglutination test (MAT), still remains limited to the lack of sufficient highly specialized laboratories.

The goal of this PEER project was to develop a sensitive, noninvasive, and inexpensive immunoassay for point-of-care diagnosis of leptospirosis. significantly improving the rate of diagnosis as well as providing a better understanding of leptospirosis endemicity within Indonesia. The research had three components: (1) production of a library of monoclonal antibodies (mAbs) specific to LPS or other circulating antigens secreted or shed during infection for the development of a prototype antigen capture enzyme-linked immunosorbent assay (ELISA); (2) construction of prototype immunoassay for leptospirosis diagnosis; and (3) a prevalence survey of leptospirosis in endemic areas in Indonesia using the prototype.

FINAL SUMMARY OF PROJECT ACTIVITIES

Working in close collaboration with their U.S. partner at the University of Nevada, the PI and her colleagues developed a molecular examination protocol for leptospirosis and three mAbs candidates for the antigen-based lateral flow test prototypes. They tested their prototype against known false and positive samples and registered it for a patent. The PI's lab has formed a memorandum of understanding with PT. Konimex (a pharmaceutical company) and the Ministry of Health to continue developing early detection of leptospirosis using various platforms.

One of the project's outputs was to help strengthen national efforts to confirm cases of severe leptospirosis. The PI's lab shared the leptospirosis examination protocol and formed a national laboratory network for the detection of leptospirosis and other zoonoses. The development of an early and rapid detection tool for leptospirosis also shows promise for further development to be used in diagnosing other emerging diseases, including the Nipah virus.

The PI and her team received three additional grants to continue their work, including $85,000 from the World Health Organization on molecular epidemiology of rodent borne diseases. The PEER project research contributed to the PIs doctoral work at the University of Indonesia. She presented her findings at the International Leptospirosis Society (ILS) Meeting in New Zealand and published one paper listed below.

PUBLICATION

Handayani, F. D., Wijayaningih, R. A., Ristiyanto, Gasem, M. H., & Wibawa, T. (2020). Comparison of DNA extraction methods for molecular identification of pathogenic Leptospira in urine samples. Health Science Journal of Indonesia, 11(2), 77-84. https://doi.org/10.22435/hsji.v11i2.3749

INDONESIA PROJECT H1-89: IMPLEMENTATION OF PHARMACHECK TO ASSURE THE QUALITY OF IMCI DRUGS IN INDONESIA

PI: Iwan Ariawan, Universitas Indonesia

U.S. Partner: Muhammad Zaman, Boston University (Funded by the National Institutes of Health)

Dates: October 2013 - December 2018

PROJECT OVERVIEW

Integrated Management of Childhood Illnesses (IMCI) developed by WHO has been adopted by Indonesia as a method used by non-physician health providers to manage childhood illnesses. Appropriate management of childhood illnesses depends on the availability and quality of essential drugs. Currently, the quality of drugs in primary health centers and district hospitals in Indonesia is rarely monitored due to the complexity and high cost of drug quality testing. PharmaCheck, developed by the NIH collaborator at Boston University, is the only user-friendly, reliable, cost-effective technology that screens for substandard drugs using active pharmaceutical ingredient concentration and drug dissolution tests. This technology is of significant value in Indonesia as an affordable, effective tool for local and central health authorities to better safeguard the efficacy of their pharmacopeia.

The goal of this study was to assess the implementation of PharmaCheck for testing the quality of selected IMCI drugs in Indonesia. Two of the most frequently used IMCI antibiotics, Cotrimoxazole and Amoxicillin, were chosen for the study. The study was to be implemented in four phases. In the first phase, probes for testing these two antibiotics were to be developed at Boston University. The second phase involved a comparison between PharmaCheck and standard drug quality testing to test accuracy. If PharmaCheck showed reliable accuracy, the third phase would commence, in which PharmaCheck would be field-tested to investigate the correct amount of active ingredients present in Cotrimoxazole and Amoxicillin in 80 primary health care centers (PHCs) and 10 district hospitals in 10 districts in West Java. The 80 PHCs chosen had been trained in implementing IMCI, and the 10 hospitals were referral sites for the 80 PHCs. During the implementation, a cost study was intended to be conducted to understand the cost of implementing PharmaCheck in Indonesia. In the fourth phase, analysis would be done to understand the potential application of PharmaCheck in Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

Initially, the project aimed to conduct an explorative pharmacokinetic (PK) study, examining different oral doses of rifampicin in TB meningitis patients. However, due to the slow development of Co-trimoxazole and Oxytocin test chips for PharmaCheck, the project objectives were adjusted. The new focus involved conducting a seminar on the use of rapid drug quality testing to improve drug quality at points of sale in Indonesia. This seminar, held in May/June 2018, was successfully executed with participation from various stakeholders.

Two meetings were conducted during the project. The first was a large conference at the School of Public Health, which was an open symposium featuring speakers on monitoring drug quality in Indonesia, the technical aspects of the Indonesian FDA, and a presentation on PharmaCheck. The second meeting was a technical discussion involving representatives from the University of Indonesia, the faculty of pharmacy, and the Indonesian FDA. These discussions emphasized the need for quick drug quality testing devices and the limitations of the current methods. During the symposium, it was highlighted that the Indonesia FDA requires indicators of drug quality not only during development but also at the point of sale. Current lab-based methods using HPLC are time-consuming and costly. Although PharmaCheck showed potential, it was not yet ready for widespread use. The MiniLab, while more portable, did not provide quantitative results and had limited probe availability.

Due to the limitations in PharmaCheck's testing capabilities and the uncommon nature of the drugs that could be tested in Indonesia, the project team planned to develop a policy recommendations paper. There are also plans for Indonesian researchers to visit Boston University for further discussions. The potential end users of the technology are labs at the provincial or district level, with current testing being done at 34 provincial labs funded by the central Indonesian FDA.

Due to the changes in project goals and the inability to utilize all the funds as initially planned, the project team returned the remaining funds to NAS.

INDONESIA PROJECT H1-16: MOSQUITO-BORNE ARBOVIRAL SURVEYS IN INDONESIA WITH A FOCUS ON DENGUE VECTORS

PI: Isra Wahid, Universitas Hasanuddin

U.S. Partner: David Severson, University of Notre Dame (Funded by the National Institutes of Health)

Dates: October 2013 - April 2019

PROJECT OVERVIEW

Arthropod-borne viruses pose a significant threat in Indonesia, an emerging pathogen 'hotspot,' due to the ease with which vectors can transfer RNA viruses between wildlife, humans, and livestock, and because of the variety of pathogenic viruses already known to exist. Although viruses like West Nile, Sepik, and Banna are known to exist at similar latitudes, they had not been recorded in Indonesia. Dengue virus, present in Indonesia, is an emerging global health threat, with prevention relying entirely on avoiding the mosquito host that transmits the virus. No other prevention or treatment methods existed for dengue at the time, and preliminary evidence suggested potential differences in allele frequencies related to vector competence in transmitting Dengue virus.

The study aimed to understand the genetic composition of mosquito populations seasonally and among communities to predict levels of mosquito diversity and movement within and between communities and to assess vector competence in transmitting dengue viruses throughout a transmission season. The researchers conducted a survey of potentially pathogenic arboviruses from mosquitoes collected throughout Indonesia to identify viruses, their vectors, and temporal transmission characteristics. The primary objective was to map the geographical risk of mosquito-borne arboviruses, estimate the force of infection, and identify potential emerging pandemic threats. A secondary objective was to investigate temporal changes in the dengue virus vector genotype and its impact on vector competence between the wet and dry seasons.

The study involved systematic collections of mosquitoes from all ecological zones on the island of Sulawesi. The team identified vectors to species to determine mosquito diversity and those known to harbor human pathogens. They performed virus isolation in vertebrate cell cultures for virus identification and examined seasonal effects on Ae. aegypti population genetics and DENV susceptibility. The team collected circulating viruses previously unrecorded at these sites, with the possibility of identifying novel viruses. These findings enabled the characterization of geographic vector-virus transmission systems and improved understanding of local dengue transmission, informing better intervention strategies.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the study period, the team collected over 50,000 mosquito samples from all major genera (Anopheles, Culex, Aedes) and stored them in a laboratory freezer while waiting for virus control clearances from the CDC. The analysis of part of the samples, with help from local clinicians, showed no positive results. The CDC permit delay of almost two years led to sample degradation, resulting in no positive arbovirus results from over 20,000 tested samples. Consequently, the team re-collected samples from three sites in West and South Sulawesi provinces, gathering 16,980 mosquitoes from nine genera. They found a Bunyaviridae family virus in a pool of Culex trinaenorhyncus mosquitoes, identified as Bunyawera virus with 99% identity to the NCBI database. A manuscript on this new report in Indonesia is being prepared.

The team developed links with national and international researchers, collaborating with entities such as the Ministry of Health (MoH), the Tahia Foundation, CDC-funded labs, and universities from the US, Italy, UK, Japan, and Thailand, along with organizations like UNICEF and WHO. This networking led to additional research grants from UNICEF, the Military Health Institute, JSPS Japan, the Medical Research Council UK, and the Indonesian Ministry of Higher Education, Research, and Technology. Several publications resulted from these collaborations, with more pending submission.

The team closely communicated with governmental organizations, including the MoH, Provincial Health Office (PHO) of South Sulawesi and West Sulawesi, and District Health Office (DHO). These agencies helped implement study results, significantly reducing dengue incidence in Makassar City by 83%. An agreement was made with PHO of South Sulawesi to use Hasanuddin University labs as referral laboratories for infectious disease outbreaks. The team provided training on mosquito-borne disease diagnostics and vector surveillance to health officers, military health staff, and other stakeholders. The MoH appointed the team as panel experts for vectors and malaria, while PHO of South Sulawesi and DHO Makassar City appointed them as consultants for vector-borne diseases. The team's research activities also influenced the medical faculty to support medical research, involve undergraduate students, increase research grants, and build a new molecular lab for infectious tropical diseases and animal experiment

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Syafruddin, D., et al. (2014). Impact of a spatial repellent on malaria incidence in two villages in Sumba, Indonesia. The American Journal of Tropical Medicine and Hygiene, 91(6), 1079-1087. https://doi.org/10.4269/ajtmh.13-0735

INDONESIA – PROJECT WMSG2-008: ASSOCIATION BETWEEN BURDEN OF MEDICINE AND THERAPY ADHERENCE AMONG MULTI-DRUG RESISTANT TUBERCULOSIS PATIENTS IN WEST JAVA, INDONESIA

PI: Melisa Barliana, Universitas Padjadjaran

Dates: February 2022 - July 2023

PROJECT OVERVIEW

As the country with the second-highest tuberculosis burden in the world, Indonesia needs rigorous research and improved efforts in tuberculosis care, drug surveillance, drug development, diagnostics, and prevention. A rise in multi-drug resistant tuberculosis (MDR-TB) complicates efforts, as it requires prolonged therapy with medication with side effects that can lead to disability, limiting patient adherence.

The researchers in this project conducted a mixed-methods study about the burden of medication for MDR-TB in West Java, Indonesia. The quantitative study sought to analyze the burden of medicine among MDR-TB patients and the association of that burden on therapeutics adherence among MDR-TB patients. A qualitative study aimed to understand the factors MDR-TB patients perceived as a medication-related burden.

The PI also developed a mentorship component for project members, coaching them on academic writing and holding discussions on research design, quantitative data analysis, and qualitative study techniques.

FINAL SUMMARY OF PROJECT ACTIVITIES

All research was undertaken at the MDR-TB Clinics of Hasan Sadikin General Hospital, Bandung, a tertiary referral hospital in West Java. The study observed a major burden due to MDR-TB medication, even in adherent patients. While side effects of the medication were the most often complained about, lack of autonomy reached the highest burden score. Age and side effects were significantly associated with medication-related burden. However, perceived burdens and barriers were only one of five areas affecting how patients behave toward medication. The researchers assert that the health belief model (HBM), where burdens are determined by sociodemographic background and patient characteristics, explains why patients kept adhering to the therapy even though it was burdensome. The perceived benefit of taking medicine would counter the perceived burden, as well as perceptions about disease susceptibility and severity and external factors that may cause patients to adhere to treatment.

The team recommends that healthcare workers, especially pharmacists, can deliver better patient-centered care by collaborating with other care workers and better responding to and respecting patients. A pharmacist has the potential to provide meaningful improvement for MDR-TB patient care, as they have the knowledge to undertake intensive monitoring of drug side effects, counsel patients on the medication with empathy and emotional support, and educate patients on the disease, appropriate drug use, and management of side effects.

The team shared their findings in a seminar and published two review articles, and they have additional articles in review. Mentees in this project took part in poster presentations on this work and completed degrees and theses during the project period.

PUBLICATIONS

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INDONESIA – PROJECT WMSG2-009: SPINAL TUBERCULOSIS IN INDONESIA: FIVE-YEAR EPIDEMIOLOGY, RISK FACTORS AND QUALITY OF LIFE OUTCOMES

PI: Astri Ferdiana, Department of Public Health Faculty of Medicine, University of Mataram and Gadjah Mada University, Indonesia

Dates: February 2022 - May 2023

PROJECT OVERVIEW

Spinal tuberculosis is an infection of the spine by the bacteria Mycobacterium tuberculosis that causes destruction and deformities of the bones. If not detected and treated, it can lead to permanent disability due to paralysis of the lower extremities. This condition accounts for 50% of tuberculosis in the musculoskeletal system and 2% of all tuberculosis cases. Due to its nonspecific signs and symptoms, many cases are diagnosed late.

This PEER project aimed to describe the epidemiology of spinal tuberculosis, identify the characteristics of persons with spinal tuberculosis in Indonesia, and explore the perceptions of persons with spinal tuberculosis about their condition, including the reasons for delaying seeking treatment. Identifying risk factors for spinal tuberculosis is essential to reach those most susceptible so that proper educational campaigns can be designed and early interventions can reduce the risk. Information on risk factors also helps increase the vigilance of healthcare professionals in suspecting spinal tuberculosis earlier in patients presenting with relevant symptoms. The mixed-method study was conducted in five provinces in Indonesia.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team used a retrospective review of medical records, a cross-sectional survey, and in-depth interviews to develop their findings. They collected and analyzed data from the 2017-2021 medical records of patients diagnosed with spinal tuberculosis from three national hospitals in Indonesia that provide care for spinal diseases. Data from two additional hospitals were delayed despite obtaining ethical clearance and administrative letters. A total of 673 medical records were retrieved and reviewed. Researchers contacted patients who lived within 20 km of the hospitals for a follow-up survey and exam; however, the response rate was low, with only 58 patients participating.

The researchers also conducted in-depth interviews with 15 patients with spinal tuberculosis. They plan to develop two manuscripts for publication and share their work at the Asia Pacific Region Conference of the International Union Against Tuberculosis and Lung Disease (APRC 2024). The PI, Dr. Ferdiana, participated in the August 2022 meeting of SPINE20 in Bali, and a mentee presented at the International Conference for Tropical Medicine. Additionally, the PI and a mentee delivered a well-received module on disability for undergraduate medical students at Universitas Mataram. Dr. Ferdiana has been appointed as the national coordinator for the international survey on spinal cord injury in Indonesia and was promoted to assistant professor.

This project also involved a series of professional development trainings for the research team and related mentees, including sessions on academic writing, research methods, ethics, and protocols for conducting basic physical examinations for testing neurological deficits.

INDONESIA – PROJECT WMSG2-006: THE EFFECTIVENESS OF THE MOBILE NURSING CENTRE AND DETERMINANTS FOR TB CARE AND PREVENTION USING TELEHEALTH AND TELENURSING APPROACH TO REDUCE STIGMA OF TB AND COVID-19 IN WEST JAVA INDONESIA

PI: Dr. Neti Juniarti, Universitas Padjadjaran, Indonesia

Dates: February 2022 - February 2023

PROJECT OVERVIEW

Indonesia has among the highest number of TB patients in the world, and the COVID-19 pandemic had a damaging impact on access to TB diagnosis and treatment, especially given socioeconomic factors and uneven distribution of services. Active case finding and outreach TB management in the community are important but are influenced by social stigma in society. Stigma, alongside financial factors, also impact noncompliance with TB treatment. Community health nurses can contribute to the active case finding and outreach in the community, including the Nursing Center (NC) model. The NC model includes a set of nurse-led interventions that integrate community health nursing services, education and research, and community engagement by empowering all resources in the community. The PI has been developing this model since 2002, but she found that face-to-face activity in the nursing centers was reduced significantly during the pandemic.

This PEER research project sought to understand how people in rural areas can access TB services and community support without feeling stigmatized, as well as to understand the determinants of successful telehealth and telenursing for TB patients during the pandemic. The researchers developed and validated a culturally sensitive social stigma scale for COVID-19 and TB specific to Indonesia, surveyed community leaders and health leaders on telehealth and telenursing and tested the effectiveness of different stigma interventions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team validated their social stigma scale for TB through an online questionnaire administered to nearly 1,000 respondents from 26 subdistricts in the Sumedang District. The researchers also interviewed 26 community leaders and 28 people in charge of the TB program at 28 community health centers. They discussed qualitative measures of TB response, the NC model, and telehealth. Among their findings from those discussions was a preference for direct communication from nurses in rural areas, rather thanthrough websites or apps. Stigma reduction can help Indonesia increase active case detection rate, which can help find TB patients at an early stage so that the spread of TB can be prevented as early as possible. This can help communities prevent and manage TB without fear or prejudice toward the disease. However, further research is needed to improve the intervention using videos and posters to reduce the stigma of TB in broader society.

The research team published three conference papers and have further academic articles under review. They also developed policy recommendations on how to use video and posters to reduce social stigma of TB. Five young female scientists Universitas Padjadjaran were mentored as part of this program on research and academic writing. The team also hosted two workshops on using secondary data from Community Health Centers in research.

INDONESIA - PROJECT WMSG2-007: PARENTS' KNOWLEDGE, ATTITUDE, AND HEALTH SEEKING BEHAVIOR TOWARDS CHILDHOOD TB DURING THE COVID-19 PANDEMIC

PI: Windy Rakhmawati, Universitas Padjadjaran, Indonesia
Dates: February 2022 - January 2023

PROJECT OVERVIEW

Indonesia ranks second globally for tuberculosis (TB) burden. During the COVID-19 pandemic, recommendations for people to stay at home reduced community-wide transmission of COVID, but may have facilitated household transmission of TB. Prolonged contact in the household is a risk factor for TB transmission. Inadequate social protection, health insurance, economic contraction, and loss of income, particularly among the most vulnerable, exacerbate TB prevalence, especially malnutrition. Stigma and fear of COVID-19 infection in healthcare facilities, along with similarities in clinical features of TB and COVID-19, might discourage people from visiting TB services, delaying diagnosis and treatment. Studies show a higher prevalence of TB among children living with adult TB patients compared to the general population. Diagnosing TB in children is challenging due to their immature immune systems, and lack of knowledge and awareness interferes with prompt diagnosis and treatment adherence.

This PEER project aimed to identify parents' knowledge about their child's TB diagnosis, parental attitudes towards child TB, and health-seeking behavior during the COVID-19 pandemic. The project also included a mentoring component, where the PI facilitated the personal and career development of junior women researchers.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers surveyed 392 parents with children diagnosed with TB. Most respondents were unemployed, lacked health insurance, lived 1-5 kilometers from a health facility, and had children aged 1-3 years with TB. Just over half had good overall knowledge of TB, but nearly half had poor knowledge of TB causes, risk factors, symptoms, and signs. Nearly 90% of respondents had good knowledge of TB treatment.

Most respondents considered TB a very serious disease, knew they could contract it, and would inform doctors and health workers about their child's TB status. Almost all (92.4%) respondents took their children with TB symptoms to government health facilities. Financial constraints, difficulties with vehicles or distance to the clinic, and uncertainty about seeking medical help were the main reasons for delays in seeking treatment.

Dr. Rakhmawati mentored two junior female researchers at the university, who actively participated in data collection and analysis. The PI organized monthly meetings to discuss their abilities, needs, and challenges in the research project, covering topics such as time management, writing grant proposals, presentation skills, work-life balance, publishing internationally, and expanding professional networks. The mentees have applied for a national grant in Indonesia to conduct new research.

INDONESIA - PROJECT WMSG2-002: STRENGTHENING COMMUNITY TO RECOGNIZE AND PREVENT TUBERCULOSIS AND DIABETES MELLITUS (SCREEN TB-DM) AMONG INFORMAL WORKERS

PI: Dr. Vitri Widyaningsih, Universitas Sebelas Maret, Indonesia

Dates: February 2022 – July 2023

PROJECT OVERVIEW

In Indonesia, 72% of the workforce operates in the informal sector. Informal workers are more likely to live in poverty and have unhealthy behaviors, with higher chances of being exposed to work and home environments that might increase the risks for TB, and higher odds of unhealthy behaviors. Studies on factors related to diagnosis and treatment outcomes for this population are also limited. Screening for tuberculosis and diabetes mellitus in informal workers is likely to be beneficial to improve case finding of these diseases. Hence, it is important to improve the workers' awareness on their health, including recognizing TB-DM symptoms and taking preventive measures through healthy behavior. Self-screenings and interventions in the workplace can reduce the physical and economic burden of non-communicable diseases. For informal workers, this can be conducted through the Occupational Health Post (OHP), which is a community-based program runs by workers focusing primarily on occupational health. As OHP is run by informal workers within their own workplaces, there is an opportunity to continue its activities and incorporate TB-DM awareness into the program.

The aim of this PEER project was to assess the feasibility of integrating screening for TB-DM in the OHP program and to develop a model to involve informal workers like farmers groups as a potential target population. As part of this project, the researchers identified the prevalence and determinants of TB-DM comorbidities and developed a community-based model for TB-DM screening in informal workers. The PI and team recruited several fellows, research assistants, and students to be part of this project, developing a strong collaborative team of younger researchers who completed degrees or achieved new academic or career milestones.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers analyzed the comorbidity of TB, DM, and hypertension (HT) through the 2014 Indonesian Family Life survey, using data from more than 30,000 adults. They found that the prevalence of TB-DM comorbidity was 0.1%, DM-HT comorbidity 3.77%, and TB-HT comorbidity 0.35%. The majority of respondents who had TB with DM and HT comorbidity were men over 45 years old with an educational level of primary school or lower, were past smokers, overweight, lived in urban areas with adequate ventilation, and had more than three household members.

The team then did a situation analysis of TB-DM, particularly screening for informal workers. They identified challenges such as societal stigma causing fear of income/job loss, inadequate integrative TB-DM screening for informal workers, lack of policies and health data pertaining to informal workers, and scheduling discrepancies between the health workforce and informal workers. Opportunities included empowering cadres and fostering cross-sector collaboration, including the establishment of a worker health unit (UKK) that effectively engages informal workers in health interventions.

Dr. Widyaningsih and her colleagues held a stakeholder meeting to discuss development of the SCREEN TB-DM model and undertook a literature search on validated tools for screening for symptoms for Tuberculosis and Diabetes Mellitus. Their model included a screening tool card for TB-DM screening in informal worker settings; an information sheet on TB-DM, its prevention, risk factors, and complications; a flipchart; and a full screening module. They piloted the model in two communities in Central Java, Indonesia, and conducted training for cadres and selected farmer groups. The training was also attended by primary health care workers, which improved the sustainability of this project. In this training, the farmers learned about tuberculosis, diabetes mellitus, and hypertension and were taught to assess health status using screening tools and use the equipment that supports the exams. The aim is to have farmers screen their own health status during routine gatherings.

The team presented their work at several conferences including the International Conference on Public Health for Tropical and Coastal Development; the International Conference on Health, Technology, and Life Sciences; and the Indonesia Tuberculosis International Meeting.

PUBLICATION

V. Widyaningsih, R.P. Febrinasari, V. Sari, C. Augustania, B. Verlita, C. Wahyuni, B. Alisjahbana, A. Santosa, N. Ng, and A. Probandari. 2022. Potential and challenges for an integrated management of tuberculosis, diabetes mellitus, and hypertension: A scoping review protocol. PLoS ONE 17(7): e0271323. https://doi.org/10.1371/journal.pone.0271323

KAZAKHSTAN

KAZAKHSTAN - PROJECT 9-472: THE EVALUATION OF CHALLENGES OF YOUTH IN KAZAKHSTAN AND PILOTING INNOVATIVE SOLUTIONS

PI: Alima Ibrasheva, Nazarbayev University Graduate School of Education
U.S. Partner: James Cox, Georgia State University (Funded by the National Science Foundation)
Dates: April 2021 – March 2023

PROJECT OVERVIEW

Over the last 20 years, the number of NEET youth (youth who are not in education, employment, or training) has decreased, and the government of Kazakhstan has taken significant measures to regulate and institutionalize youth policies regarding NEET youth, including large-scale government programs to provide systematic support for free education, employment after graduation, business creation, and mentorship assistance for young people in the workplace. However, these programs are undermined by the difficulty of identifying and defining NEET youth in the country. While the methodology is still in development, it is difficult to identify and communicate with youth outside the official tracking system. Approaches used to study this group of young people have so far not been aimed at a deep understanding of their values, needs, and motivations, which creates certain barriers to developing effective interventions for NEET youth. There is also a lack of understanding of large regional and gender differences in the share of NEET youth across the country.

This project aimed to reduce the number of NEET youth by creating recommendations on increasing the efficiency of prevention, outreach, and reintegration policies of the Kazakhstani government. The researchers applied qualitative methods and a literature review to understand the challenges faced by NEET youth in Kazakhstan and implemented innovative methods of experimental economics (laboratory and field experiments) to test various hypotheses and potential solutions. By conducting a thorough review in the global context, the project proposed a better methodology to define NEET, suggest ways to reach out to NEET youth, and work to elevate the importance of the issue in the national Kazakhstani policy agenda.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project team conducted 25 initial surveys with NEET youth stakeholders, and one researcher undertook a literature review on NEET interventions across 23 countries. Their initial analysis identified some of the main indicators affecting NEET youth: lack of information about employment opportunities, lack of willingness to take on low-prestige blue collar jobs, and low trust in governmental initiatives, among others. Key members of the team made an exchange visit to Georgia State University, where they were able to practice and design field experiments with assistance of their U.S. partners on the GSU experimental team.

Following additional data gathering through focus groups and an adjustment to the researchers' recruitment strategy, the team undertook a lab experiment where young people were divided into three groups and where they chose white collar versus blue collar jobs under varying wages and scenarios to indicate the discount potential workers put on low-prestige jobs and the impact of peer pressure on job selection.

The researchers also performed a field experiment to test the impact of the information gap on government programs on NEET youth. They sent text messages to selected groups of NEET youth containing information about government programs, particularly those listed on the website Enbek.kz, and surveyed them at the end of the intervention on social and demographic issues, as well as questions to assess their awareness of the program and whether they signed up.

The PEER team presented their results in a conference hosted by Nazarbayev University, in technical presentations, and to Kairat Baimuldinov, chairman of the Youth and Family Committee at the Ministry of Information and Social Development.

KAZAKHSTAN - PROJECT 9-38: THE EFFECTS OF EXCESSIVE WATER USE AND AGRICULTURAL INTENSIFICATION ON ARAL SEA SHRINKAGE: SES DYNAMICS WITHIN THE SYR DARYA RIVER BASIN

PI: Maira Kussainova, Kazakh National Agrarian University
U.S. Partners: Ranjeet John, University of South Dakota, and Jiquan Chen, Michigan State University (Funded by the National Aeronautics and Space Administration)
Dates: April 2021 – December 2023

PROJECT OVERVIEW

One of the most dramatic changes in the Earth's surface over the past six decades has been the shrinking of the Aral Sea in Central Asia. This PEER project focused on the causes of reduced stream flows through analysis of land cover trends, agricultural development, water withdrawals, irrigation intensity trends, population density, economic development, and policy shifts. Concepts, principles, and methods from socioeconomic-environmental systems (SES) were applied for three districts (Aralskiy, Syrdariya, and Zhanakorganskiy) along the Syr River, the largest tributary for water supply to the shrinking Aral Sea. The long-term goal is to build a comprehensive database and knowledge to understand physical and socioeconomic changes, as well as their consequences on the ecosystems and societies within the Syr Darya River basin.

The PI Dr. Kussainova and her team sought to explore interdependent changes of food, energy, and water fluxes for the three districts with high-resolution data to understand of coupled changes between climate and land use, identify critical drivers (including policy shifts) on stream flows and evapotranspiration loss, as well as construct an open-access webpage to share data and findings with the public. The research team integrated databases from multiple sources, including satellite images, government statistics, past ground measurements, and their own field measurements, including the installation of three automatic weather stations and extensive surveys of the landscapes in Kyzylorda, which will fill some major data gaps.

The project is built upon the team's past research in the Aral region, including an ongoing project on the food-water-energy nexus of Kazakhstan (working with NASA and USDA/ARS) and curriculum development for more than five universities in Kazakhstan (in conjunction with the American Council).

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted research on soil environmental issues, including the measurement of greenhouse gas concentrations in soil and the development of innovative methods for water use analysis in irrigation practices. The researchers collected soil samples from various agricultural sites across Kazakhstan and conducted comprehensive analyses to measure greenhouse gas concentrations in the soil.

On the outreach side, the PEER team organized capacity building workshops and training sessions for local farmers, agricultural extension workers, and policymakers to disseminate research findings and provide practical guidance on sustainable agricultural practices, soil conservation, and environmental management. The group also engaged with policymakers and government agencies to advocate for the integration of the findings into agricultural and environmental policies, including presenting their research findings at policy forums, workshops, and conferences.

During the project, the PEER team introduced several new courses and made changes to existing course curricula, including a new course titled "Sustainable Agriculture and Environmental Conservation," which incorporates the latest research findings and methodologies from the PEER project. They also met with farmers and heads of peasant farms who focus on crop production and animal husbandry, as well as local agricultural departments and representatives of the higher educational universities in the Kyzylorda Region.

As part of the project, the PI made two extended collaborative visits to her U.S. partners, spending October-December 2021 at the University of South Dakota and August-October 2022 at Michigan State University (MSU). During her stays, she worked with her counterparts to use archival data from libraries, various literature, and data from the statistical bureau of Kazakhstan to analyze causal and non-causal relationships between the elements of the biophysical matrix and socioeconomic variables. Dr. Kussainova was awarded a Fulbright research visiting fellowship for the 2023-2024 academic year at MSU.

PUBLICATIONS

М.Д. Кусаинова, Т.Б. Таменов, М.Р. Тойшиманов, Ә.Б.Сыздық, Г. Искакова, Н.Д. Нұрғали. 2023. Динамический мониторинг ndvi в агрономических испытаниях агро культур с использованием беспилотного летательного аппарата [Dynamic monitoring of NDVI in agronomic testing of agro crops using an unmanned aerial vehicle]. Вестник науки Казахского агротехнического исследовательского университета им. С. Сейфуллина [Science Journal of the S. Seifullin Kazakh Agrotechnical Research University] 2(117): 148-161. https://doi.org/10.51452/kazatu.2023.2(117).1386

M. Kussainova, M. Toishimanov, T. Tamenov, A. Syzdyk, and Jiquan Chen. 2023. Изучение эффективности различных систем землепользования для смягчения климата посредством измерения эмиссии парниковых газов [Studying the climate mitigation efficiency of various land-use systems by measuring greenhouse gas emissions]. Central Asian Journal of Water Research 9(2): 17-34. https://doi.org/10.29258/CAJWR/2023-R1.v9-2/17-34.rus

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F. Salehi and M. Kussainova. 2023. Assessment of the soil erosion and water quality state in the downstream portion of Syrdarya using the water quality index arithmetic method. Soil Science and Agrochemistry 4:95- 107. https://journal.soil.kz/jour/article/view/820/711

F. Salehi and M. Kussainova. 2023. Assessment of interdependent changes of NEXUS fluxes on the impact of climate change and land use on the example of the districts along the SyrDarya. 2023. Ізденістер, нәтижелер – Исследования, результаты 3(99): 171-180. https://doi.org/10.37884/3-2023/18

KAZAKHSTAN – PROJECT 5-236: SATELLITE ENHANCED SNOWMELT FLOOD AND DROUGHT PREDICTIONS FOR THE KABUL RIVER BASIN WITH SURFACE AND GROUNDWATER MODELING

PI: Jay Sagin, Nazarbayev University, with co-PIs Mohammad Najaf (Deceased), Kabul Polytechnic University (Afghanistan), and Muhammad Abid, COMSATS (Pakistan)

U.S. Partner: Jennifer Jacobs, University of New Hampshire

Dates: March 2017 – December 2020

PROJECT OVERVIEW

The overall objectives of this research were to develop (1) the Kabul River Basin (KRB) flood prediction models using NASA satellite observations that capture the magnitude, timing, and spatial distribution of watershed scale parameters; and (2) combined surface and ground water modeling and prediction analyses. The project aimed to develop the integrated surface and groundwater modeling for the transboundary (Pakistan upstream and Afghanistan downstream) KRB with satellite enhanced snowmelt flood and drought predictions. The researchers applied advanced NASA satellite data to track snow, snow melting, floods, surface water coverage, and droughts over the KRB. They adapted cost-effective approaches using remote sensing data, with expertise provided by the U.S. partner Dr. Jacobs, based on her experience working on the NASA-supported project "Satellite Enhanced Snowmelt Flood Predictions in the Red River of the North Basin, USA." A lack of accurate snow depth and snow water equivalent data and a lack of understanding of snowmelt processes and soil infiltration during soil freeze and thaw events in the KRB inhibit the ability to improve flood predictions. This project team worked to improve the models by using satellite observations that capture the magnitude, timing, and spatial distribution of watershed-scale snowmelt parameters, as well as antecedent soil conditions. Most of the existing water-related research models were developed with separate components for the surface water and the groundwater, but this project combined them into a more comprehensive model, which should facilitate better prediction analyses.

Beyond the capacity building impacts for project participants and improved modeling technologies, the project promoted better regional transboundary water cooperation outside of high-level intergovernmental channels by providing a platform for interactions among academia and community-level water management structures from Afghanistan, Kazakhstan, Pakistan, and the United States. University-led forums were be organized to promote improved sustainable management of shared water resources within the context of climate change in Central and South Asia.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project accomplished its goals to develop Kabul River Basin flood prediction models, and combined surface and ground water modeling and prediction analyses. The research outputs were shared with local stakeholders and published in a series of published in a series of 12 peer-reviewed articles. The data and conclusions are also available on the project website, as is a list of over 30 early career researchers who received training and practical experience in water resources, and set up the regional cooperation network with the joint publication works.

The research outputs were also adapted for the user friendly localized TVET (Technical and Vocational Education and Training) programs and used for training purposes. The TVET support program will continue, and at the time the final report was submitted, the project team was planning to set up a similar support program in cooperation with the Central Asia University Partnerships Program (UniCEN) and the Know Your Well program run by the University of Nebraska Lincoln.

Moving forward, the project team will continue its work under the International Partnerships for Sustainable Innovations program. They are also expanding the practical applications of the research outputs and are in negotiations with the U.S. Valmont Valley Corporation, which is planning to build irrigation factories in Central Asia. These sophisticated irrigation technologies require proper water resource studies in Central Asia, including Afghanistan but the countries are currently missing the proper irrigation TVET support programs. The project team hopes to connect their established partnership and USAID PEER research work outputs to the irrigation education program, and eventually prepare the user-friendly TVET support programs for farmers in Central Asia.

PUBLICATIONS

Hussain Ali Jawadi, Hasan Ali Malistani, Mohammad Anvar Moheghy, and Jay Sagin. 2021. Essential Trace Elements and Arsenic in Thermal Springs, Afghanistan. Water 13, 134. https://doi.org/10.3390/w13020134

Muhammad Abid, Umer Muhammad, and Zaineb Abid. 2021. Potential of floating photovoltaic technology in Pakistan. Sustainable Energy Technologies and Assessments 43, 100976, https://doi.org/10.1016/j.seta.2020.100976

Muhammad Abid, Zaineb Abid, and Umer Muhammad. 2021. Floating Photovoltaic System Technology—Prospects of Its Implementation in Central Asian, South Asian and South East Asian Region. Chapter in Energy and Environmental Security in Developing Countries: Advanced Sciences and Technologies for Security Applications. Springer, Cham. https://doi.org/10.1007/978-3-030-63654-8_26

Zaineb Abid and Abid Muhammad. 2021. Effects of Climate Change on Women—Adaptation and Mitigation. Chapter in Energy and Environmental Security in Developing Countries: Advanced Sciences and Technologies for Security Applications. Springer, Cham. https://doi.org/10.1007/978-3-030-63654-8_20

Hussain Ali Jawadi, Jay Sagin, and Daniel D. Snow. 2020. A Detailed Assessment of Groundwater Quality in the Kabul Basin, Afghanistan, and Suitability for Future Development. Water 12, 2890. https://doi.org/10.3390/w12102890

Muhammad Hasan Ali Baig, Muhammad Abid, Muhammad Roman Khan, Wenzhe Jiao, Muhammad Amin, and Shahzada Adnan. 2020. Assessing Meteorological and Agricultural Drought in Chitral Kabul River Basin Using Multiple Drought Indices. Remote Sensing 12, 1417. https://doi.org/10.3390/rs12091417

KYRGYZSTAN - PROJECT 5-519: INTEGRATED WATER RESOURCES MANAGEMENT AND STRATEGIC ENVIRONMENTAL ASSESSMENT OF KABUL AND AMUDARYA RIVERS

PI: Zheenbek Kulenbekov, American University of Central Asia
U.S. Partner: Forrest Melton, California State University Monterey Bay, and the NASA Ames Research Center Cooperative for Research in Earth Science and Technology (NASA ARC-CREST)
Dates: December 2016 – February 2020

PROJECT OVERVIEW

Afghanistan has highlighted the need for improved water resource management as an essential first step towards rebuilding rural communities and improved human health. Food security in Central Asia and Afghanistan also represents a major and worsening problem. The agricultural sector will be an important focus for upgrading human capital skills, given the size of the rural population. The aim of this research project was to lift Afghanistan out of the identified knowledge gap on its water resources and remove existing barriers to sustainable integrated water resource development and management (IWRM) in the Amu Darya Basin, as well as promoting strategic environmental assessment. At the same time, the project aimed to provide transparency on the potential impact of integrated water resource development plans and ongoing projects to downstream riparian states, as well as the donor community. Because of its international position, American University of Central Asia took the lead in data generation and analysis on the project and collaborated with research and implementing agencies in Afghanistan, Tajikistan, and Kyrgyzstan.

The purpose of this project was to close the knowledge gap on water resources and potential irrigated areas within three sub-basins of the Amu Darya Basin within Afghanistan, as well as to help determine the legal obligations of Afghanistan to its riparian neighbors. The closure of this gap should help Afghanistan and the donor community to plan their sustainable water development and environmental assessment strategies and projects. The project research team worked to assemble a dataset on water availability, changes in irrigated areas, and the irrigation potential in the three target sub-basins. They also developed a model of impacts of ongoing rehabilitation projects in Afghanistan on lower provinces within the tributary basins, as well as riparian states within the Amu Darya Basin. They aimed to provide an array of cost-effective tools to agricultural producers in the three sub-basins of the Amu Darya River Basinto assist them with optimizing irrigation scheduling and maximizing crop yields with the water available each year. In addition, they developed new tools for quantifying and forecasting irrigation demand to water managers in order to help schedule water deliveries to growers effectively.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over three years the project team successfully completed its planned objectives and closely followed the established timeline of activities. Automatic weather stations were set up in the target villages to have ground data and two field trips were conducted annually to the study areas for in-situ investigations and analysis of water and soil samples. A socioeconomic survey was also conducted in the study areas to accurately understand the day-today lives of local people including the types of crops cultivated, types of livestock bred, yield and quality of crops and domestic animals, level and usage of modern techniques and equipment in agricultural irrigation and animal husbandry, and use of contemporary technologies at schools and local administrations. Vegetation index correlation with weather data of research areas was performed using satellite images for NDVI calculations that helped the team identify plant stress in the target areas. A variety of thematic maps in 2D and 3D were designed using remote sensing and GIS tools to support regional projects. Hydrological modeling to calculate runoff of the studied rivers was still ongoing at the time project ended.

Three theses at the bachelor's level were written and defended successfully under the auspices of the project with two others ongoing. One PhD student was also supported. Several scientific papers based on outcomes of partnering teams in three partner countries were published in peer reviewed conference proceedings and international journals. Illustrated and informative brochures and leaflets about the research achievements of each partner country were published and disseminated among appropriate regional centers, universities, local administrations, NGOs, and high schools to inform stakeholders and decision makers.

The regional project enabled the team to collaborate with many research institutions and local and international organizations including the National Academy of Sciences of each partner country, UNDP, CAREC, CAIAG, CARAWAN, ECOIS, Kyrgyz State Agency for Water Resources, local administrations, Move Green, IWMI, ICRAFT, ISTC, BGI, USAID, BRI Kazakhstan, the US Embassy Kazakhstan, and international universities. Three regional workshops were hosted in partner countries including one workshop at the partner institution which provided information for local stakeholders including relevant state agencies, local authorities, institutions, and NGOs. The final international conference called "Current and Future State of Water Resource Management and Environment in Central Asia" was hosted by AUCA and had stakeholder participants from the United States, Europe, Japan, Russia, Afghanistan, Tajikistan, Uzbekistan, Kazakhstan, and Kyrgyzstan.

(Sadly, Dr. Kulenbekov passed away on September 23, 2022, at the age of only 56.)

PUBLICATIONS

Zheenbek E. Kulenbekov and Bakhtiyar D. Asanov, eds. 2021. Water Resource Management in Central Asia and Afghanistan: Current and Future Environmental and Water Issues. Springer Water. https://doi.org/10.1007/978-3-030-68337-5

Zh. Kulenbekov, S. Orunbaev, B. Asanov, and B. Sharipov. Vegetation Stress Study in Chon-Alai Area Using NDVI, Kyrgyzstan. TEST Engineering and Management 81: 5062-5084.

M. Avazbekova, A. Aitbaev, Zh. Kulenbekov, M. Nurgaziev, and B. Asanov. 2019. Environmental and Socio-Economic Assessment of Vulnerable Villages in Kyrgyzstan. Comparative Analysis of Kuntuu, Boroldoi, Oirondu and Daroot Korgon Settlements. Proceedings of the IX International Scientific and Practical Conference Social and Economic Aspects of Education in Modern Society Vol.2, January 20, 2019, Warsaw, Poland.

KYRGYZSTAN - PROJECT 4-454: WATER RESOURCES RESPONSE ON GLACIER DYNAMICS IN CENTRAL ASIA TRANSBOUNDARY RIVER BASINS

PI: Tamara Tuzova, Institute of Water Problems and Hydro Power of the National Academy of Sciences of Kyrgyzstan

U.S. Partner: David Watkins, Michigan Technological University (Funded by the National Science Foundation)

Dates: December 2015 – May 2019

PROJECT OVERVIEW

The water resources system in Central Asia is under stress. The water supply from seasonal snow and glacial melt is and will be impacted by climate change, and water demands will continue to increase with population growth and land use change. There are also gaps in hydrological measurements and related data following the disintegration of the USSR. This PEER project aimed to deliver important information about long-term climate and glacier-water resources changes in a major transboundary river basin of Central Asia, specifically the Amu Darya River basin and its tributaries in Tajikistan and Kyrgyzstan.

The researchers gathered data on Central Asia deglaciation during the Holocene based on the glacial moraine physical stratigraphy and isotope-chemistry analyses, seeking to understand the past and possible future scenarios of deglaciation and water resources change under global and regional climate change impacts. They compared data in this project with existing paleoclimate records from ice cores in the Altai, Tien Shan, Pamir, Kunlun, Tibet, and the Himalayas, to gain a better understanding of historical Asian climate variability. Analysis of the modern and Holocene data will help predict possible water resource changes in the future and evaluate adaptation options that respond to environment requirements, agricultural and urban demands, ecosystem services, and flood management.

FINAL SUMMARY OF PROJECT ACTIVITIES

Hundreds of water, melted snow, and ice samples were collected for uranium isotope analysis from the source areas of mountain river basins in the Northern Tien Shan (Chon-Kyzylsu, Kumtor, Kadjisai, Issyk-Ata, Alamedin, and Ala-Archa), Central Tien Shan (Naryn, Kara-Darya), Pamir-Alai (Kyzylsuu-Muksu-Surkhob-Obikhingou-Vakhsh, Varzob) and Pamir (Gunt-Panj). Dr. Tuzova and her colleagues used uranium isotope ratios in the samples to characterize a range of physical and chemical processes in natural aqueous ecosystems, including studying glacier contribution to the streamflow of various mountainous transboundary rivers in Kyrgyzstan and Tajikistan.

Uranium isotope ratios were also used to track the water movement dynamics and predict lake outburst floods that can be caused by melting of seasonal snowpacks or old ice. As evidenced by a number of high-altitude lakes in the Northern Tien Shan, the higher total uranium content and the greater the isotope disequilibrium in the water, the more likely that the lake will outburst. The forecasts made using this method have been verified in practice, and the PEER team recommends that the uranium isotope composition of ice and water in moraine and glacier complexes be monitored on a regular basis as a part of glacial lake outburst flood hazard assessments. The U.S. partners at the University of Colorado, Boulder also compared the uranium isotope data with water specimens of the same rivers using the ratios of other stable isotopes, and found they were compatible with the results of uranium isotope analysis.

The selected methods were field tested as part of a regional training program for geology students of the Tajik National University and Tajik branch of the Moscow University. A total of 48 people were trained on how to collect and prepare samples for isotope analysis.

The researchers also developed a preliminary forecast of glacial (and therefore climatic) changes for Central Asia. The PEER team published more than 100 peer-reviewed papers and proceedings on their findings, including presentations at international conferences. Researchers on the project built close ties with nine nongovernmental organizations and 14 research institutes specializing in water, climate, and environmental problems, allowing them to hold a range of field and laboratory workshops, and international symposiums on innovative isotopic methods of hydrological research.

PUBLICATIONS

Due to the large number of papers and proceedings produced, it is not possible to include all citations on this page. Major English-language publications are listed below:

V. Zaginaev, D. Petrakov, S. Erokhin, A. Meleshko, M. Stoffel, and J.A. Ballesteros-Cánovas. 2019. Geomorphic control on regional glacier lake outburst flood and debris flow activity over northern Tien Shan. Global and Planetary Change 176: 50-59. https://doi.org/10.1016/j.gloplacha.2019.03.003

V. Zaginaev, K. Falatkova, B. Jansky, M. Sobr, and S. Erokhin. 2019. Development of a Potentially Hazardous Pro-Glacial Lake in Aksay Valley, Kyrgyz Range, Northern Tien Shan. Hydrology 6(1): 3. https://doi.org/10.3390/hydrology6010003

I. Matveyeva, F. Meiirman, N. Nursapina, B. Satybaldiyev, T. Tuzova, Z. Shalabayev, and B. Shynybek. 2019. Concentration of uranium isotopes by in-situ coprecipitation on activated coal and iron (III) hydroxide. Chemical Bulletin of Kazakh National University, Inorganic Chemistry 92(1): 4-11. https://doi.org/10.15328/cb1000

Sergey Aleksandrovich Erokhin, Vitalii Viktorovich Zaginaev, Anna Alexandrovna Meleshko, Virginia Ruiz-Villanueva, Dmitry Aleksandrovich Petrakov, Sergey Semenovich Chernomorets, Karina Saidovna Viskhadzhieva, Olga Valerjevna Tutubalina, and Markus Stoffel. 2018. Debris flows triggered from nonstationary glacier lake outbursts: the case of the Teztor Lake complex (Northern Tian Shan, Kyrgyzstan). Landslides 15(1): 83-98. https://doi.org/10.1007/s10346-017-0862-3

R. Satylkanov. 2018. Ablation of Ice and Snow of Kara-Batkak Glacier and Its Impact on River Flow. Journal of Climate Change 4(2): 1–14. https://doi.org/10.3233/JCC-180009

Alice F. Hill, Cholpon K. Minbaeva, Alana M. Wilson, and Rysbek Satylkanov. 2017. Hydrologic Controls and Water Vulnerabilities in the Naryn River Basin, Kyrgyzstan: A Socio-Hydro Case Study of Water Stressors in Central Asia. Water 9(5): 325. http://www.mdpi.com/2073-4441/9/5/325

V. Zaginaev, J.A. Ballesteros-Cánovas, S. Erokhin, E. Matov, E. Petrakov, and M. Stoffel. 2016. Reconstruction of glacial lake outburst floods in northern Tien Shan: Implications for hazard assessment. Geomorphology *269*: 75-84. http://dx.doi.org/10.1016/j.geomorph.2016.06.028

MALDIVES

MALDIVES - PROJECT 4-463: CAN DROUGHT AND FLOOD HAZARD BE SKILLFULLY ASSESSED AT FINE SPATIAL RESOLUTIONS FROM COMBINING CONSTRAINED STREAMS OF OBSERVED, REMOTELY SENSED, AND MODEL PREDICTED DATA IN SRI LANKA AND THE MALDIVES?

PI: Piyasena Wickramagamage, Foundation for Environment, Climate, and Technology
U.S. Partner: Randall Koster, NASA Goddard Space Flight Center
Dates: October 2015 – March 2019

PROJECT OVERVIEW

Studies of the utility of drought and flood hazard indices indicate that a thorough depiction of hazard risks requires combined analysis of the co-variation of multiple meteorological and terrestrial variables such as rainfall, runoff, and soil moisture conditions. Current hazard estimations do not objectively combine separate indicators into an overall assessment of hazard risks and the impacts of climate variability. In countries such as Sri Lanka and Maldives there are severe constraints on real-time data availability. Such shortfalls can impair the reliability of and access to real-time hazard assessments if based entirely on one source of data. Freely available data from satellite estimates for soil moisture and prediction products from NASA and NOAA can be very useful, and field testing their accuracy in tropical locations should also help in validating them. This project involved expanding, testing, and implementing a hazard analysis framework for combining multiple terrestrial indicators to estimate the probability of drought and floods. This work built on studies of hazards, climate and land surface modeling, and disasters previously completed by the research team, some of it in cooperation with the U.S. Government-supported partner.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project goal was to develop operational drought, flood, and landslide hazard assessments using climate, terrestrial and societal information, and to assess drought and flood risk reliably in Maldives and Sri Lanka. In view of this, the team was able to obtain and set up data management systems for diagnosis or past disasters and has examined six significant past drought and flood disasters in Maldives and Sri Lanka and analyzed the role of climate and other factors. The team also set up monitoring systems for weather using 10 ground stations in Maldives and Sri Lanka and provided engagement and training on them. They set up tools for access to satellite data for Sri Lanka and the Maldives in real time. This data was cross checked with ground observed data. The team also set up three instruments for monitoring soil moisture in Maldives and Sri Lanka. These systems culminated in a system that compiles and digests the weather and climate predictions for Maldives and Sri Lanka, the results of which are now being provided to stakeholders and collaborators, along with the public on a weekly and monthly basis.

Through case studies and the monitoring systems, the team undertook a detailed study of information to support decision making for

- Island water budgeting
- Flood prediction without significant observation
- Drought monitoring based on satellite data
- Air quality impacts in an agricultural area affected by industry

Project Website: http://disaster.lk/

MONGOLIA

MONGOLIA - PROJECT 2-296: BUILDING RESEARCH AND TEACHING CAPACITY TO AID CLIMATE CHANGE AND NATURAL RESOURCES MANAGEMENT AT THE NATIONAL UNIVERSITY OF MONGOLIA

PI: Baatarbileg Nachin, National University of Mongolia
U.S. Partner: Amy Hessl, West Virginia University (Funded by the National Science Foundation)
Dates: August 2013 – December 2016

PROJECT OVERVIEW

Climate change affects a wide range of natural resources, including pasture, croplands, forests, and water, and it has increased the vulnerability of herders and those who live in remote forest areas of Mongolia. Effective solutions for problems related to climate change adaptation and natural resources management require well-coordinated, science-based national policies and priorities that are developed with the engagement of government stakeholders and civil society. Mongolia has limited human, technical, and financial capacities to address the multi-faceted threat caused by climate change. Institutions for higher education and research in Mongolia face difficulties in providing high-quality and relevant instruction and research, retaining staff, and ensuring adequate working environments and career prospects.

The PEER project sought to develop research capacity by collecting and analyzing data in the Central Khangai region, a typical Central Asian forest-steppe region in which climate change impacts are negatively impacting both the environment and socioeconomic development. Central Khangai has few environmental monitoring stations and limited records of past climate data, so the dendroclimatic data compiled as part of this project are urgently needed. Through training components and support for students to conduct their own research, the PEER project strengthened the institutional capacity and performance of the National University of Mongolia to deliver quality research.

FINAL SUMMARY OF PROJECT ACTIVITIES

Within this study, researchers examined the effect of aspects and slopes of sampled areas, soil types, and dominant tree species with vegetation on the litter layer and soil carbon stock in four different forest regions of Mongolia. The team undertook several field sampling trips, covering more than 50 sites and 1,500 cores. The wide data collection allowed for the development of master chronologies and other regression analyses to identify growth trends and hydro-climatic relationships. The researchers presented their results through peer-reviewed publications and several international conferences. The PEER team received four additional grants totaling about US $100,000 over the project period, including two from Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and one from the UN Food and Agricultural Organization.

Both the PI Dr. Nachin and co-PI Dr. Byambasuren Oyunsanaa won awards for Best Research organization by National University of Mongolia for three years of the project period, and the PI Dr.

Nachin was elected as a member of Mongolian Academy of Sciences based on his work regarding climate change and tree ring applications. Team member Byambagerel Suran and other graduate students established the Mongolian Tree Ring Society to share their experience and improve the application of tree ring sciences in Mongolia. The project provided research and training opportunities to 22 Mongolian students, half of them female. As an example of the impact the project had, three students began their work on the team as undergraduates and successfully obtained their Master's degrees based on their project research. All subsequently went on to pursue further postgraduate studies abroad. The project also built the Mongolian researchers' connections with not only the U.S. partners but also other international counterparts. PEER funds allowed Dr. Nachin and his team to take part in the 4th International Conference of the Asian Dendrochronological Association in Nepal in 2015 and to host the 5th International Conference in Mongolia in 2017.

PUBLICATIONS

Gerelbaatar Sukhbaatar, Batsaikhan Ganbaatar, Tsogtbaatar Jamsran, Battulga Purevragchaa, Baatarbileg Nachin, and Alexander Grade. 2020. Assessment of early survival and growth of planted Scots pine (*Pinus sylvestris*) seedlings under extreme continental climate conditions of northern Mongolia. Journal of Forestry Research 31(1):13–26. https://doi.org/10.1007/s11676-019-00935-8

Gerelbaatar Sukhbaatar, Byambagerel Suran, Baatarbileg Nachin, and Dugarjav Chultem. 2018. Effects of Scots Pine (*Pinus sylvestris* L.) plantations on plant diversity in Northern Mongolia. Mongolian Journal of Biological Sciences 16(1): 59-70. http://dx.doi.org/10.22353/mjbs.2018.16.08

A. Seim, J.A. Schultz, C. Leland, N. Davi, O. Byambasuren, E. Liang, E., X. Wang, C. Beck, H.W. Linderholm, and N. Pederson. 2017. Synoptic- scale circulation patterns during summer derived from tree rings in mid-latitude Asia. Climate Dynamics 49(5): 1917–1931. https://doi.org/10.1007/s00382-016-3426-7

A.E. Hessl, C. Leland, T. Saladyga, and O. Byambasuren. 2017. Hydraulic Cities, Colonial Catastrophes, and Nomadic Empires: Human-Environment Interactions in Asia. In: M. Amoroso, L. Daniels, P. Baker, and J. Camarero (eds), Dendroecology. Ecological Studies (Analysis and Synthesis), Vol. 231. Springer, Cham. https://doi.org/10.1007/978-3-319-61669-8_15

A.E. Hessl, P. Brown, O. Byambasuren, S. Cockrell, C. Leland, E. Cook, B. Nachin, N. Pederson, T. Saladyga, and B. Suran. 2016. Fire and climate in Mongolia (1532–2010 Common Era). Geophysics Research Letters 43(12): 6519–6527. https://doi.org/10.1002/2016GL069059

M.P. Rao, N.K. Davi, R. D'Arrigo, J. Skees, B. Nachin, C. Leland, and O. Byambasuren. 2015. Dzuds, droughts, and livestock mortality in Mongolia. Environmental Research Letters 10(7): 074012. https://doi.org/10.1088/1748-9326/10/7/074012

N.K. Davi, R. D'Arrigo, G.C. Jacoby, E.R. Cook, K.J. Anchukaitis, B. Nachin, M.P. Rao, and C. Leland. 2015. A long-term context (931–2005 C.E.) for rapid warming over Central Asia. Quaternary Science Reviews 121: 89–97. https://doi.org/10.1016/j.quascirev.2015.05.020

MONGOLIA - PROJECT 1-98: IMPACTS OF CLIMATE CHANGE ON FRESHWATER AND FISHERIES RESOURCES OF THE LAKE HOVSGOL WATERSHED

PI: Bud Mendsaikhan, Mongol Ecology Center
U.S. Partner: Olaf Jensen, Rutgers University (Funded by the National Science Foundation)
Dates: June 2012 – November 2014

PROJECT OVERVIEW

Climate change in Northern Mongolia presents extremely serious ecological and economic risks. Air temperatures have already risen by 1.7°C over the past 40 years. In recent years, hot dry summers followed by harsh winters have resulted in massive livestock die-offs. Mongolia's aquatic ecosystems and growing freshwater fisheries may also be at risk from climate change. Lake Hovsgol is an ancient rift lake that contains nearly 70 percent of Mongolia's fresh water. The "Blue Pearl" is also a premier destination within Mongolia, both for Mongolians and for foreign tourists. Despite Lake Hovsgol's importance and designation as a national park, it is threatened by climate change, rapid unplanned development, and poorly enforced conservation laws. Given the lack of adequate monitoring, it is difficult to determine the extent to which these stressors have already altered the lake's ecology.

Over the last decade, the recreational fisheries have been growing rapidly, bringing much needed income to rural areas. Taimen (*Hucho taimen*) and Hovsgol grayling (*Thymallus nigrescens*) are endangered species, and the combined impacts of fishing and climate change on their populations are poorly understood. Salmonids like taimen and grayling are extremely sensitive to warm water and associated low oxygen levels, and both species in Mongolia are at the southern edge of their range where climate change impacts are likely to be most strongly felt. This project aimed to improve the understanding of links between climate change and the ability of Lake Hovsgol and its major outflow, the Eg River, to support important and endangered fish species. A strong understanding of Mongolia's lakes and rivers, by well-trained Mongolian aquatic scientists, will be crucial if mining, tourist development, and fisheries are to be sustainable in a changing world.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team assessed the seasonal pattern of lake turnover and stratification. They determined how the timing of these events corresponds to the air temperature and weather events through deployment of thermistor strings in the lake, which recorded an entire year of water temperature measurements every fifteen minutes at four depths. These observations represent a significant advance in the study of Lake Hovsgol, as water temperature at this lake depth had never been monitored before for more than a few weeks at a time.

During the course of the project, the research team also observed special distribution of fish, specifically, Hovsgol grayling and their zooplankton prey seasonal change in response to the changing temperatures. Spatial temperature variation within the river on daily and seasonal time scales was measured as well. The extent to which the variability of air temperatures influences water temperature and the flow in the Eg-Uur Rivers and the movement of tagged Taimen was measured as well. Further information about the project can be accessed on the web at http://maaeri.weebly.com/.

Mongol Ecology Center (MEC), which served as the institutional manager for this project, established the Lake Hovsgol Conservancy in order to partner with the protected area administration, local governments, commercial service providers and local citizens. The research team has been working with the community members of the Khankh and Hatgal village (north and south of Lake Hovsgol), district government officials, director and staff of Specially Protected Area Department at the Ministry of Environment and Green Development, and with Park Administration staff and rangers. The findings of their research are being shared with the stakeholders to raise awareness in Lake Hovsgol and in efforts to apply them in park planning management. The research team also held several workshops to training Mongolian students and conservation rangers in field ecology techniques.

PUBLICATIONS

P. Tsogtsaikhan, B. Mendsaikhan, G. Jargalmaa, B. Ganzorig, B. C. Weidel, C. M. Filosa, C. M. Free, T. Young, O. P. Jensen. 2017. Age and growth comparisons of Hovsgol grayling (*Thymallus nigrescens Dorogostaisky*, 1923), Baikal grayling *(T. baicalensis Dybowski*, 1874), and lenok (*Brachymystax lenok Pallas*, 1773) in lentic and lotic habitats of Northern Mongolia. Journal of Applied Ichthyology 33(1): 108-115. **https://doi.org/10.1111/jai.13247**

Christopher M. Free, Olaf P. Jensen, Bud Mendsaikhan. 2015. A Mixed-Method Approach for Quantifying Illegal Fishing and Its Impact on an Endangered Fish Species. PLoS One 10(12): e0143960. https://doi.org/10.1371/journal.pone.0143960

Christopher M. Free, Olaf P. Jensen., Sherri A. Mason., Marcus Erikser., Nicolas J. Williamson., Bazarsad Boldgiv. 2014. High levels of microplastic pollution in a large, remote, mountain lake. Marine Pollution Bulletin 85(1): 156-163. https://doi.org/10.1016/j.marpolbul.2014.06.001

B. Mendsaikhan, E. Tengis, P. Tsogtsaikhan, B. Ganzorig, G. Jargalmaa, Ch. Chantuu, B. Menkhzorig. 2014. Fisheries and Fish Farmers in Mongolia. Geoecological Issues in Mongolia. Ulaanbaatar.

B. Onodelgerekh, B. Mendsaikhan, Olaf P. Jensen. 2014. Fish study at the Lake Hovsgol. Newsletter of the Mongol Ecology Center.

B. Mendsaikhan, B. Ganzorig, G. Jargalmaa, Ch. Chantuu, B. Menkhzorig. 2014. Embryonic study of the Lenok (*Brachymystax lenok*). Geoecological Issues in Mongolia. Ulaanbaatar.

MONGOLIA - PROJECT 1-16: DETERMINING SOURCES OF HEALTH IMPACTS OF PARTICULATE MATTER IN ULAANBAATAR CITY TO AID AND ASSESS CURRENT AIR POLLUTION MITIGATION EFFORTS

PI: Sereeter Lodoysamba, National University of Mongolia
U.S. Partner: Christa Hasenkopf, University of Colorado (Funded by the National Science Foundation)
Dates: June 2012 – July 2015

PROJECT OVERVIEW

The air quality in the capital city of Mongolia, Ulaanbaatar, is some of the worst in the world, with particulate matter (PM) levels some 17 to 35 times levels recommended by the World Health Organization. Such high PM levels are due to the natural geography of Ulaanbaatar, which is situated between two mountain ranges, the high concentration of the population that use traditional stoves to heat poorly insulated tents, and the subarctic climate that requires indoor heating up to nine months out of the year. Donor organizations such as the Millennium Challenge Corporation and the World Bank have taken several air pollution mitigation measures in conjunction with the Mongolian government, including selling more efficient stoves and offering cheap, alternative fuels. Despite these efforts, at the time this project began, there was not a robust method of monitoring the progress of these actions, in terms of air pollution concentrations or health impacts.

The researchers performed continuous measurements over an entire year at one site in Ulaanbaatar to assess the amount of $PM_{2.5}$ and PM_{10} and its source, comparing the data obtained with a similar study conducted in 2008-2009 at the same air quality station. They also assessed the impact of current air pollution mitigation efforts and determined morbidity and mortality due to air pollution via analysis of hospital records, compared to a similar World Bank study. The results from the project were shared widely with the local community and with various Mongolian agencies involved in air pollution mitigation measures.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers sampled $PM_{2.5}$ and PM_{10} at the selected site from one year. Their initial findings showed that $PM_{2.5}$ was two times lower than the comparative study. The project team analyzed more than 130 air pollution samples using x-ray fluorescence spectroscopy at the National University of Mongolia to analyze how much pollution is coming from ger stoves versus coal-fired power plants. The team sent samples to the Geophysical and Nuclear Sciences, GNS Science, National Isotope Centre, New Zealand to check their analysis.

The researchers trained medical staff at a family health center to collect data for one year to assess the health impact of air pollution. Preliminary results showed the total number of for respiratory and cardiovascular disease was decreased by 15% after the intervention to reduce pollution.

The PEER project team also helped develop curriculum for a new Master's degree program at the National University of Mongolia on environmental pollution control and management that is cross-departmental and stressed interdisciplinary techniques.

The team received a significant research grant from local company Oyu Tolgoi to automatically post $PM_{2.5}$ air pollution data to social media platforms. The PEER project team presented their work at 14 international conferences, as well as to Mongolian and U.S. government representatives. The PI was invited to give a speech to the Mongolian Parliament Standing Committee on smoke pollution mitigation. The team also gained additional data from new collaborations with UB City Air Quality and National Air Quality Agency.

PUBLICATION

Sarath K. Guttkunda, Sereeter Lodoysamba, Baldotj Bulgansaikhan, Batdorj Dashdondog. 2013. Particulate Pollution in Ulaanbaatar, Mongolia. Air Quality, Atmosphere and Health 6: 589–601. https://doi.org/10.1007/s11869-013-0198-7

NEPAL

NEPAL - PROJECT 6-182: MAPPING OF PESTICIDE RESIDUE AND (OO)CYSTS ON VEGETABLE AND FRUITS USING LOW-COST FIELD BASED ASSAYS

PI: Basant Giri, Kathmandu Institute of Applied Sciences
U.S. Partner: Toni Barstis, Saint Mary's College (Funded by the National Science Foundation)
Dates: December 2017 – November 2020

PROJECT OVERVIEW

Contamination of vegetables and fruits by pesticides and endoparasites is a major public health concern in developing countries, including Nepal. Pesticides are widely used worldwide to protect crops from pests, but their excessive and unmanaged use is harmful to humans and the ecosystem. Pesticides are well-known toxins that cause acute and delayed health effects, including disruption of the central and peripheral nervous systems and cancer. Similarly, according to the World Health Organization (WHO), about 8% of total deaths reported in Southeast Asia are caused by diarrhea. In Nepal, several instances of diarrheal outbreaks are reported every year. Human exposure to pesticides and parasites is due to contaminated food and water. Concerns over food pollution are rising in Nepal, but science-based understanding of the level of pollution is limited, due in part to the unavailability of reliable, economical, easy-to-use, and rapid field test methods to be used as important early warning tools for consumers. Conventional methods for determining pesticide residues on food involve sophisticated, time-consuming, expensive chromatographic methods that require advanced lab facilities and skilled operators. Similarly, endoparasite oocysts in food products are identified using expensive microscopes and polymerase chain reaction techniques that are not suitable for field screening of samples in developing countries.

This project aimed to develop (1) a paper-based pesticide residue assay and (2) smartphone-based oocyst assay methods. Both of these high throughput, low-cost, easy methods were first developed and validated in the laboratory and later tested with vegetable samples at various locations across Nepal. This was the first large-scale field testing of these methods with real samples. Other activities on the project included providing training to students and government technicians, organizing workshops for concerned stakeholders, creating an online map with field results, and disseminating information. In addition, the team involved undergraduate students from the Tri-Chandra Multiple Campus, Tribhuvan University. They learned to use the newly developed assay methods and went into the field to test food pollution levels. In addition, two Master's students from the Central Department of Environmental Science, Tribhuvan University, were given the opportunity to carry out their thesis work in the framework of this project. The PI and his colleagues shared their field screening findings and involved the Plant Protection Directorate (PPD) of the Government of Nepal. PPD technicians were trained in the new methods and received some of the assay tools. See more by visiting the PEER project website.

FINAL SUMMARY OF PROJECT ACTIVITIES

In this project, the primary objectives were to develop two innovative devices: a paper-based analytical device (PAD) for detecting pesticide residues in fruits and vegetables, and a smartphone-based microscope to identify (oo)cysts of Giardia and Cryptosporidium in food samples. The PAD, named PesticidePAD, utilizes an enzyme inhibition assay and includes a custom Android app for semi-quantitative analysis, helping determine if samples are safe for consumption. The smartphone microscope, optimized with a ball lens and specific stains, effectively detects protozoan parasites in samples.

The research involved collecting and testing more than 1,124 samples from various vegetable markets across Nepal, analyzing both pesticide residues and parasite contamination. The team published nine peer-reviewed papers, developed lab modules, filed patents, and designed curriculum for short courses. They presented their findings at 16 domestic and international conferences, enhancing visibility and collaboration opportunities.

Capacity building was a significant focus, with the team acquiring advanced laboratory equipment and training 12 students and researchers. They also provided short courses to more than 40 students from Nepalese colleges. Collaborations were fostered with institutions like Saint Mary's College and NAAMII, and relationships with government agencies and NGOs were strengthened.

Throughout the project, the team organized 10 events, engaging around 500 participants, including government officials, researchers, and students. They received a supplemental grant to validate and optimize their technologies further, aiming to enhance detection accuracy and disseminate findings on pesticide impacts. Future plans include expanding testing, conducting workshops, and continuing collaborations to promote sustainable agriculture and public health awareness in Nepal.

PUBLICATIONS

B. Giri, S. Pandey, R. Shrestha, et al. 2021. Review of analytical performance of COVID-19 detection methods. Anal Bioanal Chem 413, 35–48. https://doi.org/10.1007/s00216-020-02889-x

R. Shrestha, R. Duwal, S. Wagle, S. Pokhrel, B. Giri, and B.B. Neupane. 2020. A smartphone microscopic method for simultaneous detection of (oo)cysts of Cryptosporidium and Giardia. PLoS Negl Trop Dis 14(9): e0008560. https://doi.org/10.1371/journal.pntd.0008560

M. Fuyal and B Giri. 2020. A Combined System of Paper Device and Portable Spectrometer for the Detection of Pesticide Residues. Food Anal. Methods 13, 1492–1502. https://doi.org/10.1007/s12161-020-01770-y

MEDIA FEATURES

- Television interview of Dr. Basant Giri (PI) regarding pesticide contamination and low-cost technology
- PEER event covered on national television
- News about short course on Paper Microfluidics
- News on the symposium on food safety monitoring
- News on workshop on Paper Microfluidics
- News on workshop on food and water quality
- News on US partner's visit

NEPAL - PROJECT 5-576: UNDERSTANDING THE PHENOMENON OF OPEN MAPPING: CREATING OPEN-SOURCE MAP DATA AS A CRITICAL INFORMATION INFRASTRUCTURE FOR DISASTER PREPAREDNESS AND DEVELOPMENT

PI: Nama Budhathoki, Kathmandu Living Labs

U.S. Partner: Kenneth Anderson, University of Colorado Boulder (Funded by the National Science Foundation)

Dates: December 2016 - September 2022

PROJECT OVERVIEW

There is a huge potential to engage digital volunteers and map unmapped parts of the world. Citizens can contribute their local knowledge to open mapping platforms using the Global Positioning System (GPS) capability of their mobile devices and the Internet. While there is a wide range of intrinsic and extrinsic motivations to participate in open mapping, the scientific understanding on how to recruit, engage, and retain citizens in open mapping remains poorly understood, especially in the context of developing nations.

Nepal has one of the most active open mapping communities in the developing countries. The main goal of this PEER project was to investigate the phenomenon of open mapping and develop a framework and guiding principles to conduct outreach, motivate, train, and engage citizen volunteers, particularly youth, in mapping. This study employed action research methodology, making it possible to expand mapping work alongside research activities.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team ran three cohorts of the Digital Internship and Leadership (DIAL) program. Through DIAL, they trained young people from diverse academic backgrounds in open mapping using OpenStreetMap (OSM) and assigned them mapping and digital leadership-related tasks. After each cohort, researchers studied the students' experience to improve the program for the next group and analyzed their mapping behavior, making a qualitative assessment of mappers' contribution to OSM in Nepal. Participants developed multiple skills in the mappers including affective learning, technical skills and digital literacy, cognitive skills, geography-based knowledge, and professional skills, among others.

Throughout the project period, researchers worked closely with local governments to study how Open Mapping contributes to sustainable development at the local levels. They identified three Nepalese municipalities—Budhanilkantha, Pokhara Lekhnath, and Nilkantha—as study sites and conducted a focus group discussion in Budhanilkantha Municipality to understand how the local government would use geo-referenced data and Open Mapping infrastructure in their planning and decision-making process. Based on this work, the PEER team generated policy ideas for local governments to use open mapping as a local geospatial information infrastructure by engaging youth. The PI and team also presented their findings at the Impacts of Civic Technology Conference and State of the Map Asia 2017.

During the COVID-19 pandemic, the PEER team remotely trained more than 300 young people on the basics of open mapping and provided in-person training to a few schools. Further, they also organized an online mapping party to map Bardiya District of Nepal to celebrate the 17th birthday of OSM and a #VisibleWomen event to introduce OSM as a tool to address gender-based issues and introduce more women to OSM. They also mapped and validated OSM data in Thamel, Koteshwor, and Jadi Buti of Kathmandu and supported a monthly map and chat hour where OSM enthusiasts across the country could join in conversations. The team also published a monthly newsletter.

PUBLICATIONS

Aishworya Shrestha, Nama Raj Budhathoki, and Nancy Erbstein. 2022. OpenStreetMap as a tool for skill building. Proceedings of the Academic Track, State of the Map 2022, August 19 - 21, 2022, Florence, Italy. https://doi.org/10.5281/zenodo.7004677

Kshitiz Khanal, Nama Raj Budhathoki, and Nancy Erbstein. 2019. Filling OpenStreetMap data gaps in rural Nepal: a digital youth internship and leadership programme. Open Geospatial Data, Software, and Standards, 4:12, 1-10. https://doi.org/10.1186/s40965-019-0071-1

NEPAL - PROJECT 5-185: JAIBIKMAP: NEPAL'S BIODIVERSITY AND CLIMATE CHANGE TOOL FOR THE FUTURE

PI: Menaka Panta, International Union for Conservation of Nature - Nepal
U.S. Partner: Walter Jetz, Yale University (Funded by the National Science Foundation)
Dates: December 2016 – February 2019

PROJECT OVERVIEW

Nepal, a small, landlocked country in the Himalayan region, boasts an astonishing variety of floral and faunal species due to the diversity of its topography and habitat types. Nepal's biodiversity is declining due to anthropological stressors, including rapid growth in human population and settlements and human-wildlife conflict; however, the greatest risk to Nepal's biodiversity lies in a lack of spatially and temporally sensitive data that reflect potential future changes in habitat composition and distribution due to climate change. Barriers to collecting, analyzing, and sharing information have led to uninformed development, impacting livelihoods.

This PEER project aimed to fill existing and future gaps in knowledge supporting the developmental phase of JaibikMap, an interactive, open data, free web-based mapping tool that contains detailed data for addressing conservation and development challenges. The tool was built on a scalable platform to accommodate additional data layers in the future. Addressing research gaps, project partners conducted a nationwide study of forest change under different climate change scenarios and then applied these findings to species distribution models predicting shifts in habitats. Furthermore, they worked on developing a mobile application allowing anyone to upload photos and GPS coordinates to the JaibikMap repository taken during opportunistic sightings of mammal species.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team accomplished most of the project activities, which started with data collection and organization of mammalian data as occurrence points for 75 species provided by the Department of National Parks and Wildlife Conservation (DNPWC), its own field offices, and networks. Various secondary sources including online data portal, websites, published books, thesis and papers, grey and white literature, personal networks, and geo-referencing process were also used to collect additional data. Similarly, various types of spatial layers such as Red List series, protected areas (NPs/WLR, buffer zones), land use and land cover, new administrative boundaries, vegetation composition, cover/types, and other required information were collected either from government offices or from personal networks.

In total, 168 mammalian species profiles were compiled and updated with current distribution, status, and habitat requirements in Nepal. Similarly, IUCN, jointly with KLL, analyzed the habitat distribution of selected species using the Species Distribution Model (SDM). Occurrence points (GPS coordinates), climatic data layers (obtained from DHM and downloaded from Worldclim both) with slope, aspect, and elevation were used as basic inputs variables in modeling. Future predictions of the suitable habitat distribution of species were projected under RCP 4.5 & 8.5 for the years 2050/70. Finally, modeling outputs of 75 mammalians (based on available GPS point) species with current and future predicted suitable habitat distribution was obtained. The team also classified the 24 Holdridge Life Zones (HLZ) for Nepal based on Holdridge, 1967 as per plan and projected under RCP 4.5 & 8.5 using Worldclim data sets for the same years 2050/70. The climatic data sets of Worldclim from 1950-2000 was considered as current in both models (SDM and HLZ modeling). Later, SDM outputs were further translated and merged with HLZs and HLZs with forest cover/types of Nepal (DPR@2007).

Serving the massive amount of geospatial data seamlessly through web and mobile was a major technical challenge of this project; however, KLL developed an online interactive map and website after having a number of meetings, workshops, seminars and discussion with relevant stakeholders. Likewise, systems were tested and validated through various methods including user acceptance and training, and the database is hosted on the KLL website.

In addition to the national distribution map, a global distribution map was added in the form of a Map of Life iframe and incorporated a global distribution section, as well as highlighted the selected species. A project fact sheet, mammalian profile, and video and project technical reports were prepared and will be published on partner websites and IUCN regional/HQ websites after completion of the official process. NEFEJ disseminated project information to the public via media outreach in 2018 and other media outlets such as Himalaya Times, Kantipur and Gorkhapatra Ratriya Dainik also disseminated project outputs in due course. A comprehensive project report focused on the updated mammalian profile of 168 species was in process at the time the project ended.

NEPAL - PROJECT 5-17: CLUSTER-CONTROLLED IMPLEMENTATION SCIENCE TRIAL OF INTEGRATED MATERNAL NEWBORN CHILD HEALTHCARE DELIVERY IN GROUP SETTINGS

PI: Pushpa Chaudhari, Nepal Ministry of Health and Possible (formerly known as Nyaya Health)

U.S. Partner: Duncan Maru, Brigham and Women's Hospital (Funded by the National Institutes of Health)

Dates: January 2017 – December 2020

PROJECT OVERVIEW

This research team conducted a cluster-controlled, stepped wedge implementation science trial of a bundled maternal healthcare delivery intervention in rural communities in Nepal. Nepal represents an ideal setting to pilot this study based on its robust national community health worker network, progressive national healthcare priorities, and the team's personal experience in delivering healthcare in a district public healthcare setting since 2008. The intervention integrated three evidence-based approaches for maternal, newborn, and child health: (1) group antenatal and postnatal care to improve the institutional birth rate and reduce mortality among children under age two; (2) a Community Health Worker (CHW) model of home-based care to monitor and increase utilization of services, maternal and neonatal health knowledge, self-efficacy, social support, and emergency planning among mothers; and (3) a mentoring approach to quality improvement targeted at government clinic providers in the study population. This intervention was implemented and tested in the district of Achham, Far-West Nepal, within a district population of 260,000.

The study aimed to analyze the impact of the integrated care package on institutional birth rates and under-two mortality using community household survey data. The researchers assessed the mechanisms of the impact of group integrated care and assessed the efficacy of targeted CHW protocols for a home-based model of care delivery to address maternal, neonatal, and childcare, in addition to chronic disease care, continuous surveillance, and mortality assessment. They described key aspects of the implementation process, including costs, human resources, logistics, and fidelity of the group integrated care program to model content and processes. Finally, they produced a cost-effectiveness analysis to determine affordability for national government adoption and Possible's care delivery model.

FINAL SUMMARY OF PROJECT ACTIVITIES

The primary outcome of this CHW intervention providing comprehensive sexual, reproductive, maternal, newborn and child health services was an increase in the institutional birth rate. With the support of PEER, the project team was able to complete the project including enrollment of 11,416 births in the study, enrolling 55,419 households through an integrated community health worker program. For the primary outcome, the team observed an average increase from 65% in institutional birth rate at the start of the intervention to 84% at year 1, 93% at year 2, 97% at year 3, and 98% at year 4 following the intervention. This result is significant ($p<0.05$) for the impact of the intervention. The team plans to use these publications along with dissemination efforts to advocate for a professional cadre of CHWs delivering integrated services throughout Nepal.

In December 2020, the Kathmandu University Dhulikhel Hospital (KU) adopted the Dolakha Community Health Program. The university, through its hospital based in Dolakha, built upon the existing CHW program to establish and scale an integrated hospital to home model. KU utilized the technical support of Possible to facilitate the adoption of the program and the continuation of health services to these remote populations in the Dolakha district.

PUBLICATIONS

Wan-Ju Wu, Aparna Tiwari, Nandini Choudhury, Indira Basnett, Rita Bhatt, David Citrin, Scott Halliday, Lal Kunwa, Duncan Maru, Isha Nirola, Sachit Pandey, Hari Jung Rayamazi, Sabitri Sapkota, Sita Saud, Aradhana Thapa, Alisa Goldberg, and Sheela Maru. 2020. Community-based postpartum contraceptive counselling in rural Nepal: a mixed-methods evaluation. Sexual and Reproductive Health Matters 28:2, 1765646. https://doi.org/10.1080/26410397.2020.1765646

P. Nepal, R. Schwarz, D. Citrin, et al. 2020. Costing analysis of a pilot community health worker program in rural Nepal. Glob Health Sci Pract 8(2):239-255. https://doi.org/10.9745/GHSP-D-19-00393

D. Citrin, P. Thapa, I. Nirola, et al. 2018. Developing and deploying a community healthcare worker-driven, digitally enabled integrated care system for municipalities in rural Nepal. Healthcare 6: 197-204. https://doi.org/10.1016/j.hjdsi.2018.05.002

S. Maru, I. Nirola, A. Thapa, et al. 2018. An integrated community health worker intervention in rural Nepal: a type 2 hybrid effectiveness-implementation study protocol. Implementation Science 13:53. https://doi.org/10.1186/s13012-018-0741-x

D. Maru, S. Maru, I. Nirola, et al. 2017. Accountable care reforms improve women's and children's health in Nepal. Health Aff (Millwood) 36(11): 1965–1972. https://doi.org/10.1377/hlthaff.2017.0579

NEPAL - PROJECT 1-183: ESTABLISHING A COLLABORATIVE ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE ON THE HYDROLOGICAL REGIME OF THE LANGTANG RIVER BASIN, CENTRAL NEPAL

PI: Rijan Bhakta Kayastha, Kathmandu University

U.S. Partner: Mark W. Williams, University of Colorado (Funded by the National Science Foundation)

Dates: June 2012 – November 2014

PROJECT OVERVIEW

The Himalayas display great climatic variability, with the mountains acting as a barrier to atmospheric circulation for both the summer monsoon and winter westerlies. A substantial amount of the annual precipitation falls as snow, particularly at high altitudes, feeding the Himalayan glaciers.

While about one-third of the world's population depends to some degree on freshwater within the High Asia hydrological system, there is not enough data at present on river and stream flows, precipitation, and the contribution of seasonal snow and glacier melt to paint an accurate picture of the water resources there. The High Asia mountains funnel water into such major river basins as the Ganges, Brahmaputra, Indus, Amu Darya, and Syr Darya. The contribution of glacier melt to the major rivers in the region is unknown, with estimates ranging from 2 to 50 percent.

Climate change is projected to compound the pressure on natural resources and the environment associated with rapid urbanization, industrialization, population growth, and economic development. It will potentially have profound and widespread effects on the availability of and access to water resources.

This project focused on the hydrological regime of the Langtang River Basin in Nepal, including data analysis and field measurements of discharge, glacio-hydrological modeling, and estimation of future water availability in the river basin. The project team verified their modeling results using geochemical and water isotope tracer techniques studies developed by the National Science Foundation-funded Niwot Ridge Long-Term Ecological Research project, which allow researchers to follow water as it courses through mountain landscapes.

FINAL SUMMARY OF PROJECT ACTIVITIES

During field visits to the Langtang River basin, the research team collecting water samples from the river to be filtered for sediment load analysis, collected water samples from the Lirung Glacier and Khimsung Glaciers to compare their hydrochemistry, and collected river water samples from different sections from Kyanjing to Syaphrubesi to find the altitudinal variation of different physico-chemical parameters. The researchers used the Positive Degree Day (PDD) model to compute daily discharge of Langtang River basin for the period 2015 – 2050 using the Regional Climate Model (RCM) Weather Research and Forecasting (WRF) data for RCP 4.5 and the change in glacier area, which was obtained from the study done by International Centre for Integrated Mountain Development (ICIMOD).

The research team made several technical poster presentations at the International Symposium on Glaciology in High Mountain Asia and International Conference on Forests, Soil and Rural Livelihoods in a Changing Climate in Dhulikhel, Kavre, Nepal. A member of the research team, Anisha Tuladhar, won the award for best poster with her presentation of "Hydro-Chemical Analysis of the Langtang River, Langtang Valley, Rasuwa District, Nepal."

Two Master's students received scholarships under the PEER award. The research team organized a training for glacio-hydrological modeling along with their annual meeting, where fourteen students, including four women, from different institutions of Nepal participated. At the time the project ended, the team also planned to release software to estimate discharge from a glacierized river basin, which was to be made available to educational institutions free of cost for academic purposes.

PUBLICATIONS

Rijan Bhakta Kayastha and Ahuti Shrestha. 2019. Snow and Ice Melt Contribution in the Daily Discharge of Langtang and Modi Rivers, Nepal. Chapter in the book Environmental Change in the Himalayan Region. https://doi.org/10.1007/978-3-030-03362-0_1

Aastha Chhetri, Rijan B. Kayastha, Ahuti Shrestha. 2016. Assessment of Sediment Load of Langtang River in Rasuwa District, Nepal. Journal of Water Resource and Protection 8: 84-92. http://dx.doi.org/10.4236/jwarp.2016.81007

Anisha Tuladhar, Rijan Bhakta Kayastha, Smriti Gurung, Ahuti Shrestha. 2015. Hydro-Chemical Characterization of Glacial Melt Waters Draining from Langtang Valley, Nepal. Journal of Water Resource and Protection 7: 605-613. http://dx.doi.org/10.4236/jwarp.2015.78049

NEPAL - PROJECT H1-32: INVESTIGATION OF THE EFFECTIVENESS OF NATIONAL CLEAN COOKSTOVES PROGRAM IN NEPAL IN REDUCING ACUTE RESPIRATORY TRACT INFECTION IN ≤ 5 CHILDREN

PI: Sharat Verma, National Tuberculosis Center

U.S. Partner: Kirk Smith, University of California, Berkeley (Funded by the National Institutes of Health)

Dates: October 2013 – February 2019

PROJECT OVERVIEW

Acute Respiratory Infection (ARI) is the leading cause of childhood morbidity and mortality in Nepal. The Ministry of Health and Population has recognized ARI as one of the major public health problems. It has given due importance to improve medical case management strategies to lower the incidence of ARI. Despite such strategies, incidence of ARI is still prevalent. Household air pollution (HAP) from solid-fuel-burning stoves has been causally linked to ARI in children. In Nepal, about 83% of households use solid fuel for cooking and heating. A study conducted in Dhading district has attributed 50% of ARI, mainly ALRI or pneumonia, to HAP, and given this prevalence it is prudent to more thoroughly explore the roles of clean cookstoves in lowering the incidence of ARI and under-five mortality in the country. In Nepal, government has installed around 450,000 biomass improved cookstove and 132,000 biogas systems throughout the country. However, there has been no survey conducted to assess their effectiveness in either reducing HAP or health burden in the community. This prospective cohort study sought to assess whether clean cookstove technologies complement Nepal Government's effort of lowering the incidence of ARI in the country.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main aim of the PEER project was to evaluate whether the use of biogas, one of the clean cooking fuels that the Nepal government is promoting, protects children from an acute respiratory infection (ARI) or acute lower respiratory infection (ALRI). The second aim was to assess household fuel use patterns and the level of indoor air pollution associated with fuel usage. The third aim was to understand the levels of air pollution reduction that is necessary to meaningfully improve children's health.

For two years, the study followed 541 children who had either biogas or open wood-fired cookstoves in their homes. The team included 28 community nurses, Female Community Health Volunteers (FCHVs), who made 107 weekly home visits and collected information on the incidence of ARI and ALRI, as well as diarrhea in children. The FCHVs also collected information on each child's food habits, fuel, and stove use during the week and collected the child's anthropometric data. Initially, 550 children were recruited into the study; however, three children died during the April 25, 2015 earthquake. After that, another six children moved to another location. At the end of the study, there were 541 children, of which 349 had traditional biomass cookstoves and 192 had biogas cookstoves in their homes.

During the study period, five repeated kitchen level air pollution ($PM_{2.5}$ and carbon monoxide) were measured, as well as the duration and pattern of stove usage by 541 homes. Two rounds of personal exposure to carbon monoxide were measured for 60 children (20 from biogas and 40 from biomass households). In one of the study sites, the outdoor level of $PM_{2.5}$ was measured for two years. In addition, the researchers involved in the study were able to mentor many students and establish a productive and collaborative relationship with many individuals and institutions. At the time the project ended, data analysis was still ongoing, after which the team expected to publish their findings.

PAKISTAN

PAKISTAN - PROJECT 7-226: ENHANCING REPRODUCTIVE HEALTH SERVICES USE BY MARRIED ADOLESCENT GIRLS - ROLE OF WOMEN VOLUNTEERS

PI: Tasleem Akhtar, Nur Center for Research and Policy
U.S. Partner: Adnan A. Hyder, Milken Institute School of Public Health, George Washington University (Funded by the National Institutes of Health)
Dates: January 2019 – September 2021

PROJECT OVERVIEW

Despite being a priority area in the policies of all governments since the 1960s, population growth control remains a challenge for Pakistan's government. Since the early 1990s, Primary Health Care (PHC), Family Planning and Reproductive Health (FPRH), and Maternal Newborn and Child Health (MNCH) services strengthening and coverage expansion have been areas of special focus. In Punjab, many initiatives have been taken in recent years to strengthen PHC and its FPRH and MNCH components and enhance their coverage. Despite these efforts, Millennium Development Goals (MDGs) have been missed, the country's commitment to increase Contraceptive Prevalence Rate (CPR) to 50 by 2020 has not been fulfilled, and FPRH indicators are improving sluggishly. FPRH related Sustainable Development Goals (SDGs) are unlikely to be achieved if the current situation doesn't improve.

Evidence suggests that: a) critical shortage of Human Resources for Health (HRH), b) continuing low investments in PHC, c) Pakistan's demographic youth bulge, d) the resulting increasing proportion of adolescent girls and young women keeping birth rates high, and e) women's low utilization of FPRH services are barriers in the way to fulfilling the country's FPRH goals and international commitments. The many tasks assigned to Lady Health Workers (LHWs), who are the main providers of PHC and FPRH services for the poor and marginalized communities, hinder them from performing their primary duties, and prevent programs like Integrated Maternal, Neonatal, Child Health and Nutrition (IRMNCH&N) from fully achieving their goals and objectives.

On the other hand, the increasing proportion of the highly marginalized married adolescent girls and young women population which currently constitutes 20% of married women of childbearing age, demands special attention. The CPR among this group is half that of all women of childbearing age. If special focus is not brought on to the FPRH needs of this age group in programs like IRMNCH&N, Pakistan and the Punjab province are unlikely to achieve national goals and realize the many international commitments the country has made.

This research study originally aimed at testing the effectiveness of Community Women Volunteers (CWVs) in enhancing the utilization of LHW-provided FPRH services by married adolescent girls and young women aged 15- 25 years, with the following original objectives: (1) increasing access of LHWs to young women for the provision of FPRH services; (2) pursuing solution-testing research to inform policies and implementation of the IRMNCH&N program; (3) promoting community mobilization to address gaps in family planning and reproductive health awareness; and (4) increasing inter-sectoral collaboration

FINAL SUMMARY OF PROJECT ACTIVITIES

Although the study intervention-testing could not be completed due to the COVID-19 pandemic, useful data was collected through the baseline survey of the study during the pre-pandemic period, which included:

- 24 Focus Group Discussions with 145 community groups participants
- Baseline survey of 5000 married adolescent girls and young women in the age range of 15 to 24 years before the pandemic lockdowns and after the lifting of lockdowns
- Survey of 500 Community Women Volunteers (CWVs) who had been recruited by Lady Health Workers (LHWs) for the project
- Interviews with 201 Lady Health Workers participating in the study and their 14 Lady Health Supervisors (LHSs)

While the original objective of experimentally testing the effectiveness of the Community Women Volunteers (CWVs) in enhancing the FPRH knowledge and practices of married young women and increasing their use of contraceptives was not achieved, the project team was able to collect a large observational data set on the community perceptions of FPRH needs of married adolescent girls and young women, the FPRH knowledge and practices, and utilization of services by this age group of women, the potential of CWVs in providing support and facilitation to LHWs in reaching out to the community and creating awareness about the FPRH services the LHWs provide and the views of LHWs and their supervisors on the contribution of volunteers and the acceptability of volunteers..

The overall findings indicated that knowledge of FPRH was significantly lacking in all sectors of society and the resources that were available to communities were underutilized as a result. Furthermore, cultural norms dictated that families controlled FPRH knowledge and resources and would access was not allowed until the birth of at least two children, with couples expected to have three or four children as an ideal. In contrast, findings indicated that community women volunteers were available to provide support to LHWs in their work, create awareness in the community about the FPRH services they provide, facilitate their access to marginalized population, and convey counselling messages to those who are difficult to access by LHWs. Respect for LHWs and admiration for the work they were doing was the motivating factor for most of the volunteers who were recruited by the LHWs, but at the same time primary care and LHW provided FPRH services were bypassed for the more expensive doctors' secondary and tertiary care services even by the economically challenged families. The Nur Centre for Research and Policy issued four reports on various aspects of the project.

PAKISTAN – PROJECT 5-85: USING WATER RESOURCES SYSTEMS ANALYSIS TO GUIDE TRANSBOUNDARY KABUL RIVER WATER PARTNERSHIP

PI: Hina Lotia, Leadership for Environment and Development Pakistan
U.S. Partners: Julie Kiang and Jerad Bales, United States Geological Survey
Dates: February 2017 – January 2020

PROJECT OVERVIEW

Transboundary water resources systems are constrained by complex social, economic, and environmental processes that require decision making in a sophisticated framework involving many stakeholders, who are directly or indirectly affected by those decisions. The transboundary Kabul River Basin is no exception to such challenges, where sensitive geopolitical relationships and an unconventional political order have arrested efforts for any cooperative water resources management system between Pakistan and Afghanistan. Current river basin management is very fragmented and narrow in scope. Decisions are often made without a full appreciation of the cross-sectoral impacts and socioeconomic implications. The aim of this project was to support policy makers in both countries to work towards a benefit-sharing approach for the Kabul River Basin. The project team implemented a systems modeling approach for optimized water resources management in the Kabul River Basin to provide a strong scientific basis for a benefit-sharing regime between Pakistan and Afghanistan. The project addressed how natural, social, and environmental drivers combine to impact transboundary water management in the Kabul River Basin.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project concluded with a final national workshop entitled "Water beyond Boundaries: Managing Pakistan's Shared Water Resources" that was held on January 23, 2020, with the aim of highlighting Pakistan's transboundary water issues at the national policy level. Overall, the project had seven main accomplishments:

1. Improved scientific evidence base to support the case for a cooperative benefit sharing arrangement for Kabul River Basin
2. Strengthened linkages among cross-border stakeholders of Kabul River Basin to build trust and confidence for cooperative water resource management
3. Developed tools for policy discussion and dialogue for stakeholders of Kabul River Basin
4. Sensitized and built the capacity of local stakeholders for an optimized water resource management framework for Kabul River Basin
5. Increased awareness, knowledge sharing and demand articulation from stakeholders of Kabul River Basin
6. Strengthened formal and informal partnerships with national and regional stakeholders to sustain cooperation
7. Mainstreamed the transboundary water challenges at the national level among government, decision makers, development sector community

PUBLICATIONS

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PAKISTAN - PROJECT 4-323: UNDERSTANDING OUR JOINT WATER-CLIMATE CHANGE CHALLENGE AND EXPLORING POLICY OPTIONS FOR COOPERATION ON THE AFGHAN-PAK TRANSBOUNDARY KABUL RIVER BASIN

PI: Hina Lotia, Leadership for Environment and Development Pakistan
U.S. Partners: Amir Aghakouchak, University of California, Irvine, and Konstantinos M. Andreadis, Jet Propulsion Laboratory (Funded by the National Aeronautics and Space Agency)
Dates: March 2016 – March 2019

PROJECT OVERVIEW

Scientific information on water availability/use and climatic impacts in the Kabul River basin is much needed and can provide a foundation for any future discourse on the basin. Augmenting the problem, climate change has inserted a layer of complexity over the already challenging water governance issues. Keeping in mind the scarcity of research in the Kabul River basin and lack of data in the region, Phase 1 of the project included a scientific study using remote sensing data to better understand water availability in the basin and the impacts of climate change. In Phase 2 the project team explored avenues of water-related cooperation between Pakistan and Afghanistan and proposed an integrated basin wide approach for the governance, management and development of the transboundary Kabul River basin waters. The U.S. Government-supported partners provided remote sensing and GIS data support to supplement available data over the Kabul River basin, offered advice on large basin-level hydrological modeling approaches, mentored graduate students and young researchers involved in the project, and reviewed and provided quality control to the various project knowledge outputs.

FINAL SUMMARY OF PROJECT ACTIVITIES

Phase I (Scientific) comprised

1. Mapping the current status of surface water availability and river flow in the transboundary Kabul River Basin, including future demands and consumption
2. Studying the projected impact of climate change on the Kabul River Basin waters through changes in glacial melt, snow melt, rainfall and temperature

Phase II (Development) comprised

1. Exploring possible avenues of cooperation and mutually beneficial uses for both Afghanistan and Pakistan policy makers, based on the concept of benefit sharing on the transboundary waters of Kabul River basin
2. Proposing an integrated basin wide approach to guide policy making in the management, governance and development of the transboundary river

In collaboration with the Pakistan Meteorological Department and Global Change Impact Studies Centre, LEAD developed three research studies under the overall PEER project:

1. Impact of the 21st century climate change on surface water availability of the Transboundary Kabul River Basin
2. Future Climate Change Projections of the Kabul River Basin Using a Multi-model Ensemble of High-Resolution Statistically Downscaled Data
3. Spatio-Temporal Analysis of Early Twenty-First Century Areal Changes in the Kabul River Basin Cryosphere

This marked the completion of Phase I which focused on scientifically assessing the vulnerability of the Kabul River Basin through studying variables such as temperatures, snow melt, and precipitation.

As part of Phase II, multiple stakeholders' consultations and policy dialogues were held nationally and internationally. Due to the visa regime, the two stakeholders' consultation meetings were held in Kazakhstan and Dubai, respectively, where key decision makers, experts, academics and journalists from both Pakistan and Afghanistan participated. The first meeting focused on understanding the significance of Kabul River Basin for the two countries, the key challenges and the potential benefits of adopting an integrated basin wide approach. Building upon the successes of the first meeting, the second stakeholders' consultation meeting was organized in Dubai, where participants identified the components of a sustainable transboundary water management system. Similarly, policy dialogues were conducted in Pakistan and Afghanistan to share the key findings of the research and promote benefit-sharing of the Kabul River Basin.

To further mainstream the discourse on transboundary waters in Pakistan, LEAD organized numerous talks as part of its Talk Series on Managing Shared Basins. With diverse yet context specific themes such global best practices, lessons from the Indus Water Treaty and the technical aspects of governing transboundary waters, these talks provided a platform for experts to improve the overall understanding around the concept of transboundary water management. Each talk was also livestreamed in order to cater to wider audiences. The team was able to successfully disseminate the key findings from their research studies to more than 4000 stakeholders through different events and electronic mails.

The team was also able to contribute to research on the climate vulnerability of the Kabul River Basin by forecasting its water availability with reference to increasing temperatures. By conducting various policy dialogues, national consultations, and stakeholder engagements both nationally and internationally, LEAD brought experts, private sector, academia, government officials, civil society, and journalists into the discourse. To further ensure that their multifaceted recommendations are into taken consideration, the team prepared inclusive policy briefs. Despite the seemingly insurmountable challenges such as mistrust between the two nations and limited data sharing, this project managed to open an avenue for partners to collaborate and jointly conduct research.

PAKISTAN - PROJECT 4-255: ENHANCED ENGAGEMENT IN RESEARCH ON THE KABUL RIVER BASIN (EKARB)

PI: Muhammad Azeem Ali Shah, International Water Management Institute
U.S. Partner: Lauren Hay, United States Geological Survey
Dates: November 2015 – April 2019

PROJECT OVERVIEW

The Indus River system originates in the Himalayas in northern Pakistan, flows across three provinces, and meets the Arabian Sea at its southern end. It has many tributaries that contribute to its flow, and one of its most important is the Kabul River system, which contributes almost 19 MAF of water at Attock annually (IUCN, 2013). Historical data from 1937 through 2008 show a considerable decrease in annual flows in the Kabul River system, from 28 to 19 MAF. The possible reasons could be climatic variability, persistent drought, or enhanced use of water in Afghanistan. The Kabul River basin (KRB) has its unique geographical importance as it originates from Pakistan, enters Afghanistan and then comes back to Pakistan. In that sense Pakistan and Afghanistan are both upper and lower riparian states. Its tributaries—namely Bara, Konar, and Swat—originate in Pakistan. These contribute to the flows of KRB, which covers 348 miles in Afghanistan and then enters Pakistan to join the Indus River at Attock. It is in the interest of both Afghanistan and Pakistan to have evidence-based knowledge on the variability in flows of KRB and future impacts of climate change.

The lead institute on this project, IMWI, has partnered with the National Centre of Excellence in Geology in Peshawar, with the U.S. Government-supported partner being the U.S. Geological Survey (USGS). In addition, IWMI has made contacts with the Afghan Ministry of Energy and Water, which has shown keen interest in the project idea. The project researchers investigated the impact of climate change on the highly varying flows of KRB, where the ratio between lowest and highest annual flows is 1:3 (IUCN, 2013). Afghanistan has planned multiple storage facilities on KRB for irrigation and power generation purposes, and these will directly impact supplies of water to the Indus River basin. This could result in potential transboundary water conflicts in the absence of any treaty between the two riparian states. In order to facilitate any meaningful negotiation between the two states, the first step is to develop a scientific repository of evidence-based research on KRB that provides insights into future water resource development scenarios in Afghanistan with and without climate change impacts. Because surface water from rivers is a key input to agriculture, any uncertainty in future water supplies will directly affect the economy of Pakistan and increase poverty. On the Afghan side, the project aimed to contribute to the important goal of sustainable agriculture-led economic growth. This was achieved by informing Afghan policy makers through the dissemination of project findings about the impact of climate change on the variability of flows in KRB and the need to adapt to the changing climate patterns.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project was the first opportunity where the International Water Management Institute (IWMI) decided to carry out research and develop its portfolio of research on the Kabul River Basin. The first challenge was the paucity of data. Hence it was decided that IWMI would take the lead and develop an online data repository, which will not only benefit IWMI researchers but also researchers from different regions working on this topic. As a result, the Kabul River Basin Knowledge platform and a Decision Support System (DSS) was developed. The online interface developed was made live during the Indus Basin Knowledge Forum held in Colombo during the first week of July 2017. The Kabul River Basin Geodatabase is a valuable resource with a huge repository of GIS data that is available open source to all researchers and policymakers. The Kabul River Basin decision support tool includes two key change analyses considering the fragilities faced in the basin. These include Flood Hazard Mapping and the Landslide Susceptibility analysis. Since the development of these online interfaces, IWMI has received many queries and quite a lot of researchers have benefitted from this open-source data.

There were two models developed exclusively for the Kabul River Basin. The first model was HEC-GeoHMS. In this model, the future climate change scenarios were used to determine the impact on mean and peak flows of the Kabul River. Results show that there is slight decrease in mean and peak flows. Moreover, flood frequency analysis under the climate change scenarios was also carried out. . It was observed that frequent floods of ARI 5, 10 and 20 years were less sensitive to climate change as compared to extreme floods of ARI 50, 100, 200, 500 and 1000 years. The flow of 5-year flood have decreased from 1430 m3/s to 1390 m3/s under all the climate change scenarios. The decrease in flows continues and maximum decrease is observed in 1000-year flood where flow decreased from 2190 m3/s to 2000 m3/s. This observation indicates that floods with lower peaks will occur when the climate changes in the KRB continues over the period of a century.

The second model for the Kabul River Basin was developed using the WEAP modeling platform. The team developed typical water supply and demand scenarios, which were then tested by using the WEAP model for the Kabul River Basin. The total water demand, the total unmet demand, and changes in river flow on both sides of Afghanistan and Pakistan and in the river basin as whole were assessed using the model. Trainings on flow measurement using current meters and Acoustic Doppler Current Profiler (ADCP) were carried out for professionals and academia.
A comprehensive analysis of laws regulating the flow of water on both sides of the border between Afghanistan and Pakistan was also carried out.

IWMI organized for the first time in Afghanistan a national media dialogue to sensitize the journalist community on issues related to water and transboundary water challenges with support from the PEER project. The research undertaken in this project has been shared at various national and international forums through invited talks and presentations. The USAID local mission in Pakistan was kept in the loop throughout the project and as a result of this, IWMI secured a substantial grant from USAID to take this work forward for the next five years. The PI believes this has been one of the biggest achievements of the project. This will provide a platform to engage more researchers and practitioners from both sides of the border in the transboundary issues of mutual interest.

Kabul River Basin Database

Hazard Mapping and the Landslide Susceptibility Interface

PHILIPPINES

PHILIPPINES - PROJECT 9-379: ASSESSMENT AND COMPARISON OF RECOVERY OF BIODIVERSITY AND CARBON SEQUESTRATION IN PHILIPPINE MANGROVES AMONG NATURAL, REPLANTED AND NATURALLY RECOLONIZED MANGROVE STANDS

PI: Severino Salmo III, University of the Philippines Diliman - Institute of Biology
U.S. Partner: Richard Mackenzie, United States Department of Agriculture/Forest Service
Dates: July 2021 – April 2024

PROJECT OVERVIEW

The capacity of mangroves to render ecosystem services depends on their spatial extent, ecosystem health, and forest development. Intact mangroves have high primary productivity that results in elevated carbon stores and provides food for mangrove-specialist fauna (e.g., crabs, shrimp). When disturbed, mangroves lose or reduce their ecosystem functionality. In restored mangroves that have been replanted, the recovery of vegetation structure, productivity, carbon storage, and fauna are thought to follow a "chronosequence" in which these ecosystem attributes increase with mangrove age/maturity.

In the Philippines, most restoration projects have been ineffective, resulting in stunted growth and poor survival. It will take a longer period before these restored mangroves match the ecosystem attributes of an intact natural mangroves, or they could fail altogether. The recovery of naturally recolonized abandoned fishponds may follow a similar chronosequence as replanted mangroves. This project compared carbon sequestration, burial, sources, greenhouse gas emissions, and biodiversity among intact mangroves, replanted mangroves, and fishponds that have been recolonized.

The PEER team undertook their research in the highly diverse Mindoro Oriental and Panay Islands, which have experienced massive mangrove losses from fishponds. The project also included a science-community-policy linkage, in which technical research was conducted in collaboration with community groups and undergraduate and graduate students were trained in the assessment of various types of mangrove stands.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers conducted 13 total field work visits, six in Oriental Mindoro, four in Prieto Diaz (Sorsogon), and three in Ormoc City (Leyte). This included sediment sampling for carbon stock assessment, water and sediment sampling for biodiversity assessment (using eDNA metabarcoding), vegetation assessment, water quality analyses, litterfall collection, PhotosynQ analyses, a litter decomposition experiment, leaf and sediment collection (for nutrient analyses), and lichen and mollusk assessments. The activities were conducted by the PI Dr. Sev Salmo, research assistants, students from several universities, local guides, and municipal representatives and were held periodically at approximately six-month intervals to account for seasonal variations at the study sites.

Monthly litter samplings were conducted in Sorsogon (by local guides) and Ormoc (by University of the Philippines Tacloban College students) for 12 months from the trap nets set up at each vegetation plot. In Ormoc, a PhD student conducted seedling growth and physiology assessments using PhotosynQ. Students from Mindoro State University also conducted their own sampling activities in the project's vegetation plots in Oriental Mindoro. Additional field activities were conducted in the project sites of Oriental Mindoro to collect sediment samples for eDNA metabarcoding and measure greenhouse gas emissions.

The PEER project researchers conducted a carbon stock assessment using the LOI method, undertook a litterfall analysis of the Sorsogon monthly sample, and partnered with several research centers to conduct eDNA metabarcoding analyses. In August-September 2023, the PI Dr. Salmo and Ms. Maria Elisa Gerona-Daga spent three weeks at the University of Wisconsin - Milwaukee for the estimation of carbon accumulation rates in mangrove sediments using Pb_{210}. The visit was arranged by U.S. partner Dr. Richard Mackenzie.

The PEER team presented their work through several workshops and conferences, including 6th Mangrove Macrobenthos Management Meeting, the 17th National Symposium in Marine Science and 55th Federation of Institutions for Marine and Freshwater Sciences. They hosted several trainings, including ones related to mangrove assessments, blue carbon studies, eDNA metabarcoding analyses, and roadmapping activities for Philippine mangroves. The project's exit conference: "Hopespotting: Recognizing Mangrove Hotspots for Conservation and Restoration" included technical presentations from the research assistants and students, a workshop on mangrove mapping, and lectures from two guest speakers.

The researchers have already published several articles in relation to their work and the project developed an interactive online platform that integrates and summarizes the project's research outputs for biodiversity, social, policy, with an integrated real-time mangrove status reporting form and data dashboard, which should be especially helpful for their local municipal government partners in conducting their own mangrove monitoring in the years to come. The municipal government of Masinloc, Zambales, issued a municipal resolution expressing gratitude and appreciation to the accomplishments of the project and adopted the Online Mangrove Data Monitoring Dashboard for systematic mangrove assessment and monitoring. Mayor Arsenia Limen encouraged the other municipal mayors in Zambales to adopt the dashboard.

The PEER team received three additional grants for ongoing work, with $40,000 total, as a result of the project. The PI and a U.S. Fulbright Program visiting professor developed a new graduate course on Blue Carbon and Coastal Ecosystem Conservation that began in the 2023-2024 academic year. The PI also developed a new graduate course on Wetland Ecology to discuss biology/ecology of the Philippine wetlands as well as the state of research, issues/threats, conservation and restoration approaches, and policy recommendations.

PUBLICATIONS

Christine B. Corcino Russel, Maria Elisa B. Gerona-Daga, Shaina C. Samoza, John Kenneth R. Fraga, and Severino G. Salmo. 2023. Status, limitations, and challenges of blue carbon studies in the Philippines: A bibliographic analysis. Regional Studies in Marine Science 62: 102916. https://doi.org/10.1016/j.rsma.2023.102916.

Maria Elisa B. Gerona-Daga and Severino G. Salmo III. 2022. A systematic review of mangrove restoration studies in Southeast Asia: Challenges and opportunities for the United Nations Decade on Ecosystem Restoration. Frontiers in Marine Science 1865. https://doi.org/10.3389/fmars.2022.987737

S. Kannan, S. Balamurugan, P. Ragavan, B. Deivasigamani, A.K.S. Wee, S.G. Salmo III, M. Basyuni, and T. Kajita. 2022. eDNA envisaged conservation of IUCN threatened taxa of the tropical mangrove ecosystems. IOP Conference Series: Earth and Environmental Science, Volume 1115, 4th International Conference on Natural Resources and Technology 29-30 August 2022 Sumatera Utara, Indonesia. https://iopscience.iop.org/article/10.1088/1755-1315/1115/1/012032/meta

PHILIPPINES - PROJECT 7-128: BASELINING PERSISTENT AND EMERGING ORGANIC POLLUTANT LEVELS IN ENVIRONMENTAL AND ENGINEERED SYSTEMS (PEOPLES) FOR HEALTHY PHILIPPINES

PI: Caroline Jaraula, Marine Science Institute, University of the Philippines
U.S. Partner: Diana Aga, University at Buffalo (Funded by the National Science Foundation)
Dates: November 2018 – December 2021

PROJECT OVERVIEW

Working in partnership with the NSF-supported Halting Environmental Antimicrobial Resistance Dissemination (HEARD PIRE) project, this study helped lay the foundation for environmental monitoring of antibiotics in the Philippines. The overall goal of this PEER project was to increase the number of wastewater treatment plants in the Philippines sampled for antibiotics, then expand that sampling to point sources, as well as receiving river and marine environments. This research project provided baseline information on effluents so that proper government policies and community action can be implemented to quantify and manage these challenges. The data collected were used to identify critical areas to prioritize for a combined engineered and natural wastewater plan useful for local governments and organizations to leverage further detailed planning and application for business-government partnerships.

The researchers sought to consolidate watershed and basin information into a map focusing on land use and locations of point sources in the study areas, collecting data on current and planned wastewater treatments. They also determined antibiotic types and concentrations in wastewater treatment plants and in terrestrial and marine environments of Davao, Manila, and Cagayan de Oro, Philippines, as well as pesticides in the watershed and coastal areas of the target sites.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Caroline Jaraula and her team produced a map of Davao City and Cagayan de Oro in which farms and hospitals were plotted with the help of data acquired from relevant agencies and local government units. The project's sampling campaign tested a variety of sites for the target effluents and antibiotic-resistant genes. Among their findings were the identification of pharmaceutical metabolites and personal care product residues from upstream, influent, and effluent wastewater treatment plant samples from Metro Manila and Laguna, as well as Davao River Basin, Cagayan River Basin, and public and private Cagayan de Oro hospitals. A total of 157 compounds comprising antibiotics, antifungal compounds, anticonvulsants, antihypertensive drugs, pesticides, and industrial chemicals were identified in Angeles. Four antibiotic-resistant genes were detected in all of the sites from the Davao river basin, while all 11 of the targeted antibiotic-resistant genes were detected in four study sites in Lumaba. All told, the team undertook statistical analyses of five years of water quality parameters from the Davao River, as well as measuring levels of SARS-CoV2 at sampling sites in November 2020.

PEER project members presented their work at a variety of conferences and published several academic articles. They also met with local government officials to discuss emerging and persistent pollutants and possible ways forward in research and policy.

The project supported the training and research for several graduate and undergraduate students and strengthened the skills of local researchers and educators through several capacity-building activities. These included laboratory processing training conducted both at the University of the Philippines Diliman and the University at Buffalo, SUNY, as well as hands-on sample collection training for three faculty members from the Philippine Science High School during the Davao Gulf fieldwork.

PUBLICATIONS

Shyrill Mae F. Mariano, Luisa F. Angeles, Diana S. Aga, Cesar L. Villanoy, and Caroline Marie B. Jaraula. 2023. Emerging pharmaceutical contaminants in key aquatic environments of the Philippines. Frontiers in Earth Science 11:1124313. https://doi.org/10.3389/feart.2023.1124313

Maria Catherine B. Otero, Lyre Anni E. Murao, Mary Antoinette G. Limen, Daniel Rev A. Caalim, Paul Lorenzo A. Gaite, Michael G. Bacus, Joan T. Acaso, Refeim M. Miguel, Kahlil Corazo, Ineke E. Knot, Homer Sajonia II, Francis L. de los Reyes III, Caroline Marie B. Jaraula, Emmanuel S. Baja, and Dann Marie N. Del Mundo. 2022. Multifaceted assessment of wastewater-based epidemiology for SARS-CoV-2 in selected urban communities in Davao City, Philippines: a pilot study. International Journal of Environmental Research and Public Health 19(14): 8789. https://doi.org/10.3390/ijerph19148789

Luisa F. Angeles, Lahiruni M. Halwatura, Jonathan P. Antle, Scott Simpson, Caroline M.B. Jaraula, and Diana S. Aga. 2021. In silico supported nontarget analysis of contaminants of emerging concern: increasing confidence in unknown identification in wastewater and surface waters. ACS ES&T Water 1: 1765-1775. https://doi.org/10.1021/acsestwater.1c00105

Randolph R. Singh, Luisa F. Angeles, Deena M. Butryn, Jacob W. Metch, Emily Garner, Peter J. Vikesland, and Diana S. Aga. 2019. Towards a harmonized method for the global reconnaissance of multi-class antimicrobials and other pharmaceuticals in wastewater and receiving surface waters. Environment International 124(2019: 361–369. https://doi.org/10.1016/j.envint.2019.01.025

PHILIPPINES - PROJECT 5-173: USING CONTACT TRACING TO ASSESS BARRIERS TO DIAGNOSIS AND TREATMENT AND DEVELOP AN EDUCATIONAL CAMPAIGN SURROUNDING CHILDHOOD TUBERCULOSIS IN THE NORTHERN PHILIPPINES

PI: Flordeliza Bassiag, Isabela State University

U.S. Partner: Tania Thomas, University of Virginia (Funded by the National Institutes of Health)

Dates: December 2016 – December 2023

PROJECT OVERVIEW

The Northern Philippines is not exempt from the burden of childhood tuberculosis (TB), given its geographical locations with mountains and urbanizing valleys in all three regions of Ilocos, Cagayan Valley, and the Cordilleras, encompassing ten provinces and seven cities. This project used contact tracing among adults with smear-positive TB in order to assess the disease prevalence and incidence among children in the Northern Philippines and identify the spectrum of barriers to the diagnosis and treatment of childhood TB. The study design included household contact investigations among smear-positive index patients within the three regions to screen for and obtain accurate baseline statistics of childhood TB and latent TB infection among children under 15. In addition, cross-sectional surveys, key informant interviews, and focus group discussions were aimed at identifying barriers to the diagnosis and treatment of childhood TB. The project aimed to increase pediatric TB case detection in the region from 1.2% to 15%, the global average detection rate for high TB-burden countries.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over the course of six years, this PEER project impacted childhood TB contact tracing, education, and research. The team provided training sessions for healthcare workers and community leaders on efficient contact tracing and the importance of prompt referral, diagnosis, and provision of appropriate treatment among children exposed to prevent future transmission of the disease.

The study sites included 19 catchment sites in three cities and 16 municipalities within three provinces. The PEER team also coordinated with stakeholders at multiple levels. They contract traced a total of 788 households and referred 1,491 children under 15 to the nearest TB-DOTS centers from the indexed cases traced. Each household was provided with a brief information about childhood tuberculosis during contact tracing activities.

The researchers also held focus group discussions and surveys of health care workers (HCW). A total of 262 HCWs from 55 public and private clinics were interviewed to learn about barriers to diagnosis and treatment of childhood TB in the northern Philippines. The results were used as a basis for training about childhood TB and contact tracing that was provided to 374 village healthcare workers, nurses, medical technologists, and microscopists through the PEER grant.

The PEER team presented their findings widely through nearly two dozen technical presentations and received $3,300 in additional funding from Isabela State University to continue their work. The team identified additional villages and provided them with technical assistance in contact tracing. Based on the records of the health facilities, after the referral of the children, additional adults who were exposed also sought diagnosis for TB. Thanks to the PEER funding, diagnostics services were provided to 570 children and adolescents from the provinces of Kalinga and Isabela who were referred for APL/Chest X-ray. The majority of them either were treated or have ongoing treatment for active TB or for preventive therapy.

PUBLICATION

Flordeliza R. Bassiag, Tania Thomas, Beulah Estrada, Edmelyn Cacayan, Romella Tuppal, Alex Soriano, and Alexander Ritua. 2021. Identification of Barriers to Diagnosis and Treatment among Households Surrounding Childhood Tuberculosis in Northern Philippines. Journal of Social Health 4(1): 54-63. https://socialhealthjournal.ust.edu.ph/wp-content/uploads/2021/02/Bassiag-et-al-Identification-of-Barriers-to-Diagnosis-and-Treatment-among-Households-Surrounding-Childhood-Tuberculosis-in-Northern-Philippines-.pdf

PHILIPPINES - PROJECT 3-236: EARLY DETECTION OF VOLCANO FLANK FAILURE USING INSAR

PI: Alfredo Mahar Francisco Lagmay, University of the Philippines, National Institute of Geological Sciences

U.S. Partner: Falk Amelung, University of Miami (Funded by the National Science Foundation)

Dates: October 2014 – February 2017

PROJECT OVERVIEW

The project helped develop technical capability to process and interpret satellite radar data known as Interferometric Synthetic Aperture Radar (InSAR). There is limited InSAR research activity in the Philippines, with most research activities confined to traditional techniques, such as GPS and leveling surveys, which are usually expensive and time consuming. InSAR technology offers a more cost-effective way of providing ground motion data, including increased availability of open access data from the European Space Agency's Sentinel satellite missions.

The impact to volcano monitoring activities is significant, since the team's findings suggest that smaller — but still dangerous — phreatic eruptions are less likely to produce ground deformation signals. SAR Images covering a period of unrest in Kanlaon in between 2014 and 2017 showed almost no deformation in the volcano edifice despite the number of steam-and-ash explosions within the time frame. Those results were validated by GPS measurements from the Philippine Institute of Volcanology and Seismology (PHIVOLCS). Slightly older SAR images for Taal detected uplift possibly caused by inflation from pressurization of the volcano. Significant subsidence was also detected near the vicinity of Mt. Makiling where a geothermal plant is located, and other portions of the Macolod Corridor, a zone with active intense volcanism and faulting. Using this data, the possible magma source for Taal can be modeled.

Among the volcanoes the researchers surveyed, there appears to be no indication of any imminent large-scale eruptions, but the potential for smaller eruptions remains.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers were able to improve their technical capability in processing InSAR data from satellite images. The collaboration with Dr. Falk Amelung of the University of Miami expanded their network and took advantage of UM's computing and other facilities. Researcher Jolly Joyce Sulapas visited the laboratory of Dr. Amelung at the University of Miami in early 2017, where she learned to access and use their methods in generating interferograms and time-series velocity maps and was introduced to concepts on magmatic source modeling.

Through the data and technical skills acquired from this project, the researchers can provide monitoring and analysis of ground deformation related to volcano deformation and tectonic fault movement, which could potentially result in catastrophic earthquakes.

The team was able to expand the potential use of InSAR research beyond the original scope of the project, and including in areas of agriculture, urban planning and natural resource management. Taking advantage of currently free and open access SAR satellite imagery, such as those from the ESA's Sentinel mission will allow the researchers to monitor numerous areas at a minimal cost.

The team began a collaboration with the Philippines Department of Agriculture to detect and monitor ground subsidence induced by groundwater extraction in agricultural areas, both to evaluate the sector's current groundwater usage and assess new irrigation programs' use of these valuable resources. They also established a working relationship with the Rapid Analysis and Spatialisation Of Risk (RASOR) Project to write proposals for funding from World Bank and other agencies to develop comprehensive tools for disaster risk assessment efforts in the Philippines, and potentially the region as well.

PUBLICATIONS

R.C. Eco, K.S. Rodolfo, J.J. Sulapas, A.M. Morales Rivera, A.M.F. Lagmay, et al. 2020. Disaster in Slow Motion: Widespread Land Subsidence in and Around Metro Manila, Philippines Quantified By Insar Time-Series Analysis. JSM Environ Sci Ecol 8(1): 1068. https://doi.org/10.47739/2333-7141/1068

Rodrigo Eco, Audrei Bonus-Ybanez, and Mahar Lagmay. 2017. Deformation in the Bataan Volcanic Arc Complex measured with PSInSAR. Geophysical Research Abstracts Vol. 19, EGU2017-1235.

A.M. Morales Rivera, F. Amelung, and R. Eco. 2015. Volcano Deformation and Modeling on Active Volcanoes in the Philippines from ALOS InSAR Time Series. ESA Special Publication, FRINGE 2015 Proceedings of the workshop, Vol. 731. https://doi.org/10.5270/Fringe2015.pp302

PHILIPPINES - PROJECT 3-226: "A GLASS OF THE SEA:" AN IMMERSIVE, INTERACTIVE, VISUAL EXHIBITION ON THE APEX OF THE EARTH'S MARINE LIFE

PI: Maria Isabel Garcia, The Mind Museum (of the Bonifacio Art Foundation, Inc.)
U.S. Partner: Terrence Gosliner, California Academy of Sciences (Funded by the National Science Foundation)
Dates: September 2014 – September 2017

PROJECT OVERVIEW

A Glass of the Sea was an impactful, immersive, interactive, constantly updated exhibition of the discoveries being made by the National Science Foundation (NSF)-funded expedition in the Coral Triangle. Its objective was to capture larger audiences, drawing attention to the astounding beauty of marine life and the compelling importance of conservation in the Coral Triangle. Using creative, interactive multimedia technology where guests' gestures can summon graphics and impactful text, A Glass of the Sea palpably connected the science being done with the public understanding of such work. The "drinking glass" concept was implemented through a nearly 360-degree interactive screen showing the Filipino audience videos of the Coral Triangle's marine richness in three key areas in the Philippines (in Luzon, the Visayas, and Mindanao), which were identified in collaboration with the U.S. partners at the California Academy of Sciences. A marine conservation awareness campaign was also carried out nationwide to accompany the exhibit launch.

FINAL SUMMARY OF PROJECT ACTIVITIES

A Glass of the Sea was created in July 2015 to build awareness of biodiversity issues in the Coral Triangle by highlighting the work done by the California Academy of Sciences. From that date through the spring of 2017, the exhibition was hosted in 12 high foot-traffic venues (versus the originally planned 3) across the Philippines—on Luzon, the Visayas, and Mindanao—and welcomed more than 100,000 guests (versus the target of 10,000). The results of surveys of exhibition visitors showed that more than 97% (versus the target of 70%) of the respondents positively answered questions related to increased awareness of the Philippines' high marine biodiversity. Because this project was focused not on research but on public understanding of science, its impact could be evaluated based on insights from the survey findings. According to the PI, Maribel Garcia, these insights include the following:

1. Communicating science cannot be separated from doing science if it involves public understanding and involvement in such issues.
2. Exhibitions, if they are presented creatively and in novel ways, are very effective ways to increase awareness and understanding of scientific issues that affect the public. They should be considered an essential component of any scientific issue that needs to be publicly disseminated.
3. People readily pledge action in concrete ways after they are made to understand the importance of a scientific issue.
4. Partnership with venues that are highly visible to the public are also essential if the traveling exhibitions need to travel around the country (this exhibition partnered with a large chain of shopping malls, leveraging the interests of the mall owners and exhibition designers in attracting visitors).
5. There is still a significantly large untapped audience that has yet to become aware of the unique richness of Philippine marine biodiversity.

The PEER team prepared a PowerPoint presentation for distribution to environmental NGOs and relevant government agencies, containing their findings and insights in presenting A Glass of the Sea and the role of exhibitions in increasing awareness of biodiversity and other issues that are critical for sustainable development.

PHILIPPINES - PROJECT 3-191: ENHANCEMENT OF PHILIPPINES' RESEARCH CAPABILITY IN UNDERSTANDING THE ROLE OF MANGROVE ECOSYSTEM HEALTH IN THE ADAPTATION AND MITIGATION AGAINST NATURAL DISASTERS

PI: Severino Salmo III, Ateneo de Manila University
U.S. Partner: Ilka Feller, Smithsonian Environmental Research Center, Smithsonian Institution
Dates: September 2014 – January 2018

PROJECT OVERVIEW

Mangroves are coastal forests known to provide timber and fisheries products, function as habitat, and provide protection against erosion and storm surges. Mangroves also sequester huge amounts of atmospheric CO_2 and stabilize shorelines. These ecological functions qualify mangroves as important adaptation and mitigation strategies against climate change. In the Philippines, the existence of mangroves has long been threatened by anthropogenic and natural causes, primarily by sea level rise. This is further aggravated by the archipelagic nature of the country, which is located in a typhoon path where at least 20 typhoons pass annually. To address mangrove loss, massive mangrove restoration programs have been implemented since the 1990s. Unfortunately, these restoration programs employ plantation of primarily *Rhizophora mucronata* in suboptimal conditions, thus yielding low survival and stunted growth and casting doubts whether this approach can effectively function as a barrier against natural disasters.

There is a lack of understanding of how the presence, loss, or condition of mangroves will affect their ability to respond and adapt to natural disasters. This research project aimed to establish a better understanding of the relationship of the state of mangrove health to vulnerability to natural disasters in the Philippines. The project also focused on improving the capacity of Filipino researchers to monitor coastal systems. Data were generated and ecological models developed to show how mangroves respond to typhoons and the sea level rise, which is critically needed information to protect the Philippines from ongoing threats from these natural disasters..

FINAL SUMMARY OF PROJECT ACTIVITIES

The project started with the rationale that Philippine mangroves are threatened by typhoons, sea level rise (SLR), and anthropogenic activities such as urbanization, conversion to aquaculture ponds, and ineffective mangrove restoration programs. These threats are exacerbated by the lack of understanding of how the status of mangrove forests (e.g., intact, restored, or disturbed) will affect their resiliency. Given these challenges, the PI Dr. Salmo and his project team collaborated with local environmental managers to study the biodiversity and the ability of typhoon-damaged mangroves to adapt to natural disasters. These activities were made possible through the engagement and training of research assistants (RAs) and undergraduate and graduate students. The information they gathered and analyzed can be used to improve mangrove restoration programs and enhance existing local management practices.

There were three project partners' meeting in Ateneo de Manila University (2015), Masinloc (2016) and Palompon (2017). The meetings in 2016 and 2017 also served as training for the partners in sustaining the mangrove monitoring programs in their respective jurisdictions. The project also co-organized the 1st National Seagrass and Mangrove Bioshield Conference (2016), where some partners presented their mangrove conservation programs. Seven project sites were established to serve as mangrove monitoring stations: Bani, Pangasinan; Masinloc, Zambales; Subic, Zambales; Busuanga, Palawan; Kalibo, Aklan; Bantayan Island, Cebu; and Palompon, Leyte. These sites were chosen based on their proximity to landfall areas of typhoons, particularly Super Typhoon Haiyan, and their suitability for representing various forest conditions—intact, disturbed, or restored. Two sites (Puerto Galera, Mindoro Oriental, and Las Piñas-Parañaque Critical Habitat and Ecotourism Area) were recently added to complement the assessment of the contribution of mangrove restoration programs in the enhancement of biodiversity research. The project team conducted periodic site assessments (four to six months per site) to track and evaluate spatio-temporal changes in mangrove vegetation and sediment conditions. They also carried out sediment sampling for carbon stock measurements. The project provided the first estimate of total carbon stocks for Philippine mangroves and highlighted both the impacts of typhoons and the difference in the carbon storage capacity of natural versus planted stands. The team's findings point to improvements that are needed in current practices for mangrove restoration design and implementation. The project also pioneered the use of the rod Surface Elevation Table – Marker Horizon (rSET-MH) instrument in the assessment of surface elevation change (as an indicator of vulnerability or adaptability) of Philippine natural and planted mangroves against SLR. The results provide an estimate of adaptive capacity of the various sites to SLR based on the extent and health of mangroves in the area.

In addition to the research outputs in the form of conference presentations and published papers, the project resulted in significant capacity building for the many students involved. The project supported undergraduate theses by eight students and graduate theses by six (two completed and four ongoing as of April 2018). These studies focused on carbon sequestration and nutrient resorption efficiency between natural and planted mangrove stands, fish biodiversity in the mangrove-seagrass-coral continuum, carbon stocks in the mangrove-seagrass continuum, crab and microbial activity in natural and planted mangrove stands, seedling growth in natural and planted mangrove stands, effects of mining on mangrove sediments, and contribution of litter fall on the accretion in mangrove sediments. These results were also shared in several meetings with the policy makers from the government and NGOs, including in the Road Mapping and Planning Workshop sessions by the Climate Change Commission (CCC). The CCC included in their work plan the conduct of carbon stocks assessment and greenhouse gas inventories in some other representative mangrove sites in the Philippines. The PI also received a similar invitation from the Philippines' Congress to comment on their proposed coastal monitoring and management bills.

Dr. Salmo reports that even though the project has now ended, he is committed to continuing to pursue the partnerships developed and fostered under PEER and seek other funding to continue relevant research and education activities. Local mangrove managers from the municipalities involved in the project have expressed interest in continuing the joint work, which would be leveraged with their existing budget resources for environmental conservation. The PI is also working to develop additional partnerships with Conservation International-Philippines and Maynilad Water Services, Inc. to support follow-on activities. The project website at https://mangroveecology.com will continue to be regularly updated, and Dr. Salmo is working with Prof. Miguel Flores on a book on Philippine mangroves that is expected to be submitted for publication later in 2018.

“The PEER project provided me an opportunity to conduct and enhance mangrove research in the Philippines. Prior to this grant, we have difficulty in getting funding even from our national government. With the PEER program however, I am definitely confident that I will be getting more opportunities to further mangrove research in the country. Proof of it is the two-year research grant that I secured last year where the funder recognized the importance of my project proposal as it is supported by PEER. Through the PEER project, I was also able to engage RAs, undergraduate and graduate students, and local mangrove managers. This pool will definitely contribute in sustaining mangrove research and network of mangrove managers in the country. I was also engaged in various international and national networks because of the research I have done in the Philippines. These are just some of the things [for which] I will be forever grateful to the PEER program.” Dr. Severino Salmo III

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PHILIPPINES - PROJECT 3-163: LAKE TAAL: SUSTAINING NATIVE BIODIVERSITY IN THE FACE OF AQUACULTURE, CLIMATE CHANGE, AND NON-NATIVE SPECIES

PI: Rey Donne Papa, University of Santo Tomas
U.S. Partner: Terrence Gosliner, California Academy of Sciences (Funded by the National Science Foundation)
Dates: September 2014 – August 2016

PROJECT OVERVIEW

Lake Taal is a freshwater ecosystem where its geological origins, location, and the presence of the world's lowest active volcano led to the evolution of a diverse flora and fauna. Its fisheries are integral to local communities and have sustained them for centuries. In the past three decades, however, the biodiversity of Lake Taal has been threatened by aquaculture. This has eventually led to poorer water quality and alteration of species' structure. Few scientific research studies on Lake Taal have been published, which has also led to a lack of available information for making sound management policies to alleviate current problems. This research study focused on determining the range of Lake Taal's biodiversity and shed light on the impacts of aquaculture, newly introduced species, and climate change on the native flora and fauna.

The researchers were able to document 833 species in Lake Taal, 17% of which were new records. Among the most evident results from biodiversity surveys were the large number of new records from taxa that have not been sampled previously, including bacteria, fungi and herpetofauna. The project also focused on distribution patterns of selected flora and fauna through GPS associated data. Among the lake's flora, a distinct difference in the species composition of aquatic plants was observed in the North and South Basin. Native fish species were only found in limited regions of the lake and were associated mainly with littoral areas.

In addition, an analysis of available archived data, including physico-chemical and meteorological data, showed how proximate stations within Lake Taal yielded similar monitoring data within the 10-year time period, suggesting that limiting the number of proximate stations, increasing monitoring frequency and adding nutrient and biological data would provide a more comprehensive monitoring of the lake's water quality. The analysis also gave the researchers the opportunity to observe how the lake's surface water temperature responds more strongly to changes in regional air temperature compared to local and global scales and confirms Lake Taal's surface water temperatures had been rising as a response to increasing regional air temperatures.

FINAL SUMMARY OF PROJECT ACTIVITIES

Throughout the project, the research team collaborated with experts from the California Academy of Sciences (CAS). The collaboration with CAS researchers helped develop the skills and capacity of the research team to better manage the scientific collections obtained from the various sampling expeditions in Lake Taal. Team members learned sampling techniques, collections management, organization and database creation during a one-month stay at CAS. The training received by the team will be instrumental in establishing a natural history collection at University of St. Thomas. The visit also gave team members a chance to write several papers based on the gathered results, some which have already been published under peer-review.

The research results were shared through peer-reviewed publications, presentations and discussions with government agencies, conservation and community groups, as well as a pioneering museum exhibit entitled “Taalaman: The Lake’s First Biomuseum”.

Students enrolled in the Biodiversity and Conservation Biology course in the UST Graduate School had to learn independently how to mount an exhibit featuring biodiversity. The Taalaman museum exhibit helped increase public awareness on the importance of Lake Taal as a biodiversity hotspot, given how its native flora and fauna must cope with external pressures and was well-received by both the scientific community and the general public. The exhibit had many walk-in visitors. A video of live specimens of the Lake Taal sea snake (*Hydrophis semperi*), was uploaded to social media and created a lot of buzz.

The PEER grant was also the catalyst for the first Philippine Symposium on Freshwater Biodiversity and Ecosystems, which provided a venue for the dissemination of recent research findings on different freshwater ecosystems in the country, including those conducted by the PEER project members in Lake Taal and led to the establishment of the Philippine Society for Freshwater Sciences, which will organize future symposiums and serve as a professional organization of freshwater biologists in the country. The involvement of young scientists, including a majority of female team members, in all aspects of the project may help build a more educated and scientifically inclined Philippine community.

Their research activities relied heavily on collaborative work, particularly with government agencies. From the beginning, the team linked up with NGO partner Pusod, Inc., and the Protected Areas Superintendent of the Taal Volcano Protected Landscape office. During the Lake Taal Research Summit, findings were reported to the top officials of the regional office of the Department of Environment and Natural Resources (DENR), with the hope that they will utilize the results to improve conservation policies.

The PEER team shared with the Bureau of Fisheries and Aquatic Resources new recommended spacing between monitoring sites for a more comprehensive and cost-efficient monitoring of water quality in aquaculture areas in the lake, as well as additional biological and chemical data important for monitoring water quality trends. The Bureau of Fisheries Aquatic Resources also provided live specimens for display during the Taalaman exhibit. The researchers collaborated with other academic institutions in the Philippines including the National Museum, University of the Philippines, Diliman and the Ateneo de Manila University.

The PI was also recipient, as a project member, of two new collaborative research grants covering biodiversity and nutrient cycling totaling more than $130,000 USD.

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PHILIPPINES - PROJECT 1-177: ENHANCING MARINE NATURAL RESOURCE AND BIODIVERSITY MANAGEMENT IN THE PHILIPPINES BY EXTENDING POPULATION CONNECTIVITY RESEARCH

PI: Maria Carmen Ablan Lagman, De La Salle University
U.S. Partner: Kent Carpenter, Old Dominion University (Funded by the National Science Foundation)
Dates: June 2012 – May 2016

PROJECT OVERVIEW

Severe declines in fisheries resources have implications for millions of coastal families who rely on fisheries for food and livelihood in developing countries. In most cases, the communities dependent on the resources have very few alternatives to the loss of their fisheries-based livelihoods when resources are devastated. Fisheries in these areas urgently need management strategies that will not only halt overfishing and habitat degradation but also hasten recovery of fish stocks. Recovery and eventual sustainability of fisheries subjected to intense fishing pressure hinge on the availability of new recruits and their success in replenishing resources harvested from the system. Information on spatial structure of populations and connectivity will potentially benefit management efforts related to fisheries because it contributes to answering the questions: “why do species occur where they occur?” and “how can we ensure survival of populations in an area?".

This project used naturally occurring genetic tags, screening genetic markers using a recently developed technology called NextGen sequencing. The selected markers were retrieved from samples from populations within selected bioregions in the Philippines and analyzed to determine which populations have distinct genetic signatures across the Philippine archipelago, likely to be dependent on other populations. This project compliments two major USAID programs, the Coral Triangle Initiative and the Global FISH Alliance. It sought to provide badly needed biological information on fish stock structure and population connectivity to help local and regional agencies in setting and implementing fishery management policies to ensure that viable populations survive and thrive.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team collected samples of five species—*Scylla serrata, Stichopus horrens, Acanthochromis Polyacanthus, Katsuonus pelamis, Acropora hyacinthus*—from predetermined locations within marine corridors of the Philippines and used sequencing techniques to establish their population structure and connectivity across the country.

The PEER project team and the U.S. partner and other U.S. researchers participated in a Pacific Advanced Science Institute at Siliman University in Dumaguete, where participants gave lectures on the applications of NextGen sequencing to studies on adaptation, biodiversity and conservation. The PEER researchers presented their work plan, receiving feedback from invited experts.

The team conducted three major training sessions on population genetics with 85 researchers and graduate students. The PEER project increased the number of people capable of conducting research on population structure and connectivity in the Philippines by helping one Master’s student to complete her degree, two doctoral students and two Master's students to reach their final defense stage, and 13 undergraduates to complete their theses.

Two team members were awarded highly prestigious Fulbright grants: Dr. Ablan-Lagman received an advanced research and teaching fellowship for a stay of several months at Oregon State University, and PhD student Chona Camille Vince Cruz won a dissertation fellowship to pursue her research at the University of Washington from January through July 2016.

After facing challenges with a microsatellite marker, the researchers developed a semi-automated species identification system that later won the R&D Award competition of the Department of Science Technology Philippine Council for Industry, Energy, and Emerging Technologies

This project involved research undertaken by five separate institutions in the Philippines, developing a framework to strengthen national capability for marine natural resource management. The PEER grantees also reached a broader audience via the PhilGenes Diversity Network (PGDN), a community of researchers using molecular markers to study biodiversity in the Philippines, and its database. They also created a website designed for a non-scientific audience to disseminate their results more broadly. Researchers also took part in the 1st National Mud Crab Congress, organized by the Southeast Asian Fisheries Development Center, presenting findings that may be helpful in managing wild stocks of mud crabs and cultured crabs for harvest.

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PHILIPPINES - PROJECT 1-34: PATHWAYS FOR INDIGENOUS KNOWLEDGE ENGAGEMENT ON MARINE BIODIVERSITY CONSERVATION

PI: Marivic G. Pajaro, Haribon Foundation for the Conservation of Natural Resources
U.S. Partner: Douglas Medin, Northwestern University (Funded by the National Science Foundation)
Dates: June 2012 – July 2015

PROJECT OVERVIEW

The Philippines is both a global priority area for the conservation of marine biodiversity and highly dependent on marine resources, with more than one million people directly dependent upon the fisheries sector. This project is based on the belief that local people, using indigenous knowledge, are capable of solving many environmental challenges, particularly if supported by their jurisdictions. In the Philippines, moving to include a bottom-up approach for coastal resource management has become widely accepted as governments decentralize. Even so, local people remain marginalized on issues surrounding natural resource conservation and management. Larger-scale concepts such as biodiversity may be somewhat beyond local knowledge systems and require targeted learning strategies. This project addressed the related need for a cross-cultural understanding of environment and biodiversity in fisherfolk cultures, building upon fisherfolk social knowledge systems, historic and contemporary cultural profiles, and consideration of economic and political institutions and practices for linked communities.

The PIs undertook a survey that covered four of the six marine bioregions, i.e. the North Philippine Sea, South Philippine Sea, the Visayan Sea, and West Philippine Sea. A total of 5,500 people responded, including 1,500 from 60 communities that are part of the alliance of community-based marine protected areas and 4,000 from 16 communities in coastal provinces across the North Philippine Sea. The team realized their primary objective of reaching multiple bioregions through intensive work in the Northern Philippine Sea as well as the distribution and review of an initial fisherfolk toolkit.

Common cultural traits or perspectives emerged for fisherfolk in general, as well as across the coastline of the Northern Philippine Sea. The results from the survey will help in developing further educational programming, both formal and informal. The team also identified and worked on educational activities and partnerships to transfer best practices identified from merging fisherfolk knowledge, international marine science and Philippine coastal resource management.

FINAL SUMMARY OF PROJECT ACTIVITIES

As a result of this research and analysis, the team focused on developing ways to apply the findings across a wide range of educational sectors and worked closely in targeted best practices areas to transfer what they learned. They partnered with University of the Philippines School of Health Sciences and the Aurora Province Health Department to obtain data for a project on Maternal and Early Childhood Protein Nutrition, which were then analyzed by team members.

High school students were mentored and exposed to outdoor biodiversity experiences, participated in several leadership development workshops, visited a Marine Protected Area (MPA) for snorkeling, and helped plan and deliver a community-based Earth Day celebration. Now organized as the Baler Youth Environment Ambassadors, they continue to spearhead ecological solid waste management programs in their campuses and have helped communities start their own compost pit.

Undergraduate students in nursing and fisheries programs were provided with hands-on experience in conducting research, with the field research becoming part of their course work. They also gained knowledge on the concept of the cultural consensus model (CCM) and skills in data collection through interviews, the 5-point Likert Scale, and simple qualitative analysis.

Fishers, primarily members of the PAMANA KA SA Pilipinas national alliance also gained knowledge on the CCM concept and its implications for different stakeholders. Selected leaders were tapped as enumerators in several PAMANA sites after undergoing orientations and practice in data collection.

Members of Kalipunan ng Mangingisda sa Dagat ng Baler (KALMADABA), an alliance of Fishers, including female members, from different villages in the municipality of Baler participated in resource assessment of the intertidal reef flat, notably the mangrove and seagrass ecosystems, and gained skills in conducting interviews. Simple analysis of the data and presentation skills were also provided which allowed them to give feedback on the results credibly to important government officials, The aim of this mentoring program was for KALMADABA to take the lead in proposing a protected area for the deteriorating conditions of their intertidal reef flat, and the team provided them with seed funds and financial management training to continue the project.

The team sought to partner with four provinces to formalize the Aurora Marine Protected Area network and consider adding new offshore MPAs. All told, the PEER team organized or were involved in more than 25 workshops, trainings and conferences.

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PHILIPPINES – PROJECT H2-7: EFFECT OF A SMOKING CESSATION INTERVENTION PROGRAM FOR FAMILIES OF CHILDREN DIAGNOSED WITH TB

PI: Benjamin Sablan, Philippine Ambulatory Pediatric Association
U.S. Partner: Jonathon Winickoff, Massachusetts General Hospital and Harvard Medical School (Funded by the National Institutes of Health)
Dates: February 2015 – June 2018

PROJECT OVERVIEW

Prior to this project, the Philippine Program for Tuberculosis had largely focused on adult TB. Recently childhood TB has been addressed because they have more serious clinical presentations and the patients usually become the reservoir for adult TB cases. However, issues on the implementation of the childhood TB program identified problems with the clinical diagnosis and treatment of children with TB. As a result, the Philippines case detection rate for childhood TB is very low at twelve percent (12%). Children are a particularly vulnerable group with a developing immune system exposed to environmental modulators affecting this system. Substances found in tobacco have been shown to have effects not only in carcinogenesis, but in the susceptibility to diseases such as TB. In the 2011 Global Youth Tobacco Survey, it showed 48% of youth are exposed to smoke inside the homes. This study aimed to look into correlation of serum cotinine levels due to tobacco use and exposure to secondhand smoke (SHS) in children diagnosed with active and latent TB disease. It also looked at effects of a brief advice on smoking cessation and a tobacco control resource center in a community health center on outcomes of treatment of active cases of TB in children. Specifically, the researchers worked to determine the following: (1) the correlation of the level of urine cotinine, used as a proxy measure of secondhand smoke exposure, with the development of active TB and latent TB in children; (2) the effect of a brief advice on smoking cessation on the number of quit attempts of smoking parents and/or guardians of the child diagnosed with pulmonary TB; and (3) the effect of secondhand smoke exposure of children diagnosed with pulmonary TB on time to resolution of the child's clinical signs and symptoms related to TB. This was a case control study on a community in Pampanga with a population of 230,000. Exposure to tobacco use and SHS were determined with a validated interview tool developed by Richmond Center and the USG-supported partner that was translated and adapted to the local environment and correlated with levels of urine cotinine. The urinary cotinine levels were compared among those children without TB disease and with TB disease, both latent and active. A tobacco cessation intervention composed of brief advice by healthcare workers was conducted on TB patients identified to have been exposed to tobacco or SHS. The effect on treatment of TB in children was then correlated with smoking cessation or decreased exposure to SHS and levels of urinary cotinine. The primary hypothesis was that tobacco use and SHS exposure predisposes children to TB disease. The second hypothesis was that a brief advice for smoking cessation would increase quit attempts and quit rates of smoking, which would result in decreased levels of exposure to SHS.

FINAL SUMMARY OF PROJECT ACTIVITIES

The study was completed in June 2018 and took a convenience sampling of all children identified as suspect for TB in Mabalacat and Guagua Pampanga, Philippines, which yielded 327 children who were enrolled in the study. Using an adapted survey for secondhand smoke exposure from the Richmond

Center, parents and caregivers were identified as smokers and children's exposure to SHS was confirmed. All children were screened for TB and samples taken for urine cotinine. Using the HPLC Elisa test, urinary cotinine concentration was determined. Findings in all three groups of children found a range of no TB, TB infection, and TB disease to be comparable in age, sex and nutritional status. There was no significant difference in the urinary cotinine levels in the three classes of patients ($p=0.7703$). However, there was an association found between the disease state and the number of smokers in the household ($\chi2=14.1768$, $p=0.028$). For the second objective, advice was seen to increase cessation attempts of adult smokers significantly. Lastly, there was no relationship noted on the effect of SHS to the time to improvement of signs and symptoms associated with TB in children.

This prospective study concluded that the number of smokers in the household was shown to be significantly correlated to the child's development of TB infection and disease. Determining the number of smokers in the household should be an important step to identify children at risk for TB. The researchers were able to validate the measurement of urine cotinine using HPLC Elisa technique, which can serve as an alternative to HPLC mass spectrometry, especially in resource-limited locations in the country.

PHILIPPINES – PROJECT H2-6: DIAGNOSIS, TREATMENT AND MANAGEMENT OF PEDIATRIC TUBERCULOSIS IN HEALTH EMERGENCIES AND DISASTERS

PI: Salvacion Gatchalian, University of the Philippines, College of Medicine, Philippine General Hospital
U.S. Partner: Kristy Murray, Baylor College of Medicine (Funded by the National Institutes of Health)
Dates: February 2015 – April 2019

PROJECT OVERVIEW

The province of Bohol was struck by an earthquake in October 2013 and swept by Typhoon Haiyan only a month later, creating destruction and interruption of health services. Included in the disruption were TB screening, prevention, and directly observed treatment (DOTS) programs. In addition to concerns over the disruption of services, extensive crowding in emergency shelters and camps potentially put children at higher risk for exposure to TB. Although there is very limited evidence to guide TB control strategies during displacement following natural disasters, interagency guidelines have been developed to address TB treatment in the acute and recovery periods following a complex emergency. The importance of reconstructing TB services during the post-conflict phase is well recognized and requires coordination and collaboration among key stakeholders. Experience has demonstrated that major impediments to successful reconstruction of TB services include mobile populations, destroyed infrastructure, and lack of coordination and/or interest in TB treatment, leading to poor case detection and sub-optimal TB control. However, all of these challenges are also opportunities to introduce interventions to improve TB control.

This study team used a cross-sectional cluster survey using rapid assessment methods to determine the prevalence of TB infection and disease in children under age 15, as well as a descriptive study using social science mixed methods to assess barriers to pediatric TB control, prevention, and treatment post-disaster. Anticipated outcomes included an assessment of prevalence and risk of TB infection and disease among children displaced by health emergencies and disasters and a better understanding of how the disasters impacted TB treatment, prevention, and control.

The specific objectives included the following: (1) estimate the prevalence of TB disease in children in the community and those currently residing or having a history of residing in disaster camps/shelters in Bohol using rapid assessment cross-sectional cluster survey methods; (2) assess the correlation between the validated risk factor assessment score and positive TB cases and compare the actual prevalence of TB to baseline as well as differences in prevalence in displaced versus non-displaced children; (3) examine the sensitivity and specificity of GeneXpert in sputum and stool as compared to direct smear; and (4) document barriers to implementation of IPT and document additional barriers/disruption of services that occurred post-disaster.

FINAL SUMMARY OF PROJECT ACTIVITIES

After receiving approval from the ethics review committee of the University of the Philippines in November 2015, Dr. Gatchalian and her team carried out their study from 2016 through 2018 in the province of Bohol, Philippines, which experienced a strong earthquake in October 2013 and was hit by the extremely severe Typhoon Haiyan in November 2013. The study participants included children ages 0-14 who lived in 184 barangays (villages) located in 14 municipalities (towns), comparing areas heavily affected and less affected by the natural disasters. The original target sample size was 4,200 children, but the team ultimately enrolled 5,475.

The researchers found that the prevalence of TB in children was affected by living in a temporary shelter (evacuation center) with more than 25 persons; older age of children; history of prior treatment for TB; known contact with a person with TB; living on a geographically isolated island; and greater distance from healthcare resources. Based on their findings, the team designed three risk assessment tools to help identify children at risk of TB infection. They conducted a stakeholder meeting on August 13, 2018, to share their results and tools with the province's governor and representatives from all 14 municipalities involved in the study, including mayors, municipal health officers, National Tuberculosis Program coordinators, and community health workers. U.S. partner Dr. Kristy Murray and her student Lauren Leining, who assisted with spatial analysis on the study, also took part. The PEER team also had a separate meeting later with the province's health officer, who expressed concern over the findings and shared his interests in looking at the prevalence of TB among schoolchildren. Also in August 2018, Dr. Gatchalian and her colleagues presented their work at the annual convention of the Philippine Coalition Against Tuberculosis (PhilCat), which attracted some 1,500 delegates from governmental and non-governmental institutions working on TB, as well as relevant professional societies.

Sadly, PI Dr. Sally Gatchalian passed away due to COVID on March 26, 2020. She was among the first healthcare workers in the Philippines to succumb to the disease, which she acquired while selflessly treating patients in the pandemic's very early days. Her legacy will live on in the memories of her patients, students, fellow researchers, and friends, and her research continues to move forward thanks to the efforts of her colleagues. As of the date of the final report submitted by her institution in early 2021, the team had published three papers and had one more in preparation.

PUBLICATIONS

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Kristy O. Murray, Nina T. Castillo-Carandang, Anna M. Mandalakas; Andrea T. Cruz, Lauren M. Leining, and Salvacion R. Gatchalian, on behalf of the PEER Health Bohol Pediatric Study Team. 2019. Prevalence of Tuberculosis in Children After Natural Disasters, Bohol, Philippines. Emerging Infectious Diseases 25(10):1884-1892. https://dx.doi.org/10.3201/eid2510.190619

PHILIPPINES – PROJECT H2-5: ENHANCING CHILDHOOD TUBERCULOSIS IDENTIFICATION AND TREATMENT IN THE PHILIPPINES

PI: Anna Ma. Lena Lopez, Institute of Child Health and Human Development, University of the Philippines Manila--National Institutes of Health
U.S. Partner: Karin Nielsen, David Geffen UCLA School of Medicine (Funded by the National Institutes of Health)
Dates: February 2015 – June 2019

PROJECT OVERVIEW

Childhood tuberculosis (TB) in the Philippines remains under-diagnosed, despite significant gains in the control of adult cases of TB. Learning from their experience in the previous year from a prospective community-based surveillance for TB in San Juan, Batangas, Philippines, this team designed various interventions to increase case detection and improve treatment outcomes of TB in the Philippines. They conducted a cluster-randomized field trial to assess the effect of an intervention package on tuberculosis case finding, treatment outcomes, and identification of children for isoniazid preventive therapy. The intervention package was implemented in randomly chosen barangays of two study sites. Aside from the childhood TB activities included in the National Tuberculosis and Control Programme (NTP) manual, no additional interventions would be offered in the rest of the barangays. This package included (1) enhanced contact tracing through the use of a mobile phone application (app) that automatically notifies barangay health workers (BHW) of patients enrolled in the NTP; (2) reinforcement of public health programs such as the Integrated Management of Childhood Illnesses (IMCI) and the nutrition program requiring referral of children with prolonged cough or fever, or with acute malnutrition for assessment of TB; (3) use of an USAID-funded field guide for health workers on childhood TB; (4) use of nasopharyngeal aspirates as a specimen for microbiologic testing among children who cannot expectorate; (5) use of a phone app that automatically informs patient's follow-up date; and (6) use of text (or SMS) blasts to provide TB health education to enrolled study subjects.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team conducted a cluster-randomized study in San Juan, Batangas, and Los Baños, Laguna, to assess the package of interventions surrounding TB control. San Juan and Los Baños have 42 and 19 barangays (communities), respectively, and each was randomly assigned as control or intervention for the trial. BHWs and midwives in the intervention group underwent training with regards to the study procedures, including the use of the mobile app for notification of positive tests of patients for faster contact tracing, nasopharyngeal aspiration, and referral of children assessed in the Integrated Management of Childhood Illness to the National TB Program (NTP) staff in the clinic. BHWs and midwives in the control group were informed of the study, but no additional training was provided. At the time of referral to the NTP, research staff obtained informed consent and assent (as appropriate) for study participation. Those in the intervention group who were unable to expectorate underwent nasopharyngeal aspiration for smear, Xpert, and culture.

From September 2015 to August 31, 2017, 1,017 children with presumptive TB and 1,075 adults with diagnosed TB were screened. Among the children screened, 586 (57.6%) and 431 (42.4%) were eventually enrolled in the intervention and control groups, respectively, and among adults enrolled 562 (52.2%) and 513 (47.7%) in the intervention and control groups, respectively. Among children, there were more presumptive TB cases in the intervention group, with more coming from Los Baños compared to San Juan among those who were enrolled. The majority of presumptive TB cases were identified during contact tracing followed by the IMCI program.

The team found that the package of interventions improved identification of presumptive TB cases but did not significantly increase detection of TB cases and latent TB infection cases. The majority of the presumptive TB cases were identified through contact tracing and the children were mostly exposed to TB cases in the household. The team's findings support that improving and consistently monitoring contact tracing will improve identification of presumptive TB cases. In addition, identifying cases in the IMCI also contributes to identification of presumptive TB cases. Nasopharyngeal aspiration was also tolerated and found acceptable by parents and children alike.

These are preliminary results from the study available at the time the final report was submitted in 2019. At that time, both San Juan and Los Baños were implementing screening for TB during IMCI visits, as well as consistently screening and inviting household contacts for TB. Dissemination of results was under way, as they will be helpful in further screening for TB and referring cases for treatment. Unfortunately, the PI Dr. Lopez passed away in February 2020 after a long illness.

PUBLICATIONS

A.L. Lopez, J.G. Aldaba, M. Moralez-Dizon, J.N. Sarol, J.V. Daag, M.C. Ama, P. Sylim, A. Salonga, and K. Saines-Nielsen. 2019. Urine Xpert MTB/RIF for the diagnosis of childhood tuberculosis. Int J Infect Dis 79: 44-46. https://doi.org/10.1016/j.ijid.2018.11.013

SRI LANKA

SRI LANKA - PROJECT 7-201: DEVELOPING DENGUE RISK PREDICTIONS FROM ENVIRONMENTAL, ENTOMOLOGICAL, AND SOCIETAL INFORMATION TO AID PUBLIC HEALTH MANAGEMENT IN SRI LANKA

PI: Pahalagedera Hewayalage Dona Kusumawathie, Tropical Climate Guarantee
U.S. Partner: Aravinda De Silva, University of North Carolina Chapel Hill (Funded by the National Institutes of Health)
Dates: November 2018 – April 2022

PROJECT OVERVIEW

Dengue is a major vector-borne viral disease that has become a serious public health problem in Sri Lanka and elsewhere, but the lack of a vaccine against it means that control programs rely on management of environmental and human factors. Dengue is highly intermittent, has some seasonality, and is showing an exponential rise in the last few decades (Hopp & Foley, 2003). Dengue outbreaks are primarily associated with climatic variables such as rainfall, temperature, and relative humidity. Usually, peak transmission occurs after the rains in the areas where the mosquito population is high, and temperature and humidity levels are optimal. Nevertheless, there can be situations where transmission is enhanced during droughts, as water storage becomes more important. Though the risk of epidemics is contingent on a complex set of social, environmental, climatic, and epidemiological factors and their prediction is fraught with uncertainty, climate is a critical factor. As there is a 1–2-month lag between heavy rains and dengue transmission, targeted weather monitoring can give advance warning of dengue risks and trigger alerts to the authorities to launch cleanup programs of potential breeding sites.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project involved a large multidisciplinary team of 39 scientists (13 male and 26 female) working together to compile and analyze an archive of data on epidemiology, climate, entomology, and socioeconomic factors associated with the transmission of dengue in Sri Lanka. The work was particularly challenging in a setting where much of the data had previously been in paper format only, in different siloed organizations, and subject to strict access requirements. Dr. Kusumawathie and her team assembled dengue case data for research at different spatial (village, sub-district, district, provincial) levels and temporal (daily, weekly, monthly, quarterly, and annual) scales. To integrate climate factors, they compiled daily and monthly rainfall, temperature, and relative humidity data from available stations. The scientific objectives were to (1) identify relationships between prevalence and transmissivity of the dengue vectors and weather using routinely collected data; (2) identify relationships between abundance of vectors, incidence of dengue, and weather in the country's Central Region; and (3) develop dengue risk prediction methodology based on weather for high-risk centers. Through these efforts the PI and her team have developed an early warning system for dengue risk using weather, climate, entomological and epidemiological information for Sri Lanka, working in close collaboration with the Central Province Health Department and National Dengue Control officials. These government officials were engaged in helping to develop the risk prediction methodology and formats for dissemination.

The PI and her team shared their results and recommendations with public health officers and other interested stakeholders via the Internet and in-person workshops, highlighting the emerging evidence of climatic influence on dengue, both spatially and temporally. Key project outputs included the following:

- A database of fine-scale climatic, hydrological, entomological, and dengue information
- Fine-scale climate analysis and high-resolution prediction techniques
- A climate monitoring system, including 13 weather stations from which the researchers can continue to draw data that they feed into weekly climate bulletins. For the location of Akurana, they have been communicating our data online through Twitter and Facebook accounts.
- Geographic Information Systems mapping for climatic, hydrological, dengue and societal data
- Curriculum and Course Development. Several courses for health sector and other sector personnel were developed and submitted to the Tertiary and Vocational Education Commission, including on topics related to climate change and data management.

In terms of broader impacts, Dr. Kusumawathie cites the strengthening of her team's relationship with the National and Provincial Health Authority, as well as the establishment of new linkages with the U.S. Embassy and USAID. They have also built networks of local government, semi-government, and private tertiary education institutions in Sri Lanka and provided internships to students from the University of Peradeniya, University of Ruhuna, Open University Sri Lanka, Sri Lanka Institute of Advanced Technological Education, National Institute of Business Management, and International College of Business and Technology. Going forward now that the PEER funding has ended and the situation in Sri Lanka is stabilizing, the PI and her colleagues plan to continue implementing outreach and training programs for their stakeholders and students, collecting data from their weather station, and producing monthly dengue risk updates. They have made many in-person presentations to conferences and other events and plan to continue that practice, as well as publishing their work in journals. They will also continue maintaining their website www.disease.lk focusing on climate and disease and highlighting their approach based on the use of environmental, climate, and vulnerability information. Apart from dengue information, they have been populating the site with data on COVID-19 and other emerging infectious diseases.

PUBLICATIONS

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S.W.S. Sasna, K. Wikramasinghe, and L. Zubair. 2022. The effects of climate on dengue occurrence in Matale, Sri Lanka: Generalized Linear Models. Rajarata University Journal 7(2).

Project Websites: https://tropicalclimateguarantee.org/dengueand **htpps://disease.lk**

SRI LANKA AND THE MALDIVES - PROJECT 3-152: DEVELOPING MONITORING TOOLS FOR MANAGING DROUGHT RISK AND ADDRESSING THE RIDDLE OF INCREASED DROUGHT TENDENCY AMIDST THE WETTER CLIMATE CHANGE PROJECTIONS FOR SRI LANKA AND THE MALDIVES

PI: Lareef Zubair, Foundation for Environment, Climate and Technology, With Co-PI Mizna Mohamed, Maldives National University
U.S. Partner: Bradfield Lyon, International Research Institute for Climate and Society, Lamont-Doherty Earth Institute at Columbia University (Funded by the National Science Foundation)
Dates: November 2014 – October 2017

PROJECT OVERVIEW

Recent droughts in Sri Lanka and the Maldives have created water scarcity and disruption to everyday life in both countries. The PEER project developed drought monitoring data and credible information on near-term climate change for Maldives and Sri Lanka. As part of the project, the team set up publicly accessible drought information portals and offered improved and new weekly and monthly advisories on climate impacts and drought status. These portals show the climate anomalies, characterize drought, and assess the impact of droughts on myriad sectors and communities.

The PEER grant team also installed and improved meteorological and soil moisture data infrastructure in both countries and set up new systems to analyze data. The PIs published a wide selection of peer-reviewed analysis on drought and climate change in the two countries.

FINAL SUMMARY OF PROJECT ACTIVITIES

Each week, the team provides a climate advisory for Sri Lanka online used to inform national water resource allocations through a consultative process involving the host institute - the Mahaweli Authority of Sri Lanka, the Ceylon Electricity Board, the Irrigation Department and the National Water Supply Board. The PEER grant provided the resources to sustain, improve and automate the existing advisory. In the Maldives, in collaboration with the Maldives Meteorological Service, their monthly climate report is widely disseminated. The researchers are now consulted by water resources engineers, energy managers, agricultural managers and the media on seasonal predictions, including an international story on drought in Sri Lanka.

Throughout the project, the team sought historical meteorological data required for analysis in the Maldives and Sri Lanka, set up automatic web-scraping systems to archive climate data going forward, and assessed satellite rainfall estimates. In collaboration with the Maldives Meteorological Services, the researchers set up soil moisture probes and field transmitters. In both countries, the team installed automatic weather stations (AWS). The researchers implemented protocols to map rainfall deficits and drought indices in both countries and set up a database and analysis system for climate analysis mirroring a similar system developed at the IRI Data Library.

Researchers and graduate students did field research and assessed water scarcity and vulnerability to drought and worked to develop new projections. Both ongoing data collection and analysis were distributed through a variety of channels, including social media, advisory flyers, academic presentations and workshops at both the university and middle school level. About 20 graduate students were involved in the project and received advanced training as a result.

The work done through the PEER grant helped the PIs win an additional grant from Dilmah Conservation to guide research on the impacts of climate change on tea in Sri Lanka.

PUBLICATIONS

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Lokuhetti, R., Zubair, L., Visvanathan, J., M., Nijamdeen, A. 2017. Drought Monitoring for Sri Lanka: Spatial Extent and Temporal Evolution during the 2016-17 Drought. International Roundtable on the Impact of Extreme Natural Events: Science and Technology for mitigation IRENE 2017. (pp.29). Sri Lanka: South Eastern University.

Zubair, L., and Wickramagamage,P. 2017. Proceedings of the Pinga Oya Symposium, University of Peradeniya and Foundation for Environment, Climate and Technology, Kandy, Sri Lanka.Pages(106)

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Zubair, L., Yahiya, Z., Agalawatte, P. and Lokuhetti, R. 2016. The El Nino event of 2015/16 in Sri Lanka: Predictions, Preparedness, Communication and Impacts. In Climate Change Secretariat (Ed.), NEELAHARITHA-The Climate Change Magazine of Sri Lanka (pp.40-46). Sri Lanka: Ministry of Mahaweli Development and Environment.

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Agalawatte, P., Yahiya, Z., Viswanathan, J., Zubair, L. and Bell, M. 2016. Providing climate services for water management in Sri Lanka. In Climate Change Secretariat (Ed.), NEELAHARITHA-The Climate Change Magazine of Sri Lanka (pp.40-46). Sri Lanka: Ministry of Mahaweli Development and Environment.

SRI LANKA AND INDIA - PROJECT 2-475: FECAL SLUDGE AND URINE REUSE IN AGRICULTURE – OPPORTUNITIES FOR ADDRESSING PHOSPHORUS NEEDS IN INDIA

PI: Pay Drechsel, International Water Management Institute, With Co-PI Vijayaraghavan M. Chariar, Indian Institute of Technology Delhi
U.S. Partner: James Elser, Arizona State University (Funded by the National Science Foundation)
Dates: August 2013 – November 2016

PROJECT OVERVIEW

India's rapid urbanization and population growth have made food security a high policy priority and is putting significant pressure on the agriculture sector, where poor and marginal farmers especially suffer from high fertilizer prices. It is therefore imperative for India to explore alternative nutrient sources. With changing resource flows to cities, urban waste offers a variety of options for resource recovery.

Farmers in the states of Karnataka and Andhra Pradesh, as well as other parts of Southern India, are already using fecal sludge from urban on-site sanitation facilities. The informal sector has turned widespread lack of treatment facilities for sludge derived from septic tanks from a serious environmental burden into an agricultural asset. The sludge comes straight from the septic tanks and instead of being dumped into rivers, is dried on farms before use, mostly on plantation crops. Considering the declining global phosphorus reserves, treated fecal sludge, and in particular urine, can constitute a significant source of phosphorus for crops. However, the practice is not without environmental risks. More data are needed to understand the current scale of reuse, environmental tradeoffs, and limitations and to advise authorities on options for how to safeguard human and environmental health.

An existing International Water Management Institute project in Karnataka supported the establishment of business models for sludge reuse, safe reuse guidelines, and Sanitation Safety Plans through stakeholder dialogues. This PEER project fed data into the dialogue and contributed to knowledge dissemination, including empirically based recommendations on phosphorus recovery from otherwise wasted resources and preventing water pollution and a key public health threat.

FINAL SUMMARY OF PROJECT ACTIVITIES

Researchers visited 12 cities in four regions of India to understand the feasibility of carrying out research on fecal sludge management, especially given it happens largely in the informal sector. City officials, truck operators, sanitation workers, farmers, farm workers and nearly thirty different organizations working in sanitation sectors were interviewed. The team selected four cities in Southern India to better understand business practices surrounding fecal sludge management: Bangalore, Mangalore, Guntur, and Dharwad. PhD student Sharada Prasad interviewed sanitation workers and extensively surveyed 3,000 farmers and farm workers on perceptions related to fecal sludge reuse. He then analyzed and interpreted the data, publishing several papers and a PhD dissertation on the results, including on health risks associated with fecal sludge reuse, opportunities and barriers related to fecal sludge reuse in agriculture, and a review of demand for and supply of phosphorus in Indian agriculture.

The PEER team, in partnership with Arizona State University (ASU), organized two roundtables on policy interventions, technology development, and curriculum development in sustainable sanitation. The roundtables focused on identifying pertinent problem areas, exploring funding opportunities and co-developing solution pathways in consultation with relevant stakeholders. ASU has developed several new India partnerships as a result.

Researchers also undertook additional surveys of homeowners, fecal sludge truck operators, and municipal authorities. As part of the PEER project, two team members researched and finished thesis work in their graduate studies: one on sustainable sanitation systems in rural Indian villages and one on various technologies for nutrient recovery through human urine.

PUBLICATIONS

C.S. Sharada Prasad and Isha Ray. 2019. When the pits fill up: (in)visible flows of waste in urban India. Journal of Water, Sanitation and Hygiene for Development 9(2): 338-347. https://doi.org/10.2166/washdev.2019.153

B. Mayer, L. Baker, T. Boyer, P. Drechsel, M. Gifford, M. Hanjra, P. Parameswaran, J. Stoltzfus, P. Westerhoff, and B. Rittmann. 2016. Total Value of Phosphorus Recovery. Environmental Science & Technology 50: 6606–6620. https://doi.org/10.1021/acs.est.6b01239.

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S. Ramesh Sakthivel, Md Azizurrahaman, V. Ganesh Prabhu, and V.M. Chariar. 2016. Performance evaluation of a low-cost odour trap installed in waterless urinals. Journal of Water, Sanitation and Hygiene for Development 6(2): 252–258. https://doi.org/10.2166/washdev.2016.151

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Md Azizur Rahman, S. Ramesh Sakthivel, and V.M. Chariar. 2014. Techno-economic assessment of Ecosan inspired technologies for recovery of nutrients from human urine for ecological sanitation. International Journal of Environmental Sciences 3(4): 205-220.

Link to video of a January 2015 project presentation by Sharada Prasad: https://youtu.be/4ZW9jCqvUS8?t=14m50s.

SRI LANKA - PROJECT 1-194: INTRA-SEASONAL CLIMATE PREDICTIONS FOR SRI LANKA AND MALDIVES FOR WATER RESOURCES MANAGEMENT

PI: Lareef Zubair, Foundation for Environment, Climate and Technology, Mahaweli Authority of Sri Lanka
Co-PI: Piyasena Wickramagamage, University of Peradeniya
U.S. Partner: Adam H. Sobel, Columbia University (Funded by the National Science Foundation)
Dates: June 2012 – September 2015

PROJECT OVERVIEW

Climate fluctuations at intra-seasonal time scales (beyond a few days to a few months) have profound influences on management of water resources to generate hydroelectricity and irrigate agricultural lands. Any ability to anticipate these fluctuations is valuable. Recent improvements in understanding of intra-seasonal (IS) climate variability and the availability of real-time satellite-based observations have led to the emergence of methodologies for IS climate predictions from a few days up to a month. This project used climate variability insights from a National Science Foundation-sponsored program called DYNAMO to focus on the Western Equatorial Indian Ocean.

Specifically, these PEER researchers tested IS climate predictions and assessed their use for water management in Sri Lanka, promoted a better understanding of IS variability of rainfall around Sri Lanka and Maldives, refined prediction schemes, translated this information to support water management, and upgraded local capacity for climate science and climate services.

Even modest improvements in IS predictions can lead to significant social and economic consequences from anticipatory water management. Because of the principal investigator's affiliation with the Mahaweli Authority of Sri Lanka, which is the nation's coordinating agency for water management, the project has potential for near-term and longer-term impact as improved prediction models are developed and tested.

FINAL SUMMARY OF PROJECT ACTIVITIES

Throughout the PEER project, the PI and his team monitored, gathered, and disseminated weather data and models, including updated climatic data sets for both Sri Lanka and the Maldives through 2014. The team installed four automated weather observation stations as part of this project, which recorded rainfall, temperature, wind, humidity and pressure every 15 minutes. They also obtained new meteorological data through developing a new web-scraper code, with an analysis carried out in collaboration with the U.S. partner.

The PEER team shared their models and results throughout Sri Lanka and the Maldives, primarily through the generation of weekly and monthly climate advisories for Sri Lanka and Maldives online through a purpose-built website and social media channels. The team also created an annual climate report for Sri Lanka. The PI and others presented their results through lectures, conference presentations both in the target countries and internationally.

The project team also developed short videos (5-10 minutes) on causes of flooding, water scarcity and sustainable practices for the Greater Male region and drafted a report on Climate and Water in Sri Lanka for a general audience.

Due to the extended drought during part of the project period and increasing information requests from regional stakeholders, the team distributed drought monitoring products throughout Sri Lanka and the Maldives.

Climate data from this program is available at the following websites:

- Project website: http://www.climate.lk/water_climate/index.html
- Weekly climate report for Sri Lanka at http://fectsl.blogspot.com.
- Monthly Maldives climate report: http://fectmv.blogspot.com
- Maldives updates via social media including Facebook and Twitter

This work continued as part of separate PEER grants in Cycles 3 and 4.

PUBLICATIONS

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S. McDermid, P. Agalawatte, E. Wijekoon, L. Zubair, et al. 2015. The AgMIP Coordinated Climate-Crop Modeling (C3MP): Methods and Protocols. Chapter 8 in Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project (AGMIP). Joint publication with ASA, CSSA, and SSSA. Imperial College Press.

TAJIKISTAN

TAJIKISTAN - PROJECT 5-140: INTERSTATE WATER RESOURCE RISK MANAGEMENT: TOWARDS A SUSTAINABLE FUTURE FOR THE PYANJ RIVER BASIN

PI: Rano Eshankulova, Institute of Water Problems, Hydropower, and Ecology, Academy of Sciences of the Republic of Tajikistan
U.S. Partner: Mark Williams, University of Colorado Boulder (Funded by the National Science Foundation)
Dates: December 2016 – June 2020

PROJECT OVERVIEW

Assuming a temperature increase of 2°C until 2050 and no change in precipitation, the ice reserves in the Pyanj River Basin, the catchments studied in this project, will decline at an accelerated rate. Considering the dense concentration of glaciers in the Pyanj River Basins and its inflows, it should be expected that the warmer climate and melting of glaciers would lead to new mud streams. Therefore, in order to address the expected climate-related hazards, it is necessary to improve our science-based understanding of the nature and magnitude of physical and biophysical impacts of climate change under different scenarios. It will be important to gain a better understanding several important climate change indicators, as well as key aspects of vulnerability impacts on development and potential adaptation measures. Developing an evidence-based approach to solving these problems requires the creation of extensive and rich hydrometeorological database on the selected river basin. Ensuring sustainable water and glacier management, it is also important to have reliable information on present and future water-snow-glacier scenarios and their evolution in relation to global change, human activities, and climate evolution affecting the hydrological and melting regime of glaciers of the Pyanj river basin. This team of researchers focused on creating a database on the results of direct measurements and observations in order to predict more accurately the development processes against the backdrop of global climate change.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the project, the team collected meteorological data from the meteorological stations of Nizhniy Pyanj, Ishkoshim, Khorog, Dzavshangoz and Darvaz on the Pyanj River Basin for the period 1950-2000. The trend of temperature and precipitation change over the period 1950-2000 in the eastern, western, southern and central parts of the Pamir-upstream of the Pyanj River were defined. The systematization of archival data on the hydrological characteristics of the tributaries of the Pyanj River and the glaciers of the Pyanj River Basin was begun and continues.

The meteorological data from meteorological stations of Parkhar (362 m a.s.l.), Khorog (2,075 m a.s.l.), Fedchenko Glacier (4,169 m a.s.l.) and Murgab (3,576 m a.s.l.) of four climatic zones of the Pyanj River basin were collected. According to the data from meteorological stations, the change trends of temperature and precipitation for the period 1934-2014 was established. The patterns of change in the trend of atmospheric precipitation were studied and the orography influence of the terrain on the amount of precipitation was studied.

A series of expeditions were organized to the Pamir Mountain upstream of the Pyanj River to monitor weather conditions, snow cover in the Pamir climatic zones, study the hydrological characteristics of the Pyanj River tributaries, and take water samples from the rivers for chemical and isotopic analysis. A database was created on the snow depth cover at meteorological stations Khumrogi, Rushan, Khorog, Irkht, Bulunkul, and Shaimak on the Pyanj River Basin. The distribution of atmospheric precipitation and snow cover on the climatic zones of the Pyanj River catchment was carried out according to the data of stations located in each of the climatic zones.

During the reporting period, samples of snow cover, surface and groundwater in the Pyanj river basin were collected for isotope analysis and more than 85 samples were sent to the University of Colorado. The results of isotope analyses are now available, and their interpretation continued even after the project ended.

During the project, major flooding was recorded in the downstream of the Pyanj River with large economic losses. In order to study the morphometric characteristics and condition of the banks of the Pyanj River several expedition were organized to the affected areas A series of works was carried out to compare the hydrological characteristics of the Pyanj River and its tributaries to the upstream of the river with the trend of changes in precipitation and temperature in order to establish the patterns of occurrence of flooding.

Water samples were taken from four hydrological stations in the lower reaches of rivers to study the phenomena of changes in the chemical and isotopic composition of the river before and after the flood and a full GIS map of the Pyanj River Basin was compiled. The formation of glacial lakes due to a reduction in the area of glaciation in the Gunt and Vanch river basins was observed. To take into account the influence of climate change on the hydrological characteristics of the Pyanj River and its tributaries, a comparative analysis of data from hydrological stations located in different climatic zones of the river basin was carried out. These results and data were shared with the government Committee for Emergencies and Civil Defense who will use the data to develop early warning systems.

The main sources of the tributaries of the Pyanj River were identified. Samples were taken for chemical and isotopic analyzes from the upper and lower reaches of the Pyanj River, and the influence of climatic factors on changes in the chemical and isotopic composition of water was determined by comparison. Work continues on the synthesis of the research materials and the preparation of a draft version of the book is in the works.

During the project implementation period, trainings and courses for students of the Tajik National University and the Tajik Technical University were widely conducted. The program of trainings and courses covered mainly the methodology of scientific research and applied work in high-altitude conditions on monitoring and studying the meteorological conditions of river basins and hydrological characteristics of water arteries. Widely reported methods of collection, systematization and processing of data and the prediction of development scenarios for a promising future. Students were selected to perform certain sections of the project's tasks and participated in regional competitions on climate change and its impact on ecosystem components with the results obtained.

The project team worked closely with government and non-governmental organizations to exchange information and disseminate the project results. The team participated in seminars and courses and presented the results of the project. In addition, the results of the project were widely presented at more than nine International, regional, and national conferences and symposiums. During the expeditions, meetings were organized with employees of environmental organizations, environmental activists and the local population on the ground. At these meetings, they talked about the essence of the research and its importance and the important mission of solving current problems in the Republic.

PUBLICATION

Parviz I. Normatov and Inom Sh. Normatov. 2018. Monitoring of Meteorological, Hydrological Conditions and Water Quality of the Main Tributaries of the Transboundary Amu Darya River. Chapter 9 in Achievements and Challenges of Integrated River Basin Management. InTech Open. Available online at http://dx.doi.org/10.5772/intechopen.74958

TAJIKISTAN - PROJECT 4-356: RISK MANAGEMENT AND ASSESSMENT OF WATER RESOURCES OF THE AMU DARYA RIVER BASIN UNDER CONDITIONS OF CLIMATE CHANGE AND CONSTRUCTION OF LARGE RESERVOIRS

PI: Inom Normatov, Institute of Water Problems, Hydropower, and Ecology, Academy of Sciences of the Republic of Tajikistan
U.S. Partner: Mary Brodzik, University of Colorado Boulder (Funded by the National Aeronautics and Space Agency)
Dates: December 2015 – May 2019

PROJECT OVERVIEW

Central Asia’s rapid population growth will likely lead to 15-20% increases in water consumption in the region by 2030, according to one estimate. In addition, resources from natural drainage in the Aral Sea basin have been greatly reduced, and water deficiency is an increasing problem, with water demand now reaching 100-110% of capacity in the Amudarya River Basin. Urgent measures to adapt to significant climate changes and promote efficient water resource management in the region are needed. About 60% of the water that potentially flows to the lower Aral Basin originates in the high mountains of Tajikistan, where dams control and regulate the annual flow regime. The demand for winter hydropower generation in the upstream countries conflicts with the summer demand for irrigation in the downstream parts of the basin. In addition, available water resources are limited due to siltation and reduced storage capacities. Summer runoff generation has been affected by glacier shrinkage, but this change has not been taken into account in official negotiations. This PEER project was designed to provide a clearer picture of available water resources and to predict changes likely to occur into the future.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Normatov and his team undertook several expeditions to the Vakhsh River Basin to study the isotopic composition of the river and its tributaries, including Vakhsh-Kyzilsu, Muksu, Obi Mazor, Obikhingou, and Surkhob. The water samples they collected were sent to the University of Colorado, Boulder for isotopic analysis, and two staff members from the Institute of Arctic and Alpine Research at UC Boulder traveled to Dushanbe to conduct a one-week course on sampling techniques and storage, which was attended by PEER project members and students at Tajik National University.

The researchers analyzed meteorological parameters of two regions of Tajikistan—Dangara and Fayzabad. An additional expedition to the Vakhsh River Basin resulted in the collection of nearly 300 samples of water and snow, and the researchers also installed rainfall sampling devices. In addition, the team analyzed historical meteorological data, including atmospheric precipitation and formation of snow cover on the Fedchenko glacier. Two PEER researchers took part in an expedition to study the glacier status of the Surkhob River Basin, sampling ice, snow, and water from the river, while another measured tributary water flow to the Nurek reservoir, measuring lateral inflow and determining the dependence of the inflow from the average annual water discharge at the Darband Hydropost. The team carried out further research to study the influence of the Nurek reservoir on the meteorological conditions of coastal agricultural areas, using data from three meteorological stations in coastal areas.

The team developed a number of methodologies for monitoring water-ice objects and snow cover of the Amu Darya River tributaries, which allowed them to predict expected volumes of river waters depending on climatic factors. The project also helped develop two university-level courses on hydrochemistry and hydrological processes at Tajik National University.

The PI shared findings from the work with local populations through an NGO, and PEER team members presented results at several international conferences, as well as through several papers and books. The project team took part in an international conference in Dushanbe on risk assessment and risk management of water resources in transboundary river basins of Central Asia. About 100 people from higher education, research institutions, NGOs and government organizations from Tajikistan, Uzbekistan, Kyrgyzstan, and Russia attended. The researchers also sent recommendations to state ministries and departments.

PUBLICATIONS

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Parviz I. Normatov and Inom Sh. Normatov. 2018. Monitoring of meteorological, hydrological conditions and water quality of the main tributaries of the Transboundary Amu Darya River. Chapter 9 in Integrated River Basin Management for Sustainable Development of Regions. http://dx.doi.org/10.5772/intechopen.74958

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THAILAND

THAILAND AND CAMBODIA - PROJECT 6-436: CONNECTING CLIMATE CHANGE, HYDROLOGY & FISHERIES FOR ENERGY AND FOOD SECURITY IN LOWER MEKONG BASIN

PI: Vilas Nitivattananon, Asian Institute of Technology; with Co-PIs Sangam Shrestha, AIT; Thanapon Piman, Stockholm Environmental Institute; and Chheng Phen, Inland Fisheries Research and Development Institute

U.S. Partner: John Sabo, Arizona State University (Funded by the National Science Foundation)

Dates: December 2017 – April 2023

PROJECT OVERVIEW

Home to tremendous biodiversity, the Srepok, Sesan and Sekong (3S) rivers of the Lower Mekong Basin (LMB) straddle Cambodia, Laos, and Vietnam and provide food security for millions of people. An annual flood pulse provides nutrients to surrounding farmlands and sustains rice production, influences primary and secondary fish production, and cues the reproductive migration of fish species, the dominant animal protein for more than 60 million people in the LMB (Hori, 2000; Stone et al., 2011). The 3S tributaries are dammed to produce hydropower, with rapid economic growth driving the region to construct more dams. Climate change is likely to significantly alter river flow in the region, which will lower energy production from dams and threaten the timing, frequency, and magnitude of the flood pulse. Therefore, we must now assess climate change impacts on river flows, dam development and operations, and fish habitat in the LMB to reduce future risks to energy production and food security. To develop optimum hydropower projects under climate change scenarios in the 3S basin, the PI and his colleagues in Thailand and Cambodia will answer the following questions:

1. What are the scenarios of hydropower production and fish harvest under current climatic conditions?
2. How will the climate of the 3S river basin change in the near (2030s), mid (2050s), and distant (2080s) future?
3. What impact will future climate have on river flow, dam operations, hydropower, and fish habitats?

This project contributed to developing the capacity of individuals and institutions to optimize hydropower production and the fish harvest. The researchers involved generated very high-resolution climate data by downscaling multiple regional climate models (RCMs) from the Coupled Model Intercomparision Project 5 (CMIP5). Using this integrated modeling tool, the team assessed the impacts of climate change and hydropower operations on river flows, flood pulse, and energy and fish production, plus built an understanding of the key trade-offs. They used a multiple optimization method (control theory) to develop decision scenarios to optimize hydropower production and fish harvest under future climate scenarios, leading to recommendations for government policymakers nationally and regionally. A multi-modeling approach, integrated with education and capacity building, can reduce decision making uncertainties under climate change scenarios and risks associated with energy and food security in the LMB region.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project was completed after several no-cost extensions on April 30, 2023. The PI Dr. Nitivattananon and co-PI Dr. Shrestha summarize the outputs and impacts of the work packages (WP) included in the project as follows:

WP1: Develop high resolution climate change scenarios. This work package has been completed. The team quantified climate change projections (temperature and precipitation) from five regional climate models (ACCESS, CNRM, MPI, NorESM, and REMO2009) under two emission scenarios for three-time horizons, viz. 2020s (2010 – 2039), 2050s (2040 – 2069), and 2080s (2070 – 2099) in comparison with the baseline period (1981-2005). They also prepared spatial analysis maps showing the differential impacts of projected temperature and rainfall changes in various parts of the Mekong Basin. Impacts of these outputs include soft evidence of utilization of the project data as a reference for other studies.

WP2: Assess the climate change impacts on river flows, inflow to the dams, and fish production. Development, calibration, and validation of the hydrological (SWAT), reservoir system simulation (HEC-ResSim), and fish-flow models: Apart from the work progress previously reported under the same heading, the researchers have developed and calibrated a Soil and Water Assessment Tool (SWAT) model for the Srepok tributary for the period 1997−2001. Because the model performance was found to be satisfactory, the team used the SWAT hydrological model to simulate the flow at the fish monitoring station in the baseline period and ultimately to develop the fish-flow relationship. Thereafter, they developed an HEC-ResSim (Hydrologic Engineering Center's Reservoir System Simulation software) model for the Srepok Basin, including five dams (Buon Tua Srah, Buon Kuop, Dray Hinh 1 and 2, Srepok 3, and Srepok 4) in the main tributary. In addition to applying the models to fishery impacts, the researchers also used SWAT and HEC-ResSim to assess climate change impacts on future hydrology and hydropower generation using future climate data of five Regional Climate Models (RCMs) under two emission scenarios. The team notes that the project has pioneered the integrated impact of climate change and reservoir operation in the LMB region, and they have received requests for research articles for further environmental impact assessment in the region.

WP3: Optimize hydropower production and fish catch under climate change and dam operation scenarios. In order to integrate the hydrological and reservoir simulations and fish production model, the researchers fed the simulated discharge from the HEC-ResSim model at the Srepok 4 dam into the hydropower simulation model as an input for optimization. Thus, the obtained discharge from the optimization model at the Srepok 4 dam is added with the difference in discharge at Srepok 4 and the fish monitoring station (i.e., simulated from the SWAT model), which is provided as input to the optimization model developed at the fish monitoring station. The optimization was carried out for the baseline period between 2010–2014, while the projection was made for the near (2020–2049) and mid future (2050–2079). These outputs do not have a ground impact but rather serve as a medium for further assessment.

WP4: Build capacity and knowledge sharing. The team was particularly productive on this work package. They trained around 40 young professionals from departments of water resources, hydropower operations, and departments of fisheries from LMB nations (Thailand, Laos, Cambodia, Vietnam) on climate change downscaling, hydrological modelling, and time series analysis of hydroclimate and fisheries, as well as hydrological modelling and reservoir simulation. Although the project has ended, the team remains in touch with the trainees, who are applying the skills learned from the training program in their respective departments. For example, the PEER researchers regularly respond to queries related to SWAT model development and calibration in SWAT-CUP, as well as questions regarding climate projections and downscaling. Meanwhile, to promote dissemination of the team's findings, project results, news, and blog posts are shared on the project website at https://connectmekong.com/. As of July 2023, the team had also produced five peer-reviewed publications (see citations below).

Dr. Nitivattananon, Dr. Shrestha, Dr. Piman, and their colleagues plan to continue their research on topics related to the Water-Energy-Food Nexus in the context of climate change in the Mekong Region. In particular, they hope to develop reservoir operating rules to optimize hydropower generation and fish production in the selected sub-basins of the Mekong Region. Thanks to seven new research grants totaling more than $10 million, they are well positioned to build on the foundation of their PEER research.

PUBLICATIONS

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THAILAND AND BURMA - PROJECT 2-473: ANALYSIS OF HISTORICAL FOREST CARBON CHANGES IN BURMA AND THAILAND AND THE CONTRIBUTION OF CLIMATE VARIABILITY AND EXTREME WEATHER EVENTS

PI: Amnat Chidthaisong, The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, With Co-PI Khin Lay Swe, Yezin Agriculture University
U.S. Partners: Merryl Alber And Monique Y. Leclerc, University of Georgia
(Funded by the National Science Foundation)
Dates: November 2013 – February 2018

PROJECT OVERVIEW

This project focused on forests in two tropical countries, Thailand and Myanmar, as a case study to investigate responses to climate variability and extreme climate events. The PEER team sought to better understand the effects of extreme climatic events on forest ecosystems and their associated carbon. They aimed to increase scientific knowledge by merging advanced remote sensing techniques and geographic information systems technology with eddy flux tower measurements to track changes in tropical forest carbon stock and exchanges that respond to historical extreme climate conditions. Dr. Chidthaisong and his colleagues sought to improve their understanding of key driving forces affecting forest health in Southeast Asia, including carbon gain and loss, water stress, and response mechanisms to stresses.

The results of this project helped differentiate between changes due to natural extreme events and those due to anthropogenic effects. Forest and carbon maps from this project can serve as the basis for a greenhouse gas inventory and national baselines in both Thailand and Myanmar, supporting international climate negotiation schemes. The PEER project also built capacity through training, workshops, and a summer school and served as a platform to disseminate knowledge and know-how among participants from these two countries and other ASEAN nations.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers analyzed several climate extreme indices for Myanmar and Thailand using observations for daily maximum and minimum temperatures and total daily rainfall for the 1983–2012 period. After investigating changes in forest area and carbon stocks over a shorter period, they estimated the effects of climate extremes on gross primary productivity of the forest ecosystem. The team then applied the data to a Vegetation Condition Index (VCI) to investigate the forest conditions due to meteorological drought and used the Standardized Precipitation Index (SPI) to identify the drought years and non-drought years during the 35-year study period. Based on this analysis, they selected the years 2010 (driest) and 2011 (wettest) to investigate how the tropical dry forest area of Myanmar responded. Their preliminary results suggested VCI and SPI are well correlated and could provide near real-time information of drought monitoring on vegetation stress, and VCI could give a future indicator of occurrence and severity of drought-affected areas.

The team also undertook a vulnerability assessment around mangrove reserves in Ayeyarwady Delta Coastal Zone. The region has a high chance of exposure to climate extremes, exemplified by Cyclone Nagi in 2008, as well as low adaptive capacity in the communities near the mangrove reserves, based on household surveys. They also found information on the mangrove ecosystem's status, including the biomass content, species composition and its vulnerability to climate change, is useful for the ECD's management of this specific ecosystem, and to support the decision-making process.

The project team applied forest classification methodology in Lampang Province, Thailand, a region that is home to the most common types of forests in the country, including varieties of both deciduous and evergreen forests. Based on their preliminary classification, the team conducted a field survey in collaboration with the Royal Forest Department of Thailand, which was incorporated into the final forest classification and map.

Using freely available data from Landsat and Sentinel-2, the project team worked on a Google Earth Engine (GEE)-based mangrove forest classification. In field survey sampling, team members also tested the use of unmanned aerial vehicles.

This project work also involved creating and disseminating new climate change and remote sensing modules that are based on freely available moderate resolution satellite and climate data. Towards the end of the project period, the PI's university made an initial agreement to help set up basic remote sensing capabilities and a GIS laboratory at the Environmental Conservation Department (ECD) of the Ministry of Natural Resources and Environmental Conservation (MONREC) of Myanmar, including consultation and brainstorming on the design, basic infrastructure, activity development, and basic GIS training courses at ECD. Meanwhile, ECD has sent four more new students to study at JGSEE.

The team developed methods to correct terrain effect from satellite imagery used for national scale forest mapping. The Royal Forest Department of Thailand is considering implementing this method in their future forest mapping efforts. Parts of the results of this project on the relationship between satellite-derived Normalized Difference Vegetation Index (NDVI) and carbon exchange have been used regularly to update the content of a graduate course. During the project period, the PI and team received several additional grants to support further work, amounting to a total of about $1 million.

PUBLICATIONS

Rungnapa Kaewthongrach, Amnat Chidthaisong, Doojdao Charuchittipan, Yann Vitasse, Montri Sanwan gsri, Pariwate Varnakovida, Sapit Diloksumpun, Samreong Panuthai, Tiwa Pakoktom, Tanita Suepa, and Monique Y. LeClerc. 2020. Impacts of a strong El Niño event on leaf phenology and carbon dioxide exchange in a secondary dry dipterocarp forest. Agricultural and Forest Meteorology 287: 107945. https://doi.org/10.1016/j.agrformet.2020.107945

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THAILAND, LAOS, AND VIETNAM - PROJECT 2-93: BIODIVERSITY AND CONSERVATION IN THE LOWER MEKONG: EMPOWERING FEMALE HERPETOLOGISTS THROUGH CAPACITY BUILDING AND REGIONAL NETWORKING

PI: Anchalee Aowphol, Kasetsart University, With Co-PIs Niane Sivongxay, Wildlife Conservation Society and National University of Laos; and Huy Duc Hoang, University of Science, Ho Chi Minh City
U.S. Partner: Bryan L. Stuart, North Carolina Museum of Natural Sciences
(Funded by the National Science Foundation)
Dates: September 2013 – September 2017

PROJECT OVERVIEW

The Lower Mekong harbors a rich diversity of amphibian and reptile, most of which are found only in the region. Amphibians and reptiles play essential roles in intact ecosystems, serving as predators and prey. However, very little is known on the biology of most species of amphibians and reptiles in the region, and many new species of amphibians and reptiles continue to be discovered. Many of these species are considered to be threatened with extinction because of rapid deforestation and overharvesting for food, traditional medicine, and the international pet trade. Information on which species occur where, and their basic biology, is needed so that these species can be effectively conserved.

This project proposes to address the lack of knowledge on amphibians and reptiles in the Lower Mekong by supporting the research programs of nine female scientists who study amphibians and reptiles (herpetologists) at three universities in Thailand, Laos, and Vietnam. The project also helped by creating a research network among the participants and their institutions through field research exchanges among these countries and a study tour on amphibian and reptile biodiversity research in the United States.

FINAL SUMMARY OF PROJECT ACTIVITIES

This four-year effort resulted in many new linkages and capacity building opportunities and has generated interest among other funders and potential users of the team's research findings. Following are summaries of the results for each of the three countries involved:

Thailand

The PEER program provided opportunities for four female students to study herpetology and conservation. Dr. Somphouthone Phimmachak finished her PhD in zoology at Kasetsart University (Bangkok) and began her career as a lecturer at the National University of Laos, where she continues research on herpetology and conservation. She is the first Laotian herpetologist to complete a PhD. Ms. Korkhwan Termprayoon finished her MSc degree in zoology and continues her studies in the PhD program at Kasetsart, where she is conducting research on gecko systematics and conservation. PhD student Ms. Sengvilay Seateun is the second female herpetologist from Laos, and she will continue her career as a lecturer at National University of Laos. She has received additional support for her research from the World Wildlife Fund (WWF). Ms. Siriporn Yodthong is a Thai PhD student who focuses on amphibians on islands. Her ongoing research will provide knowledge on genetic relationships and conservation of amphibians in Thailand. The PEER project has provided the support for building research collaboration among Southeast Asian researchers, and the four students in PI Dr. Anchalee Aowphol's lab had opportunities to visit Vietnam, Laos, and the United States as part of the effort. As of the time the project ended in September 2017, member of the PEER team (including those based in Thailand, Laos, and Vietnam, plus U.S. partners) have published 9 peer-reviewed journal articles and one proceedings and made 21 technical presentations, providing and disseminating knowledge that can be used for conservation applications in collaboration with government agencies.

Vietnam

Led by co-PI Dr. Hoang Duc Huy, the team members in Vietnam gathered and analyzed baseline information for amphibian biology and ecology in Bidoup-Nui Ba National Park, including a list of amphibian species in the park, the first description of the tadpoles of *Leptobrachium leucops* living there, and a description of the dietary patterns of ten local amphibian species, including the tadpoles of *L. pullum* and *L. leucops*. Their research provided information for amphibian conservation in the area, including on changes in amphibian species diversity and abundance, effects of habitat disturbance and other environmental variables, and evidence that the chytrid fungus has not significantly impacted amphibian populations in the region. On the education side, the PEER funds supported the work of two undergraduate students and one PhD student.

Laos

Led by co-PI Dr. Niane Sivongxay, the Laotian team carried out 18 field expeditions. PEER funds supported two projects for students in the Master's program and two for undergraduate students on the following topics:

- Amphibian and reptile diversity in Nam Lik Reservoir, Nanxang Village, Feuang District, Vientiane Province
- Natural history and distribution of the bent-toed gekko genus Cyrtodactylus Gray, 1827 in Khammouane Province
- Species diversity of amphibians and reptiles in four districts, Khammouane Province (two students, one male and one female, finished their final projects)
- Diversity of tadpoles at Nam Lik Reservoir, Naxang Village, Feuang District, Vientiane Province (one female student finished her final project)

The PEER support allowed the Laotian team to take part in international collaborative fieldwork both in Laos and abroad and to participate in the 5th Conference on Taxonomy and Systematics in Thailand at Kasetsart University. A study visit to the United States in June 2017 allowed participants to compare their specimens collected in Laos with samples in the collections of the North Carolina Museum of Natural Sciences and the Field Museum, and they also gained experience by taking part in a field survey of salamanders in North Carolina along with their Southeast Asian and U.S. counterparts. The visitors' expertise facilitated the redescription of some Laotian amphibian and reptile species samples that had previously been deposited in the Field Museum.

Thanks to follow-on funding received from the WWF, the Kasetsart University Research and Development Institute, the Center of Excellence in Biodiversity (Thailand), and Vietnam National University, the various participants in this PEER project are continuing their research efforts and their collaboration with their U.S. partner Dr. Bryan Stuart. In addition, the Bidoup-Nui Ba National Park has expressed interest in applying the research results in their ecotourism education program and in future decisions on areas that should receive priority protection for the conservation of amphibian biodiversity.

PUBLICATIONS

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THAILAND, INDONESIA, AND VIETNAM - PROJECT 1-243: ASSESSMENT OF IMPACTS OF THE EMISSION REDUCTION MEASURES OF SHORT-LIVED CLIMATE FORCERS ON AIR QUALITY AND CLIMATE IN SOUTHEAST ASIA

PI: Nguyen Thi Kim Oanh, Asian Institute of Technology
Co-PIs: Hoang Xuan Co, Hanoi University of Sciences Vietnam National University; Asep Sofyan, Institute of Technology Bandung; and Nguyen Tri Quang Hung, Nong Lam University
U.S. Partner: Philip Hopke, Clarkson University (Funded by the National Science Foundation)
Dates: June 2012 – December 2015

PROJECT OVERVIEW

In Southeast Asia (SEA) the levels of strong short-lived climate forcers (SLCFs) such as black carbon and tropospheric ozone have been reported to be high and increasing, which may have multiple effects on air quality, health, crops, and climate. SEA is also recognized as a major emitter of both air pollution and climate forcers in Asia, with several typical emission source types of importance such as agroresidue field burning, residential combustion, solid waste open burning, and small and medium industries. Prior to this project, no comprehensive study had been conducted to explore quantitative links between the SEA source emission intensity and resulting air quality, the associated effects, and the climate impacts within the region and beyond. To meet the need for data and analysis on the topic, this project brought together leading SEA and U.S. research groups to study air pollution – climate interactions. The project involved assessment of the impacts of various mitigation measures of important SLCFs in the SEA region on air quality and climate using a co-benefit approach and generated a scientific basis for policy recommendations to integrate air quality and climate policies.

The concrete objectives and planned activities of this project included a comprehensive emission inventory database of key air pollutants and climate forcers for major emission sources for SEA, development of action plans for emission reduction, and pilot scale emission reduction projects for the target sources in selected SEA countries. Two countries, Indonesia and Vietnam, were selected for the emission inventory and pilot scale projects. The target sources were selected based on the results of the emission inventory and should have the potential to multiply, such as agroresidue field burning, solid waste open burning, and residential cooking. Realistic emission reduction scenarios were developed and assessed using a modeling tool.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the original project, the researchers sought to understand the status of the Short Lived Climate Pollutants (SLCPs) levels in the Southeast Asia. The project team actively collected available air pollution monitoring data generated by the Environmental Protection Agencies (EPA) and those previously generated by other projects in the SEA countries. From this a shared database was created which also included emission inventory data. The data was also imperative to the team’s modeling efforts, which focused on select cities in Indonesia, assessing air quality and climate change co-benefit under differing the emission control scenarios. Lastly, the project explored mitigation options for the selected emission source, i.e. rice straw (RS) OB (by AIT, HUS and NLU). AIT developed RS derived fuel (roped RS) and it was tested in a traditional (tri-pod) and a modified improved Thai cookstove to assess the emission and stove efficiency. The preliminary analysis showed that if the derived RS fuel can be used for cooking simultaneously both OB emission and the use of fossil fuel/wood fuel for cooking will be reduced.

Following the original project, Dr. Kim Oanh were awarded a PEER Evidence to Action supplement to build on their previous efforts. As a side project associated with their work on their completed Cycle 1 project, the PI and her colleagues had received other funding to further develop the RS derived fuel. This supplement allowed the team to improve the pelletizing machine as a prelude to mass production, test selected pellet/stove systems, collaborate with a Vietnamese company to create a prototype and mass production model, work to build farmers' capacity to adapt to the technology, and explore a business model for sustainable mass production. Following is a summary of activities under this now-completed supplement.

Dr. Nguyen Thi Kim Oanh of the Asian Institute of Technology (AIT), her co-PI Dr. Hoang Xuan Co of the Hanoi University of Science (HUS), and their colleagues received a PEER Evidence to Action Supplement in July 2017, and during the following 18 months they successfully implemented their demonstration project, "Turning rice straw into cooking fuel." The pellet production technology was first developed at AIT in conjunction with the spin-off SUMMERNET project, which followed the PI Dr. Kim Oanh's PEER Cycle 1 project in 2012-2016. AIT collaborated with HUS to conduct the demonstration activities in Hanoi. A local private company, Tuan Tu Agricultural Machinery Production, was the industrial partner that provided equipment and space for the pellet production. The rice straw (RS) pellets produced were successfully burned in a Minimoto gasifier cookstove (GCS) and the emissions were measured at AIT. Local farmers around Hanoi took part in field trials using the RS pellet-GCS system for in-home cooking. In addition, residents of urban areas in Hanoi were involved in indoor air quality monitoring to compare the air quality in the kitchen and the living room when the pellets-GCS system was used, compared with when LPG cookstoves and traditional coal briquette stoves were used. In the cooking trial, a farm family was given a GCS and enough pellets for their cooking needs for a week. The testers appreciated the cookstove and reported at the final dissemination workshop that it was smokeless. In fact, 0.7 kg of pellets burned in the GSC for one hour could boil seven two-liter pots of water. No soot was visible on the pot after the cooking, and there was no visible smoke during the cooking. The ash left by the pellets was soft and could potentially be used as a soil conditioner. In addition, the indoor air quality monitoring also showed the advantages of the pellets-GSC system in terms of lower PM2.5 levels indoor compared with the traditional coal-briquette cookstove system.

Analysis of the production cost of the RS pellets showed that if the cookstove efficiency is taken into account (the RS-GSC system is 2-3 times more efficient than coal-briquette-traditional stoves), the cost of producing one unit of useful energy from RS pellets and coal briquettes is comparable. The benefit of using the RS pellets for cooking lies in promoting cleaner air and less fossil fuel consumption. Turning RS into cooking fuel also eliminates the emissions from RS open burning, which is a major air pollution issue in the region.

Overall, the PEER Evidence to Action supplement also supported three workshops, in September 2017, July 2018, and September 2018. The events brought together key stakeholders (policy makers, researchers, farmers, local residents, and staff members of NGOs and private companies), who contributed significantly to the promotion of the project outcomes. The PI and her team also met with government officials from the Pollution Control Department (PCD) of Vietnam and the Hanoi Department of Nature Resources and Environment (DONRE) to gain their input and communicate their findings and recommendations.

The protocol for RS pellet production has been transferred to the local company Tu Tuan to sustain the efforts. The PI and her team have encouraged the Hanoi DONRE to implement this alternative to replace the use of dirty coal briquettes for commercial cooking in the city. The cost analysis that has been completed also supports development of a business model to ensure sustainability and affordability. Although the project has been completed, the team remains in contact with the PCD, the Center for Environmental Monitoring of the Ministry of Natural Resources and Environment, and other stakeholders to further disseminate the project findings. The policy brief they produced has been distributed in Thailand, Vietnam, and Cambodia, and the researchers have published three peer-reviewed journal papers (one with U.S. partners as co-authors) and one peer-reviewed book chapter (with the U.S. partner as co-author). Although larger scale implementation of the project findings remains a challenge due to funding issues, Dr. Kim Oanh and her group continue to link their work to other regional networks. The project team links the project activities to other regional networks such as the Climate and Clean Air Coalition to Reduce Short-lived Climate Pollutants (CCAC) to disseminate the project findings and attract additional funding.

PUBLICATION

Zeeshan Muhammad and Nguyen Thi Kim Oanh. 2015. Relationship of MISR component AODs with black carbon and other ground monitored particulate matter composition. Atmospheric Pollution Research 6(1); 62-69. https://doi.org/10.5094/APR.2015.008

UZBEKISTAN

UZBEKISTAN - PROJECT 6-310: REDUCING WATER POLLUTION AND CARBON EMISSIONS FROM IRRIGATED AREAS BY IMPROVING IRRIGATION MANAGEMENT AND RURAL LIVELIHOODS: CASE STUDIES FROM ENERGY INTENSIVE PUMP IRRIGATED AREAS OF SOGD PROVINCE, TAJIKISTAN AND KASHKADARYA PROVINCE, UZBEKISTAN

PI: Oyture Anarbekov, International Water Management Institute
U.S. Partner: James Ayars, United States Department of Agriculture/ Agricultural Research Service
Dates: December 2017 – May 2021

PROJECT OVERVIEW

This research was the first major attempt to analyze relationships between the pump irrigation practices, rural livelihoods, and health in Central Asia through transboundary partnerships. It builds on IWMI's extensive background on irrigation and health issues and applies remote sensing (RS) and geographic information systems (GIS) methodologies developed by IWMI to evaluate irrigation schemes and estimate relevant water indicators. The overall project objective was to assess whether improved irrigation management can make rural livelihoods more sustainable and reduce health issues by decreasing water pollution and carbon emissions, using the examples of two intensive energy-use pump irrigated areas of Sogd Province, Tajikistan, and Kashkadarya Province, Uzbekistan. The overall objective was achieved through five specific activities:

1. Identifying the extent of water pollution attributed to the lift-irrigated agricultural zones by conducting a comprehensive analysis of contaminant fluxes and exposure routes
2. Determining the potential impacts of improving water use efficiency on energy savings, reducing CO2 emissions, and runoff from lift-irrigated areas by building and simulating impacts with computer models
3. Improving water use efficiency by utilizing data generated from a previously initiated PEER project (i.e., a geodatabase prepared for lift-irrigated areas) to identify current water use efficiencies in selected sites according to a set of indicators and subsequently to develop and recommend potential improvements
4. Assessing the current environmental and socioeconomic impact of irrigation and identifying possible interventions to improve rural livelihoods (e.g., restoring ecosystems and their services)
5. Preparing policy documents evaluating different methods based on a set of criteria for improving water use efficiency and reducing energy use, CO2 emissions, and return flow in lift-irrigated areas

The partnerships and collaboration envisioned within the scope of this project were carefully selected to be appropriate for the complexity of the activities and to enhance transboundary institutional collaboration. In essence, the project can be viewed as two projects under a shared goal, as the two case studies are (1) located in different countries and in different river basins, (2) influenced by different sociopolitical circumstances, and (3) affected by different legal and administrative structures. Three regional partners are involved under the auspices of the lead institution, IWMI: (1) the Tashkent

Institute of Irrigation and Melioration under the Ministry of Agriculture and Water Resources of Uzbekistan; (2) the Sogd Water Authority in Tajikistan; and (3) the Institute of Sanitary, Hygiene, and Professional Disease, Department of the Hygiene of Water and Soil, under the Ministry of Health of Uzbekistan. These transboundary partnerships build on and strengthen existing coordination established under two previous projects in PEER Cycles 4 and 5 between the transboundary government agencies.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project team completed all project activities and outputs despite obstacles faced due to the COVID-19 pandemic. The research plan focused on assessing the potential impact of improvements in water-use efficiency and energy-use intensity on downstream water availability and environment It also evaluated whether improved irrigation management could make rural livelihoods more sustainable and reduce health issues by decreasing water pollution and carbon emissions in the two intensive energy-use pump irrigated areas of Sogd Province, Tajikistan and Kashkadarya Province, Uzbekistan. It built on the previous achievements of a PEER Cycle 6 project, including: (1) a geodatabase for the two study areas containing over 40 thematic maps that was developed; (2) demonstration of water-saving technologies and assessment of irrigation efficiency for furrow, gated pipe, and drip irrigation schemes in the study area was undertaken; and, (3) evaluation of water-saving technologies and methods documenting the costs and benefits to the government, farmers, and the society.

The overarching objective of project activities was to support informed and evidence-based decision making by sharing the results, data, and evidence from the PEER project with policymakers, water users, and civil society. During the last year of the project, the team translated the project outputs into meaningful and sustainable development impacts. Only three water saving technologies (gated pipes, polyethylene film, and drip irrigation) were used at the study sites, with little consideration of suitability of these technologies or other alternatives to particular crop or farm conditions. The evaluation and economic analysis of water-saving technologies and practices demonstrated the potential for water and energy saving and improved agricultural outcomes.

The team shared the project results, data, and evidence with the community and policymakers through multimedia materials. This involved a range of communication channels selected depending on the data and/or audience. The geodatabases for Zafarabad and Karshi Steppe, for example, were disseminated in hard copies and USB storage devices and shared with the local, national and regional water authorities, water users' associations, and donor organizations. This enabled easy access to the geodatabase information on site characteristics, enabling remote users with no Internet connection to access the information. Increasing the user base for the geodatabase will help ensure it is tested and assessed by more people enabling useful feedback on information contained in the database. To increase knowledge about the general project and findings on water saving technology options, new printed materials including brochures and factsheets in local languages Russian and English were developed. Additional materials were made available in digital form on the IWMI-CA webpage and social media platforms on Facebook. The data and information sharing was supported with direct contact with relevant stakeholders (office and field visits), participation in external events (e.g. national and regional symposiums, conferences, roundtable discussions), and through organizing targeted workshops that brought together water practitioners, researchers, decision makers and the donor community.

The main workshops engaged policymakers and helped draft policy recommendations on the use of water-saving technologies based on evidence acquired through work on the PEER project. The workshops involved relevant members of the governments of Uzbekistan and Tajikistan, as well as other regional stakeholders in the efforts to develop a regional water management strategy and policy framework on water use. Special focus was given to innovative methods and strategies in water policy and governance to engage stakeholders in solving complex problems in the Amudarya and Syrdarya river basins. In all of the workshops, the organizers presented community findings and proposed specific recommendations to improve management practices and policies. The project team has also coordinated with local universities, research organizations, and other parts of civil society to achieve a stronger policy impact. The PI and the project team made concerted efforts to engage with local universities, research organization, and other parts of civil society to continuously share project findings and promote their use as evidence bases in other research projects (e.g., student theses, research papers, peer-reviewed publications, etc.) to increase the visibility of project results, data, and evidence and promote their application in practice and policymaking.

Lasting impacts from the project will take the form a combination of policy changes and demand side resource use improvements triggered by improved knowledge on water saving technology solutions. Governments in the region currently provide incentives that at times are incompatible with agricultural sustainability goals. For instance, both water and energy for agriculture are subsidized encouraging excess water use. However, the governments also subsidize water saving technologies, which will hopefully lead to more positive outcomes for water users. The project activities tried to help reduce unsustainable practices by increasing knowledge through user-friendly decision support tools, such as an atlas containing GIS and RS/EO based mapping tools, and information about alternate technologies for water saving, resulting in evidence-based policymaking and improved water management practices. By bringing together government officials, authorities on water use, farmers, researchers, and other stakeholders in workshops, the project team hoped to connect theory, practice, and policy, which will then result in outcomes and impacts that will benefit the livelihood of millions of people in Central Asia.

PUBLICATIONS

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Ibrakhimov, M., U. K. Awan, M. Sultanov, A. Akramkhanov, Kakhramon Djumaboev, C. Conrad, and J. Lamers. 2019. Combining remote sensing and modeling approaches to assess soil salinity in irrigated areas of the Aral Sea Basin. Central Asian Journal of Water Research 5(2): 100-116. doi: 10.29258/CAJWR/2019-R1.v5-2/64-81eng.

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Gafurov, Z et al. 2018. Geodatabase and diagnostic atlas: Kashkadarya Province, Uzbekistan. International Water Management Institute (IWMI), Colombo, Sri Lanka, 74p. doi:10.5337/2018.217.

UZBEKISTAN - PROJECT 5-523: IMPLICATIONS OF CLIMATE CHANGE, LAND USE AND ADAPTATION INTERVENTIONS ON WATER RESOURCES AND AGRICULTURAL PRODUCTION IN TRANSBOUNDARY AMU DARYA RIVER BASIN

PI: Zafar Gafurov, International Water Management Institute (IWMI)
U.S. Partner: John Bolten, NASA Goddard Space Flight Center
Dates: December 2016 – May 2020

PROJECT OVERVIEW

The transboundary Amu Darya and Syr Darya river basins draining to the Aral Sea in Central Asia witnessed widespread land use and land cover changes (LULCC) during 20th century as a result of political reforms of agrarian systems to enhance economic opportunities for a growing population. These developments produced drastic change in the hydrological regime of these two river basins, causing widespread ecosystem degradation. The need to sustain competing water uses at the local, national, and transboundary levels, including on upstream hydropower generation and downstream irrigation requirements under climate change, make the current situation more contentious. Realizing the need to balance and sustain competing water uses, national governments in Central Asia and international agencies are supporting numerous mitigation and adaptation interventions to improve overall water use efficiency in basins draining to the Aral Sea. However, successful interventions must be based on comprehensive understanding of the interactions in agro-hydrological systems at multiple scales covering sufficiently long time periods, and they must account for forecasted climate change impacts. Prior to this project, there were no openly available models and tools with detailed descriptions of such spatio-temporal changes and interactions of agro-hydrologic systems in the Amu Darya River Basin that could be used to inform evidence-based decision-making by national research organizations and donor agencies. Even if studies on these topics were undertaken in the past, their availability is restricted.

This project promoted a greater understanding of past land use and land cover changes in the Amu Darya Basin, expected changes in the future, and basin-scale climate change impacts and adaptation interventions for water resources, using openly available long-term Earth observation datasets and a semi-distributed hydrological model (SWAT) detailing the agro-hydro-climatological system. The tools and models will act as vital management instruments for national water agencies and multilateral activities to assist in planning future interventions at basin or local scales.

FINAL SUMMARY OF PROJECT ACTIVITIES

The scope of work comprised primarily establishing partnerships, collecting data from research sites, reviewing literature and data to gather insights and gain a comprehensive understanding of water resources management in the region, establishing a database, reviewing water use issues in the region from primary and secondary data, evaluating existing water management practices in the region, and applying Geographic Information Systems (GIS) and earth observation (EO) based models, methodologies, and tools to study the management and use of water resources in the region. The project was led by IWMI in research partnership with: National Aeronautics and Space Administration (NASA), USA; Karakalpak branch of the Scientific Research Institute of Irrigation and Water Problems

(KSRIIWP), Uzbekistan; Balkh University, Afghanistan; and the Institute of Water Problems, Hydropower Engineering, and Ecology of the Academy of Sciences, Republic of Tajikistan (GU TajikNIIGiM).

Activities undertaken by the project team during the three years included the following:

- Collection of data from both upstream and downstream partner organizations in Uzbekistan, Tajikistan, and Afghanistan to be used as input for modeling. The partner organizations were actively involved and contributed with valuable information, data, and technical assistance. The data provided by partners was processed, cleaned and prepared for input to the SWAT model.
- Collection of remote sensing data and information from open sources and local partners, including satellite data from USGS for the Amu Darya river basin, and establishment of a database for further analyses of land cover and development of irrigated area mapping. Moreover, with the assistance of project partners, the team also collected ground truth data in the irrigated zones of the basin. Ground truth data was collected using GPS tools providing geographical locations of different crops and land cover types in irrigated zones of the study area.
- Development of Google Earth Engine scripting methods for modeling delineation of irrigated areas and spatio-temporal variation of vegetation coverage in the basin. Additionally, the team was able to set a model in ArcGIS model builder to automatize the process of vegetation change analysis.
- Collection of climate data for the Amu Darya river basin from the Centre of Hydrometeorological Service of Uzbekistan (UZHYDROMET) as well as from the database of the World Meteorological Organization (WMO). This data was used as input for the SWAT model and Evapotranspiration calculation using available methodologies.
- Development of digital elevation models for Amu Darya river basin, as well as Syrdarya river basin, which are located partly in the territory of Central Asian countries and Afghanistan. Based on prepared elevation maps, the team extracted slope information and its characteristics for the study area.
- Analyses on multiannual spatio-temporal variation of vegetation coverage for the period 2000 – 2016 was conducted using available MODIS satellite images. This analysis was done through scripting in Java API of Google Earth Engine and integrated with ArcGIS ModelBuilder.
- Irrigated area change analyses for Amu Darya and Syrdarya river basins were successfully calculated using LandSat satellite images for different years (1993, 2000, 2010 and 2016). Similar to the previous activity, scripting approaches were applied and integrated with ArcGIS. Additionally, ArcMap tool for Normalized Difference Vegetation Index (NDVI) calculation using satellite images were developed. This tool also allowed the team to delineate the point of interest in the study area.
- Historical climate variables (input data for the SWAT model) were retrieved from Global Weather Data for SWAT (https://globalweather.tamu.edu/), which provides daily Climate Forecast System Reanalysis (CFSR) data (precipitation, wind, relative humidity, and solar) in SWAT file format for a given location and time period. This data was used to set up the model for the study area. Additionally, climate data from meteostations were also obtained from UZHYDROMET.
- The team also collected available soil type data from various sources to use as soil input data for SWAT model. Soil type maps developed by FAO were analyzed for accuracy to meet the requirements of SWAT model. Moreover, soil maps for the territories of Uzbekistan and Tajikistan were obtained in paper format from Tajik Soil Science Research
- GIS and RS/EO based geodatabase and mapping tools for a region in Kashkadarya province, Uzbekistan (which is part of the Amu Darya river basin) were completed. The primary goal of the geodatabase creation was to convert raw data into graphics and maps (using GIS and RS/EO mapping tools) for visual interpretation so that they are user-friendly and can serve as a decision-support tool.

It consists of various input data (land use, hydrologic data, climatological, infrastructure, basin characteristics, etc.), which were obtained from the domains of several government and non-government organizations. It shows the spatial and temporal distribution of water and land resources. The geodatabase also includes maps and tools on irrigation infrastructure (e.g., pump stations, irrigation canals, drainage network, etc.), irrigated areas by sources of irrigation, WUA boundaries, soil type and soil salinity, ground water table and its quality, digital elevation model, slope and aspect, irrigated land use change (for years 1977, 2000, 2015), and crop classification for 2016.

- The team also conducted a systematic literature review on socioeconomic conditions in the various sites of the Amu Darya river basin, which involved establishing a strategy for scanning and identifying relevant literature (i.e., search parameters, inclusion/exclusion criteria, coding, etc.), performing review and analysis of relevant open source databases, examining data and information collected through fieldwork and surveys, and drafting a comprehensive report with analytical findings and recommendations for next steps.
- The project employed the SWAT model to evaluate hydrological behavior of the Aral Sea basin and to provide remote sensing products, tools and information for the stakeholders in the region. This was one of the first attempts to run the SWAT model for entire Aral Sea basin. This model was developed using remotely sensed land use maps and soil data including climatic parameters. Outputs of the SWAT model will help better understand the use and management of water resources and serve as a decision-support tool.
- The project team carried out several capacity building activities at Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME) involving students and researchers from TIIAME and UZHYDROMET, in which team members provided lectures and training sessions based on the findings from project activities. One of the major events was a two-week international summer school (Summer 2018) organized in collaboration with CAREC for students and researchers from Central Asian universities, in which team members provided lectures and training sessions based on the findings from project activities. These activities have been well received by participants, and following their success, the project team has been invited back to conduct more of these events.
- The project team also participated in numerous conferences, policy dialogues, seminars and exchange meetings to share and disseminate project outputs and discuss project findings in collaboration with ongoing PEER projects and other development projects in the region.

UZBEKISTAN - PROJECT 5-323: PROVISION OF SCIENCE BASED EVIDENCE ON CLIMATE INDUCED WATER QUALITY CHALLENGES IN AMU DARYA BASIN

PI: Iskandar Abdullaev, Regional Environmental Center for Central Asia (CAREC)
U.S. Partner: Antarpreet Jutla, West Virginia University (Funded by the National Aeronautics and Space Agency)
Dates: December 2016 – May 2019

PROJECT OVERVIEW

Most climate-related studies in Central Asia are focused on water quantity impacts and their implications for transboundary water allocation in the region. However, these studies have neither investigated nor documented the water quality aspects of climate change impacts, especially for Central Asia's two biggest river systems (Amu Darya and Syr Darya). This PEER project aimed to assess the impacts of climate change on surface water quality of the Amu Darya River and develop a climate change water quality model that will provide much needed information to decision makers for elaboration of possible adaptation actions. The project also transferred knowledge and data to the region and enhanced research capacities in Central Asia based on the tools, approaches, and methods applied.

The project was carried out by scientists from CAREC and counterparts from Afghanistan, Tajikistan, and Turkmenistan, including the basin organization BVO Amudarya, with special focus on building capacity in water quality maintenance at BVO Amudarya. In addition to helping with the calibration, validation, and simulation stages and analysis of results, the U.S. partner organized training workshops for CAREC researchers on methodological aspects and relevant numerical and analytical tools for water quality predictions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER researchers began by analyzing the current literature on water quality issues in the Amu Darya River and similar hydrologic systems, building a research team and network of experts on the subject. The team members collected and systematized data on hydrology, water quality, and agriculture for the basin and in October 2017 they visited the U.S. Geological Service, California Water Science Center for a workshop on research methodology.

The project team members began their statistical analysis of hydrological, climate, and water quality data to establish a relationship between water quality and climate indicators. During the process, the team realized there were gaps in data from other countries such as Tajikistan and Turkmenistan. Therefore, two specialists were recruited to collect the missing data. A modeling exercise also revealed a need for additional data on agricultural water intake and discharge to the Amu Darya River basin. Therefore, the team requested additional data on monthly water quality parameters from the State Hydrometeorological Agency of Uzbekistan.

The researchers found that data availability and quality were relatively low and further endeavors in the region should be aimed at increasing the number of sampling stations, regularity of the observations, and recording of dates when the samples were made. They did observe relatively high phosphorus levels at all sampling stations, with high values at the upstream gauges, indicating possible point-source pollution. There was also a strong correlation between the mineralization and the discharge: the maximum levels of mineralization are occurring during the spring months during the low flow period and when the leaching of the drainage water is slightly higher. The relationship between the mineralization and discharge shows stronger correlation for the downstream gauges, allowing the suggestion that the dilution processes have stronger influence on the downstream water quality than the upstream. The team also found an inverse relationship between the phosphorus levels and discharge and direct relationship between the nitrogen and discharge, especially for the upstream stations.

The team hired experts from the Potsdam Climate Institute (PKI) to apply their model for analysis of the climate change and water quality linkages. Their results are in line with results of the PEER research team. During the project period researchers presented results at the Central Asian Environmental Forum and the Central Asian Climate conference. Although no published papers had appeared by the end of the project, the PEER team's findings supported one graduate thesis. The researchers also shared their results with the regional working group on water quality and met with representatives of various basin organizations and nature protection agencies.

UZBEKISTAN - PROJECT 4-407: USE OF NON-CONVENTIONAL AGRICULTURAL WATER RESOURCES TO STRENGTHEN WATER AND FOOD SECURITY IN THE TRANSBOUNDARY WATERSHEDS OF THE AMU DARYA RIVER BASIN (UNCAWR)

PI: Kristina Toderich, International Center for Biosaline Agriculture
U.S. Partner: Robert Nowak, University of Nevada, Reno (Funded by the United States Department of Agriculture/ Agricultural Research Service)
Dates: December 2015 – December 2019

PROJECT OVERVIEW

This project was based on the hypothesis that marginal (low quality) water sources and marginal lands can be used for irrigation and production of non-conventional crops (NCC) as food for human consumption and/or forage for livestock while simultaneously conserving water quality and protecting economic benefits for households. Through practical and analytical experiments on selected sites within the Amu Darya River Basin, Dr. Toderich and her team investigated economic and environmental impacts of using NCC on salt-affected lands and mineralized waters. These experiments, coupled with their previous results and experience studying various halophytes (salt-tolerant plants), were integrated into biophysical models that will allow for broader-scale assessment of NCC capacity to improve marginal lands across the region. The project analyzed current and future projected scenarios of water availability in the region, at the same time investigating possible options for reducing water and land stress. The researchers assessed current and future water policy in the region under the impact of the utilization of NCC and use of mineralized waters in creating forage for cattle breeding. Such analysis can show the potential of marginal resources as an important link in creating a full cycle of environmentally friendly and economically beneficial scenarios of community development in arid and semi-arid regions.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project has been a tremendous success story. The team succeeded in focusing the attention of policy makers and governments on the utilization of marginal agricultural resources. Adaptation measures and preparedness scenarios were developed for rural communities in order to address severe land degradation (mostly affected by salinity) and inconsistent water availability. By bringing public attention to the current situation in the Aral Sea Delta, the team was able to make an essential contribution to the developing of the long-term strategy (2020-2030) on agriculture development in Central Asian countries.

The main focus was to expand the distribution and application of the findings in the Central Asian countries and to invite leading institutions from all over the world to cooperate.The Government of Uzbekistan has made significant efforts to address the challenges of the Aral Sea region and improve socioeconomic and cultural aspects of local communities. A long-term State Program on Implementation of Strategy of Actions for the period of 2020-2030 was initiated by highlighting the significance of innovations, international partnerships, and investments in the development of agrarian sector.

The main achievements of the project included the following:

- More than 80 events with over 4900 participants were organized, including international conferences, forums, symposiums, workshops and technical presentations to bring attention to the issues of marginal resources and provide new solutions and innovations for development in the Aral Sea Delta.
- More than 60 peer-reviewed publications in international journals, including books and book chapters were published.
- 11 patents were approved in Uzbekistan, Kazakhstan, Tajikistan and Kyrgyzstan.
- 6 education courses in National University of Uzbekistan, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers and Tottori University, Japan were prepared and started.
- 12 field trips to the upper -and middle and down reaches of the Amu Darya River Basin (Uzbekistan, Tajikistan, Turkmenistan) were organized to collect samples and investigate water quality conditions, as well as to understand the cause of primary soil salinity and high mineralization of some tributaries that lead to land degradation.
- A research program with the International Platform for Dryland Research and Education, Tottori University on studies of commercial value and market based approach for NNC was established.
- Guidelines on best practices and mechanisms for practical dissemination and application of more resilient land use were developed and shared. Biosaline practices (5 technologies developed by ICBA) were up scaled on more than 600 ha.
- The project outputs include description of 48 species of halophytes and 22 salt tolerant cultivars/crops, which continue to be tested in three watershed sub-basins of the Amu Darya River.
- Team findings fully supported the hypothesis that diverse, multiple-crop-livestock pasture (mixed crop-livestock) as well as afforestation and agroforestry-based practices are additional means to counter the abandoning of marginal lands.
- The nutritional value of 66 species of halophytes was analyzed in comparison with traditional crops like alfalfa and corn to provide information for the forage and forage mix production in the region
- Policy briefs on the agricultural economy cost of saline lands and technologies was developed. 8 project briefs were disseminated online
- Two vocational and academic training curricula were developed at professional colleges, lyceums, and universities to enhance national capacity and to sustain the application of sound land use management under saline environments. These activities were jointly done with UNDP/GEF-5/ICBA within the framework the FAO-GEF project.
- Two monographs on desert fruit morphology and pasture improvement were published. A collaborative monograph on 'Drylands Salinity, Halophytes and Landscape Restoration" was produced by ICBA in collaboration with the International Platform for Drylands Research and Education (IPPDRE), Tottori University, Japan. The book represents an overview of the drylands and salinity issue in a global context. This book is a first edition based mostly on PEER/UNCAWR project materials and will provide a valuable resource and tool for livestock owners, managers, ecologists, and decision makers developing a strategy for the sustainable management of marginal lands (mostly saline) and improving food security and nutrition of rural communities over the world.

SELECTED PUBLICATIONS

Shuyskaya, E.V., Rakhmankulova, Z.F., Toderich, K.N. 2020. Role of Proline and Potassium in Adaptation to Salinity in Different Types of Halophytes. In: Grigore, MN. (eds) Handbook of Halophytes. Springer, Cham. https://doi.org/10.1007/978-3-030-17854-3_75-1

Abdiev, A., Khaitov, B., Toderich, K., & Park, K. W. 2019. Growth, Nutrient Uptake and Yield Parameters of Chickpea (Cicer arietinum L.) Enhanced by Rhizobium and Azotobacter Inoculations in Saline Soil. Journal of Plant Nutrition 42(20): 2703–2714. DOI: /10.1080/01904167.2019.1655038

Gasimova, Khatira, et al. 2019. Comparative Studies of Reproductive Biology, Seed Morphology and Anatomy of New Salt Tolerant Accessions of Quinoa (Chenopodium quinoa Wild) Introduced in Kur-Araz Lowlands. Plant & Fungal Research 2(2): 31-40. The Institute of Botany, ANAS, Baku, AZ1004, Azerbaijan, December 2019. http://plantfungalres.az/en/journals.

Voronin, P. Yu., Shuyskaya, E. V., Toderich, K. N., Rajabov, T. F., Ronzhina, D. A., & Ivanova, L. A. 2019. Distribution of C4 Plants of the Chenopodiaceae Family According to the Salinization Profile of the Kyzylkum Desert. Russian Journal of Plant Physiology 66(3): 375–383. DOI: 10.1134/S1021443719030166.

UZBEKISTAN - PROJECT 4-112: TRANSBOUNDARY WATER MANAGEMENT ADAPTATION IN THE AMU DARYA BASIN TO CLIMATE CHANGE UNCERTAINTIES

PI: Viktor Dukhovniy, Scientific-Information Center of Interstate Commission for Water Coordination of Central Asia
U.S. Partner: Benjamin F. Zaitchik, Johns Hopkins University (Funded by the National Science Foundation)
Dates: November 2015 – April 2018

PROJECT OVERVIEW

The goal of this project was to build adaptive capacity of the countries sharing the Amudarya basin to manage effectively their transboundary waters under climate change and other uncertainties. The Uzbekistan- and Turkmenistan-based members of this collaborative group studied transboundary water management issues in the Amudarya basin over the long term under conditions of climatic and other changes, along with national plans regarding irrigated agriculture and hydropower development. Some specific areas addressed included the following:

- Assess possible changes in the hydrologic regime and future crop water requirements due to climate change;
- Study scenarios for long-term flow regulation by a system of large reservoirs on the hydrology of rivers, as well as on available water supply for irrigated lands and sustainability of aquatic ecosystems in the basin;
- Evaluate the potential impact of national plans for irrigated agriculture and hydropower development on future crop water requirements in the basin's countries;
- Elaborate possible tradeoffs between national priorities and requirements at the basin level on the basis of legal analysis, with the focus on global water conventions.

The main outcomes of the project included scientifically grounded recommendations for various stakeholders (policy makers, macroeconomists, environmentalists, hydropower managers, and agriculture specialists) on a number of relevant topics. These included tradeoffs in water management in the basin, economically sound development options, regionally sound cropping patterns based on national food and energy security strategies and water conservation needs, environmental management in deltas, and alternative options for multiyear river flow regulation.

FINAL SUMMARY OF PROJECT ACTIVITIES

These PEER researchers studied water management problems within the basin and sought to improve the Aral Sea Basin management model. They used their own planning zone model to assess the river basin's future development through 2055, including climate change's impact on water requirements and available water resources, agricultural development, alternative hydropower scheme operations and growing water withdrawal by Afghanistan. The researchers developed recommendations for adaptation to climate change, and management of transboundary water resources, among others.

The project improved the understanding and awareness of the impact of climate change on water availability and management in the Amu Darya. A wealth of new data and research was generated to help stakeholders be better prepared for climate change impacts by showcasing options for more sustainable water management, both adapting to negative impacts and harvesting positive impacts of climate change in the basin. The project contributed to strengthening regional cooperation by improving the knowledge base and enabling more active interactions between researchers and policy makers across Central Asian countries.

The researchers used the basin planning zone model and a variety of numerical experiments to produce a comprehensive assessment of future basin development through 2055. The team member who developed the model visited Johns Hopkins University to demonstrate their work. The major results of the PEER project were presented at the Central Asian International Scientific-Practical Conference held in Taskent in 2017, and at the world's biggest water-related event, the 8th World Water Forum in Brasilia. While there, team members visited the IItaipu Dam to study a successful experience of benefit sharing across countries and draw lessons for the Amu Darya.

During the final PEER project workshop, the team discussed results with key stakeholders, as well as follow-ups to the project and further cooperation with partners and donors. The project results were uploaded on a public website in the form of reports, publications, and presentations. The team prepared a number of policy briefs for decision makers, including on future development in the basin, quick responses to climate changes, improved coordination between the countries on water resources, and tackling water accounting and water management for the river and its tributaries.

The PI Dr. Dukhovnyi also published a book, *The Future of the Amu Darya Basin in the Context of Climate Change*, which assesses climate change's impact on water resources and crop requirements in the basin through 2050. The findings have been already included and will be included in future training curricula developed by the Regional Training Centre at the PI's organization. They also formed the basis of a short video presentation for a distance-learning course based at the University of Geneva and are being developed into a new educational module at the SIC ICWC Regional Training Center that serves five Central Asian countries. During the grant period, PEER team members also expanded and solidified their professional networks by reconnecting with collaborators at the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes.

PUBLICATIONS

V.A. Dukhovnyi, ed. 2018. The Future of the Amu Darya Basin in the Context of Climate Change. Scientific-Information Center of the Interstate Commission for Water Coordination (ICWC) of Central Asia, Tashkent, Uzbekistan. Available for download (PDF, 13.8 MB) at http://www.eecca-water.net/file/peer-amudarya-final-book.pdf

V.A. Dukhovniy, D.R. Ziganshina, A.G. Sorokin. 2017. Amudarya - the great river on the threshold of signature decisions. Proceedings of the International Water and Climate Summit, October 23-25, 2017, Rome, Italy.

UZBEKISTAN - PROJECT 4-097: MITIGATING THE COMPETITION FOR WATER IN THE AMU DARYA RIVER BASIN, CENTRAL ASIA, BY IMPROVING WATER USE EFFICIENCY

PI: Kakhramon Djumaboev, International Water Management Institute
U.S. Partner: James Ayars, USDA/ARS Water Management Unit
Dates: November 2015 – October 2018

PROJECT OVERVIEW

The growing population of Central Asia has resulted in an increased demand for water for food and hydropower generation. Most of the renewable water resources are transboundary, with the main rivers flowing through several states. The hydropower generation potential is upstream, where the key reservoirs regulate the river flow, while the irrigated land, requiring 80% of the river flow, is located downstream. With water in short supply the competition for water between hydropower upstream and agriculture downstream results in reduced water use efficiency and, overall, in reduced basin-wide water productivity. Prior to recent changes, the operational regime of the upstream reservoir gave priority to upstream hydropower needs in the Syrdarya River basin, while the downstream states faced significant losses for irrigation. Developing the upstream hydropower potential may cause further reduction of water availability downstream during the crop-growing season. Under the current operating practices of the upstream reservoir, which prioritizes the needs of agriculture in the Amudarya River basin, the upstream states face significant energy shortages. The issue is very politically sensitive, when a win for one side means a loss for the other. Under these conditions securing water for agriculture through increased water use efficiency is critical for Central Asian states (Karimov et. Al, 2012).

The solution for the problem is highly complicated because of significant shortage of water to supply the needs of both – water for food and water for energy in Aral Sea basin. This project applied a two-step approach. The first was determining water and energy “gains” through increasing current water use efficiency and reducing current energy use intensity in different sectors (such as agriculture, domestic water and energy supply, industry, and power generation), which can be considered while supplying the water and energy needs of upstream and downstream users. The second was considering the above-indicated gains of demand management while analyzing benefits of cooperation. Close cooperation was established between the International Water Management Institute (IWMI) Central Asia, the United States Department of Agriculture – Agricultural Research Service (USDA-ARS), and local partners, including specialists from the Research and Design Institute UzGIP under the Ministry of Agriculture and Water Management, Uzbekistan.

FINAL SUMMARY OF PROJECT ACTIVITIES

One of the main objectives of this research project was to identify management practices and strategies to improve water and energy use in the Amudarya and Syrdarya river basins of Central Asia. Specifically, the project focused on assessment of water-use efficiency and energy-use intensity of different irrigation schemes at two sites in Uzbekistan and Tajikistan. Specific achievements of the project to date are (1) a geodatabase for the two study areas containing over 40 thematic maps; (2) demonstration of water-saving technologies and assessment of irrigation efficiency for furrow, gated pipe, and drip irrigation schemes in the study area; and, (3) evaluation of water-saving technologies and methods documenting the costs and benefits to the government, farmers, and society.

The overarching objective of project activities was to support informed and evidence-based decision making by sharing the results, data, and evidence from the PEER project with policymakers, water users, and civil society. During the last year of the project, the team did their best to translate the project outputs into meaningful and sustainable development impacts. A supplemental grant they received helped fund activities to translate project data, results, and evidence into user-friendly policy documents and multimedia materials, which can be easily accessed by policymakers and other relevant stakeholders, which should then enable them to develop informed and evidence-based policies and practices.

The team made a strong effort to share project results, data and evidence with the community and policymakers through multimedia materials. This involved a range of communication channels selected depending on the data and/or audience. The geodatabases for Zafarabad and Karshi Steppe, for example, were disseminated in hard copies and USB storage devices and shared with the local, national, and regional water authorities, water users' associations, and donor organizations. This has enabled easy access to the geodatabase information on site characteristics, enabling remote users with no Internet connection to access the information. Increasing the user base for the geodatabase will help ensure it is tested and assessed by more people, enabling useful feedback on information contained in the database. To increase knowledge about the general project information and findings on water saving technology options, new printed materials including brochures and factsheets in local languages Russian and English were developed. Additional material haves been made available in digital form on the IWMI-CA webpage and social media platforms on Facebook. The data and information sharing was supported with direct contact with relevant stakeholders (office and field visits), participation in external events (e.g. national and regional symposiums, conferences, roundtable discussions), and through organizing targeted workshops that brought together water practitioners, researchers, decision makers and the donor community.

The project team organized three workshops to disseminate information to policymakers and to draft policy recommendations on the use of water-saving technologies based on evidence acquired through work on the PEER project. The PI and project team disseminated PEER project research findings by engaging farmers and policymakers. Two workshops were convened in Uzbekistan to discuss project results: a hands-on workshop near the Karshi steppe site for mid-level decision makers and farmers, including field visits and discussion of good practices, and a second workshop in Tashkent for high-level policy makers to disseminate research results on effective water- and energy-saving methods in agricultural production, as well as on the benefits of using decision-support tools such as GIS and RS/EO mapping tools and data in policymaking. The third workshop and associated training course were organized in Khujand, Tajikistan. The workshops involved relevant members of the governments of Uzbekistan and Tajikistan, as well as other regional stakeholders in the efforts to develop a regional water management strategy and policy framework on water use. Special focus was given to innovative methods and strategies in water policy and governance to engage stakeholders in solving complex problems in the Amudarya and Syrdarya river basins. In all of the workshops, the organizers presented community findings and proposed specific recommendations to improve management practices and policies.

The project team has also coordinated with local universities, research organizations, and other parts of civil society to achieve a stronger policy impact. The PI and the project team made concerted efforts to engage with local universities, research organization, and other parts of civil society to continuously share project findings and promote their use as evidence bases in other research projects (e.g., student theses, research papers, peer-reviewed publications, etc.) to increase the visibility of project results, data, and evidence and promote their application in practice and policymaking.

On July 17, 2023, PEER staff received the sad news that Dr. Djumaboev had passed away. Colleagues noted his wonderful, kind-hearted nature and willingness to lend a helping hand in all situations. PEER offers its deepest condolences to his family and friends.

UZBEKISTAN - PROJECT 1-041: UTILIZATION OF LOW-QUALITY WATER FOR HALOPHYTIC FORAGE AND RENEWABLE ENERGY PRODUCTION

PI: Kristina Toderich, International Center for Biosaline Agriculture
U.S. Partner: Laurel Saito, University of Nevada (Funded by the National Science Foundation)
Dates: July 2012 – June 2015

PROJECT OVERVIEW

Salinization is a major problem facing the agricultural sector in arid and semi-arid regions of the world. A possible avenue for reclamation of saline lands is the use of halophytic species (salt-loving plants) that remove salts from saline soils and water. This project targeted the cultivation and sustainable production of halophytes on unproductive, marginal salinized lands surrounding hundreds of small lakes in the Aral Sea Basin in Uzbekistan.

These small lakes have potential utility as an aquatic resource for aquaculture or irrigation but are sensitive to inducing salinization that could render the water unusable. Hence, reclaiming saline lands near these lakes may benefit the economic utility of both land and water by reducing salt loads to the lakes. This project aimed to assess the potential for halophytic plants as an economic resource via food for humans, animal feed, biofuel production, or through maintaining or restoring agricultural production of conventional crops on high saline soils. Specific objectives included: (1) to characterize halophytic growth, yield and salt uptake rates; (2) to identify halophytic nutritional value potential; (3) to examine impacts of halophytic crops on soil and water quality; (4) to model halophytic crop production and salt removal; (5) to assess the economic feasibility of halophytic crops for food security and salt removal; and (6) to conduct cost-benefit analysis to determine farmers' perceptions of planting halophytic crops and assess their willingness to do so.

The team's research involved collaborations with several partners, including the Institute of Water Problems of the Academy of Sciences of Uzbekistan, Urgench State University, the Hydrometeorological Research Institute of Uzbekistan, and the NGO Khorezm Rural Advisory Support Service (KRASS).

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER grantee team established two research & demonstration sites: one in Central Kyzylkum (demonstrating natural inland salinity), the other in Khoresm (exhibiting secondary salinization of old irrigated agricultural lands near Shurkul Koshkupur Lake) in Uzbekistan. They monitored and sampled soil and water from fields, lakes and irrigation canals. The researchers cultivated salt-tolerant and halophyte plants and studied their agrobiological characteristics, including under what methods and conditions they grew, total biomass, as well as their contents of protein, lipids/fat and hydrocarbons for foraging and biofuel.

During the project period, researchers found that these ecosystems were vulnerable in terms of climatic extremes and availability of water resources. In addition, soils affected by secondary salinization were difficult to manage through conventional methods.

Growing halophytes in pure stands or intercropped with salt-tolerant fodder crops, cereals and oil plants showed good results on enhancing natural resources management, improving food security and diversifying income of agropastoralists in these remote desert areas. A socio-economic evaluation also showed environmental and economic feasibility for using dual- purpose crops for forage production and for livestock feeding systems using marginal saline water for irrigation.

A promising research area was the diversification of crops with alternative salt and drought tolerant crops, such as sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and various species of legumes (alfalfa, licorice, soya bean, mung bean, vicia, and cow pea). The research team found two main advantages for the cultivation of a variety of nontraditional crops: creating a stable grain production and fodder supply necessary for the development of local livestock, and preventing erosion and improving soil productivity.

The project team worked with partners to organize a training seminar for farmers to present and discuss technological innovations in agriculture and food security. Approximately 180 participants included farmers, animal breeders, extension officers, scientists, policymakers, private sector representatives, students, international consultants and governmental leaders. The seminar covered topics such as best practices in conservation agriculture, biosaline agriculture and soil salinity management, pasture improvement, irrigation, land, and water and dryland ecosystems function.

Farmers have shown great interest in transfers of agricultural innovations, modern technologies for growing plants on degraded and marginal lands, effective methods of water use, adoption of conservation agriculture technologies, and integrated pest control.

PUBLICATION

Natalya Akinshina, Azamat Azizov, Tatyana Karasyova, and Edgar Klose. 2016. On the Issue of Halophytes as Energy Plants in Saline Environment. Biomass and Bioenergy 91: 306–11. https://doi.org/10.1016/j.biombioe.2016.05.034

VIETNAM

VIETNAM - COV-139: UNDERSTANDING THE IMPORTANCE OF ECOSYSTEM SERVICES AND MEDICINAL PLANTS DURING AND AFTER THE COVID-19 CRISIS IN VIETNAM

PI: Tuyen Nghiem, Vietnam National University—Central Institute for Natural Resources and Environmental Studies
U.S. Partner: Pamela McElwee, Rutgers, The State University of New Jersey
(Funded by the National Science Foundation)
Dates: September 2022 – April 2024

PROJECT OVERVIEW

The COVID-19 pandemic severely affected Vietnam, causing impacts on the economy and vulnerable populations. Disruption of regional supply chains led to stagnant production and business in Vietnam and the unemployment rate increased. Vulnerable working people lost their main income sources and developed their own coping strategies, including increasing their dependence on natural resources.

This PEER project studied the impact of the COVID-19 pandemic on the use of ecosystem services in Vietnam. Before the pandemic, people used ecosystem services widely, especially medicinal plants for the production of traditional medicines. The researchers sought to understand how the use of ecosystem services and medicinal plants has changed since 2020, developing findings that can be used to design more effective interventions for supporting vulnerable groups of people in similar situations in the future and maintaining important ecosystem services.

The PI and her team worked directly with local communities and government and non-government actors to inform and allow changes in scientific evidence-based policies, which in turn enhance conservation of forests and medicinal plants, improve forest management practices, and strengthen forest governance at the local level. Officials from the relevant Vietnamese government agencies such as the Ministry of Agriculture and Rural Development and the Ministry of Natural Resources and Environment were encouraged to participate in the project activities to help them improve their knowledge and research capacity.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted in-person interviews in Tram Tau special forest area (Yen Bai Province), Tam Dao National Park (Vinh Phuc Province), and Ba Vi National Park. They conducted preliminary interviews with local people to understand their access to medicinal plants and their connection to the urban area through consumption of traditional medicinal products and to pretest further interview questions. As a result, the team chose to conduct further research in Ba Vi, as well as Hanoi and Ho Chi Minh City.

The research team conducted interviews with government officials at Department of Natural Resources, Department of Health, and Oriental Medicine Association, as well as with key informants including the vice chair of Ba Vi Commune's People's Committee and the head of Hop Nhat village. Two focus group discussions were also held. The team subsequently interviewed 100 households in Hop Nhat and Hop Son villages of Ba Vi Commune (Ba Vi District) and surveyed 200 individuals in Hanoi and Ho Chi Minh City. They organized a final workshop in Hanoi and a field visit to the marine ecosystem of Ha Long Bay (Quang Ninh Province). During the workshop, the research team presented initial research results, highlighting changes in access and use of ecosystem service during and after COVID-19 in Vietnam. Other research groups shared findings on ecosystem services used at the community level and policy factors affecting ecosystem service use.

As of the time they submitted their final report in May 2024, Dr. Nghiem and her colleagues were finishing up on papers to be submitted for publication. Key topics will include changing attitudes on the value of urban green spaces and the impact of the increased use of home gardens to raise medicinal plants that were formerly harvested in national parks and other natural environments.

In additional to strengthening the team's longstanding partnership with Rutgers University, the research project helped build international cooperation with the University of Mataram in Indonesia and Hwa Dong University in Taiwan. It also improved capacity among Vietnamese university faculty and the staff of the Thuong Tien Nature Reserve in Hoa Binh Province through research exchange activities in the field. The data collected under this project will be combined with the U.S. partner Dr. Pamela McElwee's NSF-funded research on other ecosystem services projects in Southeast Asia. Dr. Nghiem and her team also had the opportunity to take part in a capacity building activity on putting research results into action led by USAID's Research Technical Assistance Center (RTAC), attending five webinar sessions on topics such as identifying and engaging stakeholders, developing communications objectives, and tracking and measuring success.

VIETNAM - PROJECT 9-554: DEVELOPING A FRAMEWORK FOR THE IDENTIFICATION OF SOIL LIMITING FACTORS FOR BIOREMEDIATION OF DIOXIN COMPOUNDS IN CONTAMINATED SOILS OF VIETNAM

PI: Nguyen Khoi Nghia, Can Tho University
U.S. Partner: M. Scott Demyan, The Ohio State University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: July 2021 – June 2024

PROJECT OVERVIEW

In Vietnam, soil contaminated with dioxin has been detected in many areas, especially in and immediately surrounding the Bien Hoa, Da Nang, and Phu Cat airbases. Although dioxin concentration in these soils is much lower than before, there are still significant impacts on the environment and ecosystem health. This PEER project sought to develop a framework for site-specific, synergistic bioremediation approaches to decontaminate soils containing low concentrations of dioxin (between 20-1000 ppt) in Vietnam. The PI Dr. Nghia and his colleagues aimed to accomplish this through identifying soil limiting factors regulating and preventing successful remediation of dioxins and test biostimulation and biosurfactant strategies to alleviate site-specific limiting factors.

Developing these strategies should help to address a major environmental health issue for local stakeholders by means of soil and water quality improvement, giving the local people the opportunity to use the bioremediated soils for beneficial uses such as crops, livestock, and forests, which in turn should eventually increase their income. The data collected from this project will also advance the body of research about the limiting factors of bioremediation strategies of soil dioxin and will be helpful for developing a framework for site-specific bioremediation approaches of biostimulation and biosurfactants.

FINAL SUMMARY OF PROJECT ACTIVITIES

The COVID-19 pandemic meant researchers could not access the Bien Hoa Airbase or other airbases for soil samples, so another PEER project team shared their samples of dioxin-contaminated soil from Bien Hoa, Da Nang, and Phu Cat airbases to analyze the current concentration of dioxin in these airbases. The researchers found the concentration of dioxin residues in the soil at A Luoi and Bien Hoa airbase was higher than at Phu Cat airbase.

The team analyzed the physical, chemical, and biological properties of the soil samples in the lab to determine the limiting factors of soil properties for the degradation of dioxins. In a separate experiment, the team isolated biosurfactant-producing bacteria from three dioxin-contaminated soil samples collected from Bien Hoa, Da Nang and Phu Cat airbases. They found interesting results for the use of *Pseudomonas aeruginosa* bacterial strains to achieve almost complete biodegradation of dibenzofuran (DF) after 30 days of incubation. The researchers also isolated three dibenzofuran-degrading microbial communities that degraded a very high percentage of dibenzofuran in the liquid MSM medium supplemented with 100 ppm DF after 21 days. They continued to compare the efficacy of different approaches in soil treatment and developed a dioxin bioremediation approach, that used a combination of coal slag, enriched dioxin-degrading communities or dioxin-degrading bacterial strains as bioremediation agents, bio-surfactant producing bacterial strains as dioxin bioavailability enhancer, chemical fertilizer as a biostimulator, organic material as a food source for microbes, and hydrogen peroxide as the oxygen supplier. This synergistic approach was tested in the lab and showed very promising effectiveness.

The PEER team published papers and conducted a workshop on their findings, as well as attended seminars on infrared reflectance spectrophotometry and curriculum development from the US partners. They shared their findings at the International Conference on Environmental Pollution, Restoration, and Management and a Ministry of National Defense workshop on treating and minimizing the effects of residual toxic chemicals/dioxins. The team received nine new grants, worth a total of $149,000, for their work from funders such as The Australian Centre for International Agricultural Research and The International Center of Tropical Agriculture (CIAT).

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VIETNAM - PROJECT 9-553: BIOCHAR FACILITATED BIOREMEDIATION: A GREEN SOLUTION FOR DIOXIN/FURAN POLLUTION

PI: Dang Thuong Huyen, University of Technology, Vietnam National University-Ho Chi Minh City

U.S. Partner: Karl Rockne, University of Illinois at Chicago (Funded by the National Institutes of Health)

Dates: June 2021 – June 2024

PROJECT OVERVIEW

Agent Orange was used to defoliate more than 31,000 km^2 of forest in Vietnam. Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans formed during the manufacturing process, together with co-contamination by other chemicals and heavy metals, have resulted in widespread contamination of soils across the country. More than 35.42 million liters of Agent Orange, Agent White, and Agent Blue were transported and stored during the Vietnam War, and the most widely used of these agents was Agent Orange, resulting in dioxin hotspots at airbases where the substance was stored and transferred.

This PEER project focused on the Bien Hoa site, given its proximity to the Ho Chi Minh City University of Technology (HCMUT) and the team's extensive experience working on bioremediation efforts at this location. High concentrations of dioxins have been observed at several boreholes obtained from the site, and earlier results demonstrated that the greatest concentrations were due to defoliants in a restricted zone within a few meters of the surface. The PEER team sought to address this problem through a collaboration between HCMUT and the University of Illinois at Chicago on a green, circular economy solution using plant-based biochars sourced from waste stocks. The team investigated how the beneficial properties of biochars to sequester hydrophobic pollutants and facilitate electron transfer to microbes living on/near the organic matter surface can be optimized for improved bioremediation of PCDDs/TCDDs

A significant added benefit of this approach is its promotion of circular economies by using the waste product of one industry (by-products from coffee, straw, and other agricultural feedstocks) to solve a problem in another industry. Vietnam generates a huge amount of agricultural waste, which is often disposed of in landfills or burned.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers collected samples of coffee husks and jackfruit peels in the Central Highlands, as well as rice husks, coconut shells, and durian rinds in the Mekong Delta. After converting the materials into biochar using a high-temperature furnace acquired with PEER funds, they characterized the biochars for various parameters (gravimetric, chemical, Boehm titration, aqueous extraction, polycyclic aromatic hydrocarbons, and pesticides). In preparation for the soil-related aspects of the work, they attended safety courses in soil sampling with the support of Trigon Associates and subsequently analyzed approximately 70kg of dioxin-contaminated soil collected from two areas at the Bien Hoa airbase.

The PI Dr. Huyen and her colleagues then collaborated with Can Tho University to carry out experiments on dioxin biochar treatment using aerobic methods. They selected two types of biochar synthesized from coconut shells and rice husks at two different temperatures and tested them for a shorter period (15 days) to evaluate the processing potential. The longer treatments took two months, with researchers taking samples every 20 days to analyze dioxin and microbial DNA levels. The researchers found that although remediation occurred even without biochar, the addition of biochar yielded better results. Rice husk biochar proved more effective than coconut shell biochar and high-temperature pyrolyzed biochar showed better remediation efficacy compared to low-temperature pyrolyzed biochar.

The PEER team conducted seminars with students about dioxin to teach them about the projects and overall awareness of the pollution issue. They also presented their research results to the Shimizu Corporation and Bandung Institute of Technology (ITB) in Indonesia, a workshop on the circular economy, and conferences focusing on dioxin. They collaborated and shared soil samples with other PEER projects focused on dioxin in Vietnam. The research team has submitted or is working on several academic articles, including conference proceedings. The PI is part of three additional teams that have received nearly $2 million in grant funding for their work.

Five student members of the team have now graduated as engineers, and the project sponsored an undergraduate and a PhD student pursuing dioxin treatment issues. The equipment purchased with PEER funds has enabled the team to conduct a series of studies on the use of biochar to address other environmental issues in Vietnam as well. The pyrolysis of agricultural residues from five types of waste (coffee husks, coconut shells, rice husks, and durian rinds, and jackfruit peels) and subsequent morphological, physicochemical, heavy metal, and organic pollutant risk analysis of the biochar produced have demonstrated its vast application potential.

VIETNAM - PROJECT 9-551: NANOASSISTED BIOREMEDIATION OF DIFFUSED DIOXINS IN SOIL AND SEDIMENT

PI: Nguyen Thi Kim Oanh, Asian Institute of Technology (AIT) Center In Vietnam and AIT Thailand

U.S. Partner: Dana Barr, Emory University (Funded by the National Institutes of Health)

Dates: April 2021 – June 2024

PROJECT OVERVIEW

This PEER project studied reducing residual dioxin contamination in soils and sediments from the past use of Agent Orange during the Vietnam War. Contaminated soil with high dioxin concentrations (>1,000 ppt) has been or will be treated to destroy residual dioxins. However, large volumes of soils and sediments containing dioxins below 1,000 ppt remain. Current attempts to address these soils and sediments focus on landfill/containment to prevent direct human and ecological contact. This project aimed to develop technologies to eventually destroy dioxins using enriched indigenous microbes, which have a high potential for application to convert the passive landfills in Phu Cat, Da Nang, and Bien Hoa Air Bases into active landfills. It will also consider the effects of any additives, including nanomaterials, used in the treatment on the microbes and the quality of the soils and sediments.

Dioxins can be removed from contaminated soils and sediments via anaerobic and aerobic metabolism by microorganisms using a novel stepwise procedure of sequential anaerobic-aerobic biodegradation. This process can ultimately destroy dioxins in soils and sediments, eliminating the need for any additional steps to handle the pre-concentrated dioxins in plants or other media. Building on past experience, this project conducted lab-scale experiments to find optimal conditions for dioxin removal. The aim was to include a range of diffused dioxin levels, from below 1000 ppt to a few ppb. A design for the full-scale treatment is still under preparation to be proposed for future application for the bioremediation, taking into account the actual pollution situation and local climate.

The project also built capacity of the local partners in Vietnam by involving research teams from local universities to develop this new treatment approach, hence sustaining the local human resources to deal with the dioxin contamination in soils and sediments in Vietnam in the long term.

FINAL SUMMARY OF PROJECT ACTIVITIES

The co-PI and his team at Ho Chi Minh University of Technology (HCMUT) synthesized and tested nanomaterials, investigating several key factors and testing their capabilities to facilitate breakdown of a common pollutant, Congo Red, in various types of soil samples. Meanwhile, the co-PI and colleagues at Van Lang University focused on the enrichment of microbes collected from sediment near Gate 3 outside Bien Hoa Airbase and other sites near the adjacent town. The sediment materials (before and after enrichment) were analyzed using 16S rRNA Metagenomics at the K-TEST Lab, which identified several species reportedly capable of destroying dioxins.

The team then began the lab-scale experiments testing various mixtures of microbes, nanomaterials, and molasses to treat dioxin-spiked soil and dioxin-spiked sediment. These experiments used 64 vials at four conditions with 20 weeks in the anaerobic stage, followed by 6 weeks in the aerobic stage. The next phase involved experiments on actual contaminated soil from inside Bien Hoa Airbase with dioxin levels ~1.2 ppb, and the results were promising, showing that for some treatment regimes the removal of dioxins under anaerobic conditions reached more than 70%.

The researchers had visited Bien Hoa Airbase to identify potential locations to conduct the planned pilot scale experiments onsite, but the necessary permission from Vietnam's Ministry of Defense was granted only late in August 2023, leaving not enough time to prepare for the on-site field experiments. The team instead conducted further experiments off-site in an isolated corner outside the Van Lang University dioxin lab. They collected contaminated sediment materials from outside the airbase near Gate 3, with additional sediments from the pond located in front of Gate 2. Six plastic 200-liter tanks were used in four treatments, and researchers collected samples under a preplanned schedule. The team completed these experiments in early June 2024 and the analytical results are forthcoming.

Students and early career researchers from across the three Vietnamese partner institutions were heavily involved in this PEER project, and the team developed two patent applications as part of their work: one on the indigenous microbial community enrichment procedure and one on the innovative stepwise anaerobic-aerobic treatment of dioxin-contaminated soil. The project received media attention from online newspapers and local broadcasters, and the team published several of their own findings and social media posts about their project. The PEER team delivered two dozen technical presentations across conferences and workshops and published one academic article, with additional manuscripts forthcoming. The PI also received a $80,000 grant for new research from the AFD Group.

PUBLICATION

Ngoc-Minh-Thu Vuong, Phuong-Thao Nguyen, Thi Kim Oanh Nguyen, Duy Binh Nguyen, Thi-My-Dieu Tran, Le Thi Kim Oanh, Thanh-Binh Nguyen, Tan-Thi Pham, Kun-Yi Andrew Lin, Xuan-Thanh Bui. 2023. Application of nano zero-valent iron particles coated by carboxymethyl cellulose for removal of Congo red dye in aqueous solution. *Case Studies in Chemical and Environmental Engineering* 8: 100469. https://doi.org/10.1016/j.cscee.2023.100469

VIETNAM - PROJECT 8-014: IMPROVED MANAGEMENT OF WATER AND SEDIMENT YIELD IN 3S BASIN – UPPER PART OF MEKONG RIVER BASIN

PI: Duong Bui, National Center for Water Resources Planning and Investigation, in partnership with the National University of Civil Engineering
U.S. Partner: Venkataraman Lakshmi, University of Virginia (Funded by the National Aeronautics and Space Administration)
Dates: December 2019 – November 2020

PROJECT OVERVIEW

Through the project, the PI and his colleagues at the National Centre for Water Resources Planning and Investigation of Vietnam (NAWAPI) sought synergy with the NASA-funded project “Improved hydrologic decision support for the Lower Mekong River basin through integrated remote sensing and modeling, (2016-2019)” and the World Bank project “Understanding land use planning for the Vietnam Delta (2016-2019),” both of which were led by U.S. partner Prof. Venkataraman Lakshmi of the University of Virginia. In addition, the NAWAPI team worked with another U.S. partner, Dr. Hyongki Lee of the University of Houston, who is led two other NASA-supported projects. The ultimate goal of the new PEER partnership was to scale up the beneficial impact of state-of-the-art research in water management for the Mekong Delta residents of Vietnam, one of the most vulnerable regions to various climate change and water-induced challenges today. More specifically, the project aims to build capacity in water and sediment yield management agencies of Vietnam to independently use tools recently developed tools by the U.S. partners’ universities to address some of the most critical current questions in the region. Once all the new mainstem dams built by upstream countries on the Mekong become fully operational, how will they impact freshwater inflow downstream, as well as food production and the nutritional status of the population? Which regions within the Mekong will be more vulnerable to adverse impacts of upstream reservoir construction? These questions would apply similarly for ongoing and planned dam development, with critical impacts on downstream water, food, and energy in the region.

The Mekong River Basin is one the world’s most productive and diverse ecosystems. The Vietnamese Mekong Delta is a “rice bowl” for the country, providing more than one-half of the country’s rice yields, and the river is second only to the Amazon in terms of its diversity of freshwater fish species. However, due to the operational dams, the hydrologic flow changes and sediment trapping could have severe consequences to the river’s floodplain, reducing the sediment transport and nutrient loads for the Mekong Delta and threatening food security for the region. At the time the project began in 2019, NAWAPI had recently completed a water planning project for the Srepok River, part of the 3S Basin. However, the results were limited only to water allocation planning and included only initial results from a field survey on water quality for the Srepok portion of the 3S Basin only. Meanwhile, given that there are more than 40 upstream hydroelectric dams in this basin, the evolution of the total amount of sediment will be a very important issue because it directly affects rice farming, fisheries, and other related industries in the downstream area. Therefore, the main purpose of this project was to build on the outcomes of the previous project to develop the next step for calculating the amount of sediment yield in the basin. Combined with socioeconomic development factors and climate change scenarios, a modelling tool could simulate streamflow and sediment for various scenarios to optimize dam operations to balance economic development and ecosystem requirements and help key government stakeholders make decisions on the sustainable management of water and sediment yield for the Vietnamese people.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Bui and his team developed a database consisting of satellite-based products and ground observations of different variables, including rainfall, sediment, and streamflow, as well as a well-calibrated model that can predict streamflow, sediment, and reservoir operation with respect to various scenarios in the 3S River Basin (the upper part of the Mekong River Basin).
This study not only has scientific significance for improvement of current sustainability frameworks but also provides an evidence-based toolkit useful for decision makers to respond and adapt to climate change. The PEER project's outcomes are providing necessary inputs for two other recently funded projects on which Dr. Bui serves as co-PI: a National Foundation for Science and Technology Development project on evaluating sustainability of the water resources system of the 3S Basin and a United Kingdom Newton Fund project studying river bank erosion in the downstream delta due to changes in sediment yield from the upstream basin.

The PEER project created two key online dissemination products in cooperation with U.S. partners at the University of Washington:

1. ASEAN Water Portal open data platform: http://waterportal.vaci.org.vn/
2. Automated water resource forecasting system http://forecasting.vaci.org.vn/

The team also produces a monthly water newsletter for distribution to the central water authority (the Water Department under the Ministry of Natural Resources and Environment, MONRE) and the relevant local authorities in five provinces over the study basin. Uptake from government agencies has been strong. Dr. Bui notes that based on the results of his team's research, they had identified methods for conserving soil and preventing erosion in the study region. MONRE issued Circular No 4 on water resources planning that presents a conservation strategy and recommendations reflecting findings from the PEER project. In addition, the team's understanding of the procedures on how to use the HYPE model and how to manage the project database has been translated into an operational regulation for water resource monitoring and forecasting at NAWAPI (Guideline No. 262).

The young Vietnamese researchers who participated in the project improved their technical skills to the point that they can now function independently using the new tools and technologies they mastered through the mentorship of the U.S. partners. This will allow Vietnamese specialists to develop their own solutions for water and sediment forecasts, including space techniques, data bias correction, modelling, coding, cloud computing and webGIS development. The PEER project also fostered an ecosystem model of regional scientist-practitioners and U.S. partners that effectively supports translating research findings into applied products and policy formulation. Cooperation with other national, regional and global initiatives will provide a strengthened mechanism for the exchange of developed solutions worldwide.

PUBLICATIONS

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VIETNAM - PROJECT 8-006: SUSTAINABLE GROUNDWATER MANAGEMENT UNDER SOCIOECONOMIC AND CLIMATE CHANGE IN MEKONG DELTA, VIETNAM

PI: Chau Nguyen Xuan Quang, Vietnam National University - Ho Chi Minh City,
With Co-Pi Sangam Shrestha, Asian Institute of Technology
U.S. Partner: John Sabo, Arizona State University (Funded by the National Science Foundation)
Dates: December 2019 – November 2023

PROJECT OVERVIEW

The Vietnamese Mekong Delta (VMD) in southwest Vietnam is home to 18 million residents. The VMD produces half of Vietnam's rice and contributes a substantial part of the country's gross domestic product. In the delta region, groundwater is an essential and valuable resource, especially in coastal and remote areas. However, this resource is under threat due to over-extraction, drought, climate change, sea level rise, and other factors. Groundwater extraction has increased considerably to meet the demands of agriculture, aquaculture production, and domestic and industrial water supplies.

This PEER project sought to provide robust, science-based evidence on the combined impacts of socioeconomic factors and climate change on groundwater and propose feasible adaptation options and implementation pathways for groundwater governance for policymakers. They also wanted to create a knowledge platform for involved stakeholders to eventually facilitate the decision-making process. The research team generated high-resolution future climate data using regional climate models to evaluate the impacts of climate change on groundwater in the near (2030s), mid (2050s), and distant (2080s) future. Socioeconomic were used to analyze and estimate the existing and future groundwater demand in the VMD. The technical knowledge and regional experience of the U.S. partner provided insights to the Vietnamese researchers in analyzing the modeling results.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team gathered and analyzed historical meteorological data from 1986 to 2019 in the VMD to develop an updated climate change scenario for the VMD region. The updated and high-resolution climate change scenarios provided more reliable rainfall and temperature inputs for hydrological and water assessment in the VMD. The researchers also established hydrological and groundwater flow models. Using survey data on current groundwater demand and future development scenarios, they developed future groundwater demand scenarios for Tra Vinh and Ben Tre provinces.

Their study revealed significant socioeconomic influences on groundwater in Tra Vinh and Ben Tre provinces, particularly the adverse effects of groundwater exploration for irrigation and shrimp farming during dry seasons. The study also identified clear indications of recharge zones within the province, and the team found that groundwater resources hold significant potential to support socioeconomic development and climate change adaptation in the VMD. The application of innovative solutions for groundwater recharge is essential, and strategies for using water during critical times should be incorporated into climate change adaptation plans.

The team also hosted capacity-building workshops, including on topics such as sustainable groundwater usage, policy formulation, and the impact of climate change on water resources. They also used a workshop to present the research results to the scientific community and stakeholders. During the project they met with several key national and regional agencies managing water resources. They are developing an article for publication.

VIETNAM - PROJECT 8-003: IDENTIFYING CONDITIONS FOR SUCCESSFUL LANDSCAPE-SCALE CONSERVATION POLICY IMPLEMENTATION IN VIETNAM

PI: Pham Thu Thuy, Center for International Forestry Research, in partnership with the Vietnam National University of Forestry
U.S. Partner: Darla Munroe, The Ohio State University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: January 2020 – December 2022

PROJECT OVERVIEW

Data collected by CIFOR's Global Comparative Study on Reducing Emissions from Deforestation and Forest Degradation (GCS-REDD, 2008-2020), partly funded by USAID, provides an empirical foundation to study the connection between conservation stakeholder networks and the ecological and livelihoods impacts of landscape-scale forest conservation in Vietnam. While Vietnam's Payment for Forest Environmental Services (PFES, 2008-present) and REDD+ (2012-present) policies were implemented, CIFOR collected data on national forest policy networks. In this PEER project, the PI and her team collected socioeconomic and remote sensing data on land cover before and after PFES and REDD+ implementation for the entire country, using landscape ecology statistics to characterize forest change around and landscape connectivity between sites. They used archival materials from government, NGO/CSO, and other organizations' websites and annual reports, newspaper reports, and policy literature, alongside GSC-REDD's national policy network data, to identify collaborative networks involved in PFES and REDD+ implementation in an sample of provinces. These additional data, combined with the large existing archive of qualitative data collected as part of the GCS-REDD study, allowed them to model connections between conservation stakeholders, testing the relationship between network structures, land-use changes, and ecological outcomes.

This project's findings should fill a critical gap by collecting and assessing evidence on the impacts of PFES and REDD+ on forest cover and structure and local livelihoods. The project also helped build capacity for multiple stakeholders (government agencies, NGOs, research institutes, the private sector, and the media), bridging organizations to encourage participation, dialogue, and coordination across scales and sectors. The project's cross-scale focus is particularly important given that REDD+ capacity building in Vietnam has focused on the national level, and collaboration beyond the state forest sector has been difficult due to scarce resources and limited capacity.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project provided scientific evidence for the Ministry of Agriculture and Rural Development and practitioners in Vietnam to design and implement more effective, efficient, and equitable payment for forest environmental services in Vietnam. As of March 2023, the PI Dr. Pham and her team produced six peer-reviewed publications and nineteen Center for International Forestry Research (CIFOR) information briefs and other publications. Although the shutdowns and travel restrictions of the COVID era understandably delayed progress, by 2022 the team was able to bring to fruition their efforts to gather data, train young students and scientists, publish their findings and recommendations, and disseminate those to audiences in Vietnam, the U.S., and beyond. They held their final project workshop on December 20, 2022, and it was entitled "Forest Carbon Market Post COP27 and Transformative Pathway for Vietnam. This workshop included sessions on (1) the current status and future trends of the forest carbon market; (2) updates from COP27 and its implication for the global carbon market and Vietnam; (3) lessons learned from other forest-rich countries (e.g., Peru and Indonesia) on how they set up and operationalize the forest carbon market; and (4) opportunities and challenges for Vietnam to design and operate the forest carbon market. This workshop co-organized by the Ministry of Agriculture and Rural Development (MARD), CIFOR, and the International Union for the Conservation of Nature (IUCN). There were 188 participants (both online and in person), including several donors from Canada, Norway, and the United Kingdom.

Dr. Pham noted in her final report that the PEER project had helped her and her colleagues generate findings and identify policy gaps that need to be addressed with support from international donors, and disseminate lessons learned in past activities. She has already received two other grants totaling US $324,000 (one from Amazon and one from USAID) to carry out additional work on sustainable wetland adaptation and mitigation research on mangroves in Vietnam. Another key achievement cited by the PI is the learning and information exchange PEER supported between U.S. and Vietnamese scientists. The researchers held virtual meetings on a weekly basis and exchanged in-person visits in both directions. The U.S. partners also used content from the PEER-supported research to enhance their curricula and instructional materials for their students. The Vietnamese and U.S. researchers plan to continue collaborating and identifying additional funding opportunities to support their work.

PUBLICATIONS

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VIETNAM, CAMBODIA, LAOS, THAILAND, AND MYANMAR - PROJECT 6-435: RIVERSCAPE GENETICS TO INFORM NATURAL HISTORY OF EXPLOITED FISHES IN THE LOWER MEKONG RIVER BASIN

PI: Dang Thuy Binh, Institute for Biotechnology and Environment, Nha Trang University; With Co-PIs Chheng Phen, Inland Fisheries Research and Development Institute; Latsamy Phounvisouk, Living Aquatic Resources Research Center; Chaiwut Grudpan, Ubon Ratchathani University; and Mie Mie Kyaw, University of Mandalay

U.S. Partner: Jeffrey Williams, Smithsonian Institution

Dates: December 2017 – April 2023

PROJECT OVERVIEW

Riverscape genetics, or the influence of hydrographic features on the genetics and ecology of fish populations still and moving water, is a young discipline. There have been several temperate riverscape studies with a few tropical studies – limited mostly to the Amazon and Australia. As a result, very little is known about the population genetics of fishes in the Mekong River Basin (MRB), which is characterized by complicated hydrographic features, including wide seasonal fluctuations in flow and ongoing changes from already constructed and planned hydropower dams.

This PEER project supported the completion of population genetic studies of 14 species across 26 MRB locations from Myanmar to the Vietnam delta, augmenting information on two species collected and analyzed during the PI's project in PEER Cycle 2, adding new localities to species collected in PEER Cycle 3, and add an additional six species not already covered in previous PEER projects.

The PEER team undertook advanced genomic analyses, providing important information on the population structure, effective population size, and directionality of gene flow of Mekong River fishes. The extent of collection sites throughout the Lower Mekong Basin and the number of species in this study provide the basis for the first ever comparative riverscape genetic analysis of fishes of tropical Southeast Asia.

This project solidified collaborations initiated during the Cycle 3 project, including researchers in four Lower Mekong Basin partner countries (Cambodia, Laos, Thailand, and Vietnam) and expanded the work to researchers and a collection site in Myanmar.

FINAL SUMMARY OF PROJECT ACTIVITIES

Field work was the primary focus of this project, and the researchers remained in regular contact, including annual project meetings, to ensure they were all in agreement on sampling protocols and selection of target species. The PEER team collected samples through the end of 2022, and after long delays due to COVID pandemic-related travel restrictions in the region, all collaborators were able to deliver fish specimens to Nha Trang University (NTU) by March 2023. NTU staff extracted DNA from more than 100 fish specimens and sent the results to Texas A&M University for DNA library preparation and sequencing while continuing to work on data analysis.

In Laos, the PEER team organized a training course for university staff on identification of the key characteristics of the target fish species, how to take fish tissue for DNA analysis and how to preserve the samples.

A final workshop was held at NTU to exchange knowledge and explore new opportunities. Researchers presented five studies on different topics related to freshwater fish, including biodiversity, aquaculture, ecology and population genetics and summarized the PEER project results. A doctoral student researcher on the PEER team won the VinIF Foundation scholarship for the third consecutive time, and the PIs have been awarded $300,000 between two new grants to continue work on DNA studies as well as restoration of mangrove forests.

During the final workshop, PEER team members commemorated the life of co-PI Dr. Chheng Phen of the Cambodian Inland Fisheries Research and Development Institute (IFReDI) who died in 2022. Colleagues noted his kindness, humility, good humor, and willingness to share his exceptional knowledge of Mekong fisheries. He was an outstanding teacher and mentor to his students, an irreplaceable expert and leader in his field, and a treasured friend who will be greatly missed by his many colleagues and associates worldwide. PEER offers its deepest condolences to his family and friends.

PUBLICATIONS

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In October 2020, the international science website SciDev.Net Asia & Pacific published a story on this PEER team's research in the Mekong

VIETNAM - PROJECT 6-220: FIELD-SCALE APPLICATION OF VETIVER GRASS TO MITIGATE DIOXIN CONTAMINATED SOIL AT BIEN HOA AIRBASE

PI: Ngo Thi Thuy Huong, Phenikaa University and RIDES (NGO) (formerly based at the Vietnam Research Centre on Karst and Geoheritage of the Vietnam Institute of Geosciences and Mineral Resources)
U.S. Partner: James Landmeyer, United States Geological Survey
Dates: December 2017 – February 2023

PROJECT OVERVIEW

Vietnam is one of the worst dioxin-contaminated areas in the world as a result of extensive use of the herbicide "Agent Orange" (AO) during the war (1961–1971). The worst contaminated sites in Vietnam are located at airbases where large quantities of AO were stored/handled. These areas still pose serious environmental and health risks. Prior to this project, no low-cost, effective phytoremediation technology had been developed to stabilize, mitigate, and remediate soils with low to moderate levels of dioxin contamination over large areas. Initial studies with vetiver grass (*Chrysopogon zizanioides L.*) indicate that it is a very promising candidate for providing such an alternative. This PEER project (1) assessed the use of vetiver grass for the phytoremediation and phytostabilization of dioxin-contaminated soils on a field scale at Bien Hoa Airbase and (2) deepened our understanding of the mechanisms of dioxin uptake and degradation pathways of Vetiver grass. The Monto genotype–a known, noninvasive type of vetiver grass (hereafter "Monto")—was used in the two experiments. The indoor experiment helped address and clarify the remaining issues in phytostabilization and phytoremediation from a previous project completed by the PI. The field experiment helped reevaluate the results from the indoor experiment and assess the potential use of vetiver in phytostabilization of dioxin-contaminated sites.

The results of the project should significantly contribute to advances in phytoremediation technology that can be applied elsewhere in Vietnam and worldwide. The practical measures to be developed and tested will also help local, regional, and national policy makers and NGO-sponsored programs develop and evaluate short- and long-term mitigation and remediation alternatives and ultimately implement remedial actions effectively. By providing funding support for PhD and MSc students, the project also fostered a new generation of environmentalists interested in phytoremediation technology.

FINAL SUMMARY OF PROJECT ACTIVITIES

After more than a year of preparatory work devoted to close coordination with the relevant military authorities and detailed site selection survey work, this project involved more than three years of field experiments at the Pacer Ivy site on the Bien Hoa Airbase. Despite the challenges of the COVID pandemic, including lockdowns that made even domestic travel temporarily impossible, members of the project team traveled to the airbase every few months to maintain the field site, monitor the growth of the Vetiver plants being used in their phytoremediation experiment, and collect soil, water, and vegetation samples. Project co-PI Dr. Nguyen Hung Minh and his colleagues analyzed the samples at their laboratory and the PI Dr. Ngo Thi Thuy Huong and her team subsequently evaluated the data.

The experiment was divided into two groups, an experimental group with Vetiver and a control group without Vetiver, with each group being repeated three times over a 100 m^2 area. Vetiver grass (*Chrysopogon zizanioides L*.) was chosen for this study because it had previously been used successfully in similar studies in Australia and many other countries, and the PI and her team wanted to see how results under Vietnamese conditions would compare. Their results show that Vetiver grass effectively reduces soil erosion and contaminant runoff compared to the control group, confirming previous research on Vetiver's ability to stabilize dioxins in soil in contaminated areas. A comparison of the dioxin content in the plant roots versus that in the shoots suggests a clear biodegradation of dioxin by plants, with very little dioxin being transferred to the shoots. According to the PI, the findings of this study confirmed the effectiveness and suitability of Vetiver grass in stabilizing dioxins in soil structure and preventing their flow into the surrounding environment, as well as treating dioxin contamination in soil by plants in areas with moderate dioxin contamination.

The final dissemination workshop for this PEER project was held February 9-12, 2023 in Quy Nhon, Binh Dinh, Vietnam, with more than 40 participants and 10 speakers. As of May 2023, the researchers had published two papers in Vietnamese journals, with one more due for presentation at The Seventh International Conference on Vetiver (ICV-7) to be held in Thailand later that month. That paper, entitled "Using Vetiver Phytoremediation Technology to Mitigate Dioxin–Contaminated Soils at Bien Hoa Airbase, Dong Nai, Vietnam," has been awarded the King of Thailand Vetiver Award 2023 for Outstanding Research in the Field of Non-Agricultural Applications. Further publications are planned, and Dr. Huong indicates that she intends to transfer this technology to government organizations and other stakeholders that are interested in working in this field. In the future, she and her team hope to learn more about the mechanisms behind phytoremediation and how they can be combined with other approaches to make it an even more powerful tool for cleaning up polluted environments, not just those tainted with dioxins. Thanks to the increased visibility provided by the PEER project, Dr. Huong reports that faculty from Hanoi National University, Hanoi University of Mining and Geology, Hanoi Open University, and Naresuan University (Thailand) are interested in collaboration, as are Ecofarm Mekong (a private company) and the Vietnam Vetiver Network (a non-governmental organization). On the education side, the project resulted in two PhD students, four MSc students, and five undergraduate students receiving training in soil sampling methods for dioxins, enzyme, microbial, and soil physical structure samples, as well as sample processing and preparation and vetiver transplanting. In addition, knowledge of planting and using Vetiver for wastewater and contaminated soil treatment has been transferred to Nam Sach High School in Hung Yen Province, and 1000 Vetiver tillers have been donated to the school as well.

To support her continued research efforts, Dr. Huong and her colleagues have been awarded one Vietnamese and seven international grants totaling approximately $3 million just in the period from 2020 to mid-2023. They continue to publish the findings, with two new papers appearing in May 2024.

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VIETNAM - PROJECT 5-666: AN ASSESSMENT OF SMOKING AND ACCESS TO CARE AS RISK FACTORS FOR GENDER-DIFFERENCES IN TB RATES: A SUBSTUDY OF THE VIETNAM NTP TB PREVALENCE SURVEY 2016-2018

PI: Nguyen Van Hung, Vietnam National Tuberculosis Program
U.S. Partner: Payam Nahid, University of California, San Francisco (Funded by the National Institutes of Health)
Dates: March 2017 – February 2020

PROJECT OVERVIEW

The global burden of 9.4 million annual cases of tuberculosis (TB) overwhelmingly falls on low-income countries, with 80% of cases occurring in just 22 high-burden countries. Between 1998 and 2008, the average male-to-female ratio of new smear-positive cases for high-burden countries was 1.85. Although every country is unique, gender differences observed in case notifications are often mirrored by gender differences in prevalent TB cases, indicating there are genuine gender differences in the biology and epidemiology of TB. Vietnam falls among the countries having the highest TB burden in the world, with an estimated incidence of around 140 new TB cases per 100,000 population annually. Additionally, the Annual Report of the Vietnam National Tuberculosis Program (NTP) notes that the program detects nearly three times more male than female TB patients in the notification rate of pulmonary TB.

Repeat TB prevalence surveys provide useful data on trends in the burden of disease caused by TB, and can also be used to assess the impact of efforts to control TB. In addition to the prevalence survey, this PEER project assessed smoking and access to care as risk factors for TB to determine the role smoking might play in creating gender differences among TB cases.

While the DOTS (directly observed treatment, short-course) strategy has become the standard treatment protocol for TB control in most countries, most current TB control strategies fail to account for the increased risk of recurrence due to smoking. A better understanding of the incidence of, and factors associated with, TB infection and recurrence may help in identifying the most vulnerable populations and developing effective control measures that lower the rate of TB infection. This study aimed to inform policy and program managers and identify gender-sensitive recommendations on smoking policy and prevention to improve current TB control policies and programs to reach Vietnam’s ambitious targets for 2020 and 2030.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team undertook a pilot research study at four sites, trained data collectors, and set up online data collection tools. They collected data on various elements of individuals seeking care for prolonged cough, including education and smoking history, through a survey questionnaire within Vietnam. Ten national research team members finished data collection in 120 selected clusters. The TB Prevalence Survey (TBPS) team organized a workshop to discuss data cleaning, validation, and analysis. Validation of data collected from the clusters was done by cross checking between digital and paper-based data. Preliminary data analyses of the TBPS data included multiple imputation and sensitivity analysis steps.

The researchers worked with external partners at the Dutch foundation KNCV, the World Health Organization, and the U.S. Centers for Disease Control and Prevention office in Vietnam to review their findings and develop a technical report. By the spring of 2023 they had published four papers, with the latest focusing on the gender aspects of TB rates in Vietnam. Given the close linkages between the project team and the relevant government agencies and programs, some results of the study were also expected to be used in developing the Vietnamese national strategic TB plan from 2021 to 2025.

PUBLICATIONS

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VIETNAM - PROJECT 5-618: STUDY ON CORAL REEF RESILIENCE IN COMPARATIVE AREAS IN SOUTH VIETNAM FOR MARINE BIODIVERSITY CONSERVATION IN A CHANGING WORLD

PI: Tuan Si Vo, Institute of Oceanography
U.S. Partner: Mark Eakin, NOAA Coral Reef Watch
Dates: December 2016 – July 2022

PROJECT OVERVIEW

This project was aimed at understanding coral reef resilience capacity in comparative areas in southern Vietnam under changing stresses (increased temperature and human activities) and developing guidelines for biodiversity conservation and resources management. To achieve these goals, the researchers assessed coral bleaching in 2016 in three representative reef areas (Nha Trang Ninh Thuan coastal waters as an example of an upwelling area, Con Dao islands in the western South China Sea, and Phu Quoc islands in the coastal Gulf of Thailand). They also conducted studies on biological and physical features associated with coral reef resilience at the site level of each area in order to develop recommendations on possible changes in zoning and adaptive management of marine protected areas (MPAs). Studies were also carried out on settlement and recruitment of corals and inter-population connectivity of target reef organisms among the three areas. Near the end of the project, the team developed guidelines for the conservation of marine biodiversity in southern Vietnam to promote resilience to sea temperature changes and human activities. The U.S. partner and his colleagues will provide their experience and data, especially in nowcasting and forecasting of sea temperatures in relation to coral bleaching and other phenomena. NOAA methodology on coral reef resilience was critical in order to ensure that data on the project are aligned with international standards.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the course of this nearly six-year project, Dr. Vo Si Tuan and his team conducted 26 field campaigns to the four target areas in their study: Nha Trang Bay, Ninh Hai coastal waters, Con Dao islands, and Phu Quoc islands. The data collected under this and previous studies were provided to the Global Coral Reef Monitoring Network (GCRMN) as a contribution to their report on the status and trends of East Asian Coral Reefs: 1983–2019 (Kimura et al. 2022). In numerous papers produced under the project, team members also analyzed their data to identify trends in coral reef degradation and resilience in the face of anthropogenic impacts, extreme weather events, rising sea temperatures, and coral bleaching. The PEER team also cooperated with another national project to study the genetic structure and population connectivity of *Siganus guttatus* (orange-spotted spinefoot) and *Amphiprion perideraion* (pink anemonefish) in marine habitats in the coastal waters of Vietnam. The findings from this work enabled the researchers to make recommendations on the appropriate establishment of marine protected area (MPA) networks and sustainable management for these fish species.

To help ensure the greatest impact for their research, the team worked closely with authorities of local MPAs. They provided multiyear data on changes of coral reefs in Nha Trang Bay to support Khanh Hoa Province in evaluating the severe degradation of coral reefs in this bay and suggesting solutions for management and restoration. The team presented further proposed activities at the International

Symposium on New Frontiers in Reef Coral Biotechnology held in Taiwan in May 2022. The integration of the project data and previous records also facilitated the evaluation of marine conservation effectiveness of Con Dap National Park during 2009-2019 (Vo et al. 2020). The results from this study were used as inputs for the revised management plan of Con Dao National Park for the period 2020-2030. The same approach was applied for the rezoning and developing the revised management plan of Phu Quoc MPA. The project also integrated with local activities in propagating and implementing new approaches on marine conservation within MPAs, including coral reef management for the development of ecotourism in Nha Trang and restoration of hard corals and pearl oysters in Phu Quoc (Vo & Hua, 2021). In addition, the project provided updated information and approaches for a book entitled Ecology and Resources of Coral Reefs in Vietnam (Vo Si Tuan & Nguyen Van Long, 2022). Chapter 7 of the book provides guidance on development and management of MPAs in Vietnam and related issues such as reef restoration, monitoring, participatory management, and integrated management within MPAs. Chapter 8 on research and management of target reef areas highlights physical features, biodiversity, threats, and proposed solutions for adaptive management in five reef areas (Cu Lao Cham, Nha Trang, Ninh Hai, Con Dao and Phu Quoc).

Besides their collaboration with U.S. partner Dr. Mark Eakin and colleagues at NOAA, the project also supported cooperation with a national Vietnamese project and a joint Vietnamese-Russian project to develop the baseline data on ocean acidification in nearshore and offshore South Vietnam (southwestern South China Sea) (Phu et al, 2021). Three years of data on the parameters related to ocean acidification collected in reef and non-reef areas were provided to the UNESCO/IOC database for tracking implementation of Sustainable Development Goal 14 in Vietnam. For reef areas, Linh et al. (2021) provided a baseline of the parameters on the reefs at Phu Quoc islands, Binh Thuan skerries, Nha Trang Bay, Con Dao, and Tho Chu islands. In addition, data on reef features collected by the PEER team contributed to an improved understanding of reef fauna in Vietnam.

On the capacity building side, the project cooperated with the Intergovernmental Oceanographic Commission (IOC) Vietnam and the OC Sub-Commission for the Western Pacific (WESTPAC) in organizing an October 2019 workshop on oceanography and ocean acidification for 25 trainees from research institutions and universities. Furthermore, the project cooperated with IUCN and WWF to organize an integrated training workshop in April 2022 for improvement of management effectiveness of MPAs in Vietnam. Following that workshop, the project team conducted a site training to help the staff of Bai Tu Long National Park develop a monitoring program with appropriate ecological and socioeconomic indicators. The project PI Dr. Tuan was also invited to attend a series of national workshops on management of national MPA network in 2019 and 2020. The inputs from the project on coral reef status, reef fisheries, coral bleaching, and reef resilience, as well as impacts from economic activities on the marine environment, were provided in the workshops. Through these events, several solutions were proposed to the Ministry of Agriculture and Rural Development to improve the MPA network, including co-management and enforcement, rezoning to ensure conservation purpose under development demands, integration of conservation and tourism, enhancement of responsibility of users in MPAs, delivery of provincial guidance on engagement of private sector in management, restoration and utilization of ecosystem resources, forecasting of coral bleaching, and minimization of cumulative impacts to enhance coral reef resilience.

The project was also notable for the degree of integration with local private sector organizations on activities for propagating and implementing new marine conservation approaches within MPAs. For example, the PEER team worked with four tourist companies (Vinpearl, Dong Tam, Tri Nguyen, and Hong Hai – Six Sense) on models of coral reef management for the development of ecotourism in Nha

Trang Bay. The analysis of trends of coral cover and density of reef fishes and large invertebrates at three sites allowed the researchers to assess the effectiveness of three years of management and propose further actions for sustainable use of coral reefs in the tourism industry in Nha Trang Bay. With the support from the Phu Quoc MPA, restorations of hard corals and pearl oysters were conducted by the Ngoc Hien Pearl Company at two sites to promote both marine conservation and tourism. In terms of management, the participation of private sector in oyster restoration demonstrated the usefulness of the MPA's policy of engaging local stakeholders in management of marine resources.

By the time of their final report in August 2022, Dr. Tuan and his colleagues had received three follow-on grants from Vietnamese sponsors totaling more than $80,000. They plan to continue their work in cooperation with national and provincial entities to conduct further activities related to coral reef conservation and MPA management. Additional papers on their findings and recommendations are also anticipated. In addition, the team has been contributed actively to IOC/WESTPAC efforts in developing an initiative entitled "Save Our Corals: A partnership programme on coral reef resilience" to submit as a program proposal for the UN Decade on Ocean Science for Sustainable Development. Recently, the team has also developed joint project between their institute and the Australia Institute of Marine Science on coral reef research and management, which would include the involvement of MPA authorities.

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VIETNAM - PROJECT 5-257: GIS AND REMOTE SENSING APPLICATION FOR ASSESSMENT OF LAND DEGRADATION IN THE LOWER MEKONG RIVER BASIN

PI: Quyet Vu, Soils and Fertilizers Research Institute
U.S. Partners: John Bolten, NASA Goddard Space Flight Center, and Venkat Lakshmi, University of Virginia
Dates: December 2016 – July 2019

PROJECT OVERVIEW

Land and forest are being overexploited in the Lower Mekong River Basin (LMB) due to the pressure of rapid economic development and high population growth. These factors may impact the functions and services of land ecosystems, including biomass productivity. Because human livelihoods in the LMB still rely strongly on agricultural production, land degradation will be a significant issue for development strategies. In tropical regions, poverty and land degradation are often part of a downward spiral: poverty and economic marginalization lead to overexploitation of land resources, resulting in land degradation, which then leads to more serious poverty. To combat land degradation, policy makers often need information to identify areas of most intense degradation in order to plan strategic interventions. The specific objectives of this project included

- Producing a map of geospatial biomass productivity decline for the LMB (Vietnam, Laos, Cambodia, and Thailand), using long-term biomass productivity trends as a proxy for land degradation;
- Differentiating human-induced land degradation from climate-driven signals by examining the temporal correlation between long-term biomass productivity trends and climate data; and
- Identifying potential underlying processes (population density, soil/terrain conditions, and land-cover types) that affect land degradation.

FINAL SUMMARY OF PROJECT ACTIVITIES

This study aimed to delineate the geographic hotspots of land degradation in the Lower Mekong Basin (LMB) countries (Vietnam, Cambodia, Laos, and Thailand) as observed from space by tracking the greenness of the vegetation signal expressed in the Normalized Differenced Vegetation Index (NDVI). A long-term time-series (1982–2015) of NDVI at a resolution of approximately 9.16 km x 9.16 km was used to specify the areas with significant decline or increase in productivity, and rainfall time-series maps were used to identify areas that might have been affected by land degradation from those correlated with rainfall. With these data, the PI and his group examined the relationships between land degradation and land attributes, such as climate, population density, soil/terrain conditions, and land-cover types. They identified land degradation in different climate zones in relation to population density, finding that most of the land degradation areas were located in areas of low population density. Only some areas in the Mekong River Delta, the cities in the Northwest of Vietnam and the areas near Bangkok, Thailand show land degradation with high population. Finally, in order to obtain a better insight into where exactly this degradation is occurring, the land degradation map was cross referenced with the land cover map of SERVIR Mekong to differentiate the degradation areas according to land cover types. In the absence of other instruments for monitoring the rate of land degradation in the LMB, satellite-based systems offer the best hope for tracking the state of this vital natural resource. The team found that about 15% (186,228 km2) of the total land mass of the four countries studied experienced land degradation over the last 34 years. The largest degraded areas were found in Cambodia; Northwestern Vietnam; the Highlands of Vietnam; the Northern Mountains of Thailand and Laos; and the mountainous border between Laos, Vietnam, and Cambodia. By relating these hotspot areas of land degradation in the basin with different attributes of the region, the researchers found that deforestation, conversion of land use, and pressure of population in urban areas are the potential processes that play important roles in degradation.

The findings of this study provided a broad overview of land degradation for LMB countries based on biomass productivity, even though the maps and assessments made by this study need further verification in the field. The study can be used to offer guidance to the research community and to policy makers. With better data identifying areas of land degradation, it could help policy makers in prioritizing limited budgets and planning strategic interventions.

Based on the hotspots of land degradation that have been better defined, research organizations should be able to select pilot research sites where in-depth research can be undertaken to assess land degradation and design sustainable land management options. The maps created with PEER support are expected to be posted on the website of the SERVIR Mekong project (https://servir.adpc.net/) to ensure broad access.

Dr. Vu and his colleagues published their first paper on the project in 2018 (see citation below). The paper outlines the trends of NDVI data derived from AVHRR/NOAA and Terra MODIS in the overlapping period (2001-2015). The authors analyze these trends and examine the relationship with rainfall from CHIRPS data. They found that the trend over 15 years of human-induced biomass productivity declines from the two datasets was relatively similar (around 13-14% total land mass). In addition, they note in the paper that MODIS NDVI data with a shorter tracking time can be used as in complementary fashion to existing NDVI AVHRR data sources. In 2019, they also published a book on their work (in Vietnamese) entitled *Biomass Productivity-Based Assessment on Land Degradation in the Lower Mekong Basin*, including all their results, data, and maps. It is available for download through the link below. Their first English language paper on the project appeared in *Remote Sensing* in 2019.

In addition to publications, the team is also continuing to disseminate their results and approaches to the academic community through conferences and workshops. Among other venues, the project will be presented at the International Conference "Integrated Land and Water Management and Climate Change in Vietnam and Japan" in Hanoi November 18-20, 2019. The research team will also continue their work thanks to two new grants they received in 2019. Dr. Vu is co-PI on a new project entitled "Developing and promoting market-based agroforestry and forest rehabilitation options for northwest Viet Nam," which is funded by the Australian Centre for International Agricultural Research (ACIAR) through the World Agroforestry Centre (ICRAF). He is co-leading "Objective 2: To understand suitability of different agroforestry options in relation to different contexts, and create linkages to markets and government programs and policies to scale up adoption" and will participate in some other objectives of the project. The grant supporting Objective 2 totals approximately U.S. $150,000. The Department of Science and Technology of Lai Chau Province (Vietnam) has also provided about $35,000 to support another new project on which Dr. Vu is co-PI. It is entitled "Studying and evaluating soil quality in the rice paddy fields for planning and developing high quality rice product in Lai Chau Province." Dr. Vu and his colleagues also remain in contact with U.S. partners Dr. John Bolten and Dr. Venkat Lakshmi to continue their collaboration and plan new research efforts.

PUBLICATIONS

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VIETNAM - PROJECT 5-253: USING MULTI DATA FOR BIODIVERSITY CONSERVATION AT DAK NONG PROVINCE IN THE CENTRAL HIGHLANDS OF VIETNAM

PI: Nguyen Thi Thanh Huong, Tay Nguyen University
U.S. Partner: Volker Radeloff, University of Wisconsin–Madison (Funded by the National Aeronautics and Space Agency)
Dates: December 2016 – June 2021

PROJECT OVERVIEW

Development of sustainable forest management and conservation strategies requires an understanding of how the composition and structure of tropical forests change in response to different disturbance regimes and how this affects both species distributions and people living in and near these forests. Most forests in Vietnam are affected by land cover change (LCC) resulting from human activities. To map and quantify the patterns of LCC, Dr. Nguyen and her team analyzed Landsat satellite images, GIS data, and field inventory data to classify forests by type and disturbance status. They used these maps to stratify their field sampling and assess plant biodiversity among forest types and their changes following different levels of human disturbances (i.e., minor, moderate, and heavy impact). Furthermore, they compared tree composition and structure along different ecological gradients, such as topography. By combining remote sensing, field data, and statistical processing, they worked to advance current methods to measure disturbance and biodiversity in the Central Highlands, which are largely based on field inventories. However, remotely sensed data is likely insufficient to map rare and endangered species, and hence areas of high conservation value. Therefore, the researchers integrated spatial data with the experience of forestry workers and the indigenous knowledge of local people in the second phase of the project. Dr. Huong and her colleagues collaborated closely with their U.S. partner Dr. Volker Radeloff, who provided expert advice on forest sampling, analysis of vegetation diversity, and the use of remote sensing in ecology and biodiversity.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project achieved its goals with regard to research and capacity building for both team members and staff from stakeholder agencies, production of scientific publications, and strengthening of collaborative linkages with Vietnamese and international research partners.

Outreach and collaborations were very important aspects of the project, and the PI and her team collaborated closely with both professional foresters and local residents, who were involved in many project activities, including discussions of problems related to forest management, participation in forest inventories, and training on relevant technical skills. Through these activities, foresters and citizens alike gained a greater understanding of the importance and status of rare and endangered tree species in their local areas, as well as approaches for more effective forest management. Through working with the PEER team, they learned how to use inventory tools, design field activities, and collect biophysical data. A total of 285 people participated in the project, including undergraduate and graduate students, lecturers from Nong Lam University and Tay Nguyen University, and forestry staff and residents from four provinces in Vietnam's Central Highlands. Prior to the project, forestry staff at various levels in Dak Nong Province lacked any training in using remote sensing and GIS techniques in forest management. The PI reports that the training met their expectations and gave them confidence to collect and analyze forest data independently, skills that will be very useful in their fulfilling their forest management responsibilities. Three Master's students and one undergraduate completed their degree requirements based on their work on the PEER project, with two subsequently being hired by provincial forest management agencies and two continuing as members of the PI's research team. Three other PhD students on the project are completing their compulsory courses and beginning their research projects under the PI's supervision.

At the time the final report on this project was received in August 2021, the PI and her colleagues had published 11 journal articles and conference papers, including one in the international journal *Remote Sensing*. At least two more papers and a book of technical guidelines are still in preparation. In addition, the PI and her colleagues presented their results at four workshops, culminating in a final one in April 2021 at which they transferred their final report to the Department of Agriculture and Rural Development (DARD), Department of Science and Technology, and Department of Planning and Investment for Dak Nong Province. The head of DARD emphasized they will use the results in updating and integrating the province's development programs and plans.

In 2020-2021 alone, the PI and her team received five new grants or contracts for a total of about $125,000 to support their ongoing efforts on crop mapping, provision of remote sensing and GIS training, forest restoration, and organic agriculture development. The team was invited to serve as a core member of a national project conducted by the Vietnam Academy of Science and Technology (2018-2021). They are also contributing to other projects under Dak Nong Province agencies, and they have been invited to complete work packages related to community forest management, REDD+ (Reducing Emissions from Deforestation and Forest Degradation), and the forest value chain as part of a new project the International Fund for Agricultural Development—Green Climate Fund for 2022-2026. Dr. Huong notes that participation in the PEER program not only helped her team members develop their professional skills but also built a strong reputation for the group in the agro-forestry development sector. These aspects, combined with the enhanced research infrastructure from equipment and software bought with PEER funds, put the team in a strong position to compete for additional funding. In addition to the larger grants and contracts supported by Dak Nong Province agencies, Tay Nguyen University is also supporting small research grants for several team members.

Based on the experience and results obtained from their PEER project, Dr. Huong and her colleagues have established an official research team entitled Resources Integration Management, one of only four such research units at their university. In addition to following up on publishing additional papers resulting from their PEER-supported work and carrying out their newly funded projects, the researchers will be pursuing new opportunities to continue providing training, data, and recommendations to environmental agencies in their region and beyond.

SELECTED PUBLICATIONS

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VIETNAM - PROJECT 4-189: APPLICATION OF GEODETIC, SATELLITE REMOTE SENSING, AND PHYSICAL MODELING TOOLS FOR THE MANAGEMENT OF OPERATIONAL GROUNDWATER RESOURCES IN THE RED RIVER DELTA, VIETNAM

PI: Nguyen Duc Luong, Institute of Environmental Science and Engineering, National University of Civil Engineering

U.S. Partner: Faisal Hossain, University of Washington (Funded by the National Aeronautics and Space Agency)

Dates: October 2015 – March 2019

PROJECT OVERVIEW

The overall goal of this project was to transfer and build locally developed applications of advanced technologies, including GRACE satellite gravimetry, satellite altimetry, and hydrologic and hydraulic models to Vietnamese institutions and agencies that manage groundwater resources in the Red River Delta (RRD) of Vietnam. In this project, the Institute of Environmental Science and Engineering (IESE) and the National Center for Water Resources Planning and Investigation (NAWAPI) partnered with the NASA-supported project "NASA WATER—Towards Operational Water Resources Management in South Asia Exploiting Satellite Geodetic and Remote Sensing Technologies (2014-2018)," which is led by Dr. Faisal Hossain at the University of Washington (UW). This three-year project was the first ever study adopting the promisingly integrated approach of geodetic, satellite remote sensing, and physical modeling tools for groundwater assessment in Vietnam. It provided a totally new spatial and temporal dataset for groundwater monitoring in the RRD, where groundwater is being over-exploited for domestic use and intensively irrigated agriculture activities. These efforts will support NAWAPI and relevant governmental agencies in their decision-making activities for sustainable management of groundwater in this region and Vietnam. To achieve its goal, this project provided technical training for IESE and NAWAPI staff members on independently managing and interpreting data from geodetic and satellite remote sensing, hydrologic, and hydraulic modeling tools for extracting regional and local-scale changes in groundwater storage anomalies for the RRD. This would then facilitate making projections for water resources planning at 30- to 180-day timescales for the RRD.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over its duration of more than three years, from October 2015 to March 2019, Dr. Luong and his team on this now-completed PEER project achieved the following key results and impacts:

• **Scientific findings:** Using the VIC hydrological model and GRACE satellite data, they have performed simulations for Red River flows and assessed groundwater resources for the Red River Basin. They shared these findings with their local partners (NAWAPI and NCHMF) and other national and local stakeholder agencies for reference and use in their ongoing operational tasks with regard to water resource management.
• **Publications:** Based on their PEER project findings, as of February 2019 the team had published three joint peer-reviewed papers involving their U.S. partner Dr. Faisal Hossain, plus another peer-reviewed paper individually authored by Dr. Luong. Their work also appeared in three published proceedings.

• **Educational impacts**: With the accumulated knowledge and skills they gained in the application of the VIC hydrological model and satellite tools for water resource management, the PEER team has developed new courses that will be offered to undergraduates at NUCE as part of the program "Environment and Urban Sustainability." The curriculum is expected to be launched in the summer of 2020 and will include newly designed courses on Environmental Systems Modelling, Application of Geographic Information Systems (GIS), and Remote Sensing in Natural Resources and Environmental Management, thus sharing the benefits of the project with a new generation of Vietnamese students.
• **Tools and products**: In close collaboration with their U.S. partner, Dr. Luong and his colleagues developed real-time web-based water forecasting systems based on hydrologic modeling, weather model data, and satellite observations. Although the PEER project has ended, these systems continue to be to provide useful data and results for NUCE and other research institutions and agencies in both their research and agency operations. The system designed for NUCE is available at (http://forecast.water.numos.org/) and the system for NAWAPI is at (http://forecasting.vaci.org.vn/).
• **Outreach and collaborations**: Through their project events and participation of project members in several conferences and workshops, the team has widely disseminated their results and established valuable connections for future collaboration with local, national, and international research institutions, universities, governmental agencies, non-governmental organizations, and other stakeholders. They continue to work with U.S. partners on ongoing projects supported by the National Science Foundation and the National Aeronautics and Space Administration.
• **Capacity building**: Through their PEER project, Dr. Luong and his group have built valuable capacity for their project members and students on using modelling and satellite tools for water resources research. They have also provided capacity building for relevant local, national, and regional agencies and institutions. Their group's website at www.numos.org will continue to serve as a resource and focal point for the NUMOS (NUCE Modeling and Earth Observation System) research group. This is one of the few research groups in Vietnam currently working on the modeling and earth observation system at present. They also plan to upload all of their project materials and findings on the website to make them freely available to the general public and broaden the impact of the project. As Dr. Luong confirms, all of their efforts have been devoted to facilitating true empowerment for the people of Vietnam and ensuring the long-term sustainability of satellite-based ground water management in the country and the region.

In February 2019, the journal *EOS Earth and Space Science News* published a joint article by this team on the flood forecasting system they developed as part of this project, entitled When Floods Cross Borders, Satellite Data Can Help.

PUBLICATIONS

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VIETNAM - PROJECT 3-190: WATER GOVERNANCE OF MINORITY COMMUNITIES IN THE MEKONG DELTA

PI: Nguyen Van Kien, Research Centre for Rural Development, An Giang University

U.S. Partners: Carol Xiaohui Song and Venkatesh Merwade, Purdue University

(Funded by the National Science Foundation)

Dates: October 2014 – August 2019

PROJECT OVERVIEW

Water is critical to all life. Unfortunately, there are still hundreds of millions of people without access to proper water and sanitation facilities. Unequal or unethical distribution of water and access to resources is a critical issue worldwide. Underrepresented groups and minority communities are often the most vulnerable to the effects of climate change, and it is critically important to engage minority populations in the management of water resources. The goal of this research project was to work with underrepresented communities in Southern Vietnam to improve water resource management by studying water governance and water access within local villages. Specifically, this project investigated and documented water management knowledge of the Khmer communities in Southern Vietnam, where there is a big gap between science and knowledge in water governance. The investigators involved in this project had already proven the importance of village-level analyses through previous work with the Vietnam Delta and on resilience of populations to flooding. This project built on their previous work and created new knowledge on underrepresented groups living in the Mekong Delta. The project also strengthened the scientific merit of the hydrologic modeling work being conducted by the U.S. partners at Purdue University. Understanding management decisions and strategies of the Khmer people, as well as other underrepresented groups, can better inform the assumptions made in hydrologic modeling.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project was originally expected to last three years, but thanks to careful planning and leveraging of other support he obtained, the PI Dr. Kien was able to extend the project for almost five full years. He and his colleagues were able to expand on their original goals to accomplish more than anticipated, including with some additional support provided by a PEER discretionary supplement. Following is a list of key project outcomes by this productive team:

- Undertook a stakeholder workshop, 12 focus group discussions, 125 in-depth key informant interviews, and 200 structured interviews (household surveys) in Tri Ton and Tinh Bien Districts of An Giang Province and Vinh Chau Town of Soc Trang Province.
- Made four research presentations, including at the National Groundwater Conference in Australia in 2017, a Vietnam stakeholder workshop in Soc Trang Province (2015), an international workshop at An Giang University (2018), and a training workshop in Tinh Bien District, An Giang Province (2019).
- Supported five students to complete their Master's degree programs.

- Completed two international visits by the PI and co-PI to the United States in 2015 and 2017, one trip to Australia by two research assistants and PI, and one trip for the PI from Australia back to An Giang University to organize the international workshop in September 2019.
- Set up and piloted a community-based rainwater harvesting system and an organic vegetable garden at Ta Ngao Temple in Tinh Bien District, An Giang Province.
- Set up a pilot automatic irrigation system for a Khmer farmer (this project was adopted by local NGO GREEN ID for replication at other project sites in Tinh Bien District, An Giang Province, in 2018).
- Developed three policy briefs and two video clips to advertise the pilot activities to the community.
- Developed strong ties between researchers and government officials, international collaborators, and experts in water governance and community development.
- Built a linkage with the Vietnam Field School Program from Australian National University to visit the PEER project site since 2015.
- Gathered and provided baseline data for other research on the Khmer community in the Mekong Delta.

The PI Dr. Kien reports receiving eight other grants during the period of his PEER award to help expand and now continue his activities even now that PEER support has ended. For example, in November 2018 he received AUD$15,000 for 2018-2019 from the Aus4Skills Small Grants Fund to help develop partnerships between Australia and Vietnam for the organic agriculture movement. He and two colleagues hosted the first Mekong Delta Forum on the movement and undertook a study tour in several Australian states to visit organic farmers, educators, NGOs, and industry. They also piloted community-based organic vegetable gardens for Khmer people in temples in southern Vietnam (An Giang Province) and promoted the Mekong Organics Platform. In 2019, he received his most recent follow-on grant, which was funded for 2019-20 by SEARCA (Southeast Asian Centre for Graduate Study and Research in Agriculture) in the amount of USD$15,000. As part of this nationwide project, which is entitled "Social perceptions of the organics industry in Vietnam," Dr. Kien leads a multidisciplinary research team (encompassing social science, food science, agronomy, economics, nutrition, public health, and agricultural policies). As of October 2019, the team was reviewing the relevant literature and designing questionnaires for use in their study.

PUBLICATION

Trung Thanh Nguyen, Van Kien Nguyen, Minh Man Dang, Tri Thich Le, and Nhat Huy Nguyen. 2022. Domestic water qualities of Khmer minority communities in the Mekong Delta, Vietnam. *GMSARN International Journal* 16: 279-286. http://gmsarnjournal.com/home/wp-content/uploads/2021/10/vol16no3-8.pdf

VIETNAM, CAMBODIA, AND LAOS - PROJECT 3-149: BIODIVERSITY CONSERVATION IN INDOCHINA: INTEGRATING RESEARCH AND TRAINING TO ENHANCE WILDLIFE TRADE MANAGEMENT

PI: Minh Le, Central Institute for Natural Resources and Environmental Studies of Vietnam National University, with Co-PIs Seak Sophat, Royal University of Phnom Penh, and Sengdeuane Wayakone, National University of Laos
U.S. Partner: Mary Blair, The American Museum of Natural History (Funded by the National Science Foundation)
Dates: December 2014 – February 2018

PROJECT OVERVIEW

One of the biggest direct threats to biodiversity in Indochina is the illegal wildlife trade, which has driven many species to the brink of extinction. This problem will likely get worse without immediate and effective measures to control the trade. Conservation efforts in the region have been hindered by the lack of understanding about the pattern, scale, and drivers of the trade. A more comprehensive approach is therefore critically needed to characterize the trade network, and design cost effective conservation measures. In this project, the research team addressed issues related to the trade by surveying wildlife markets and by strengthening the existing research and conservation activities between Indochinese countries, such as Cambodia, Laos, and Vietnam. The research team built capacity in conservation genetics, forensic science, and socioeconomic analyses of trade activities, as these skills are critically needed to tackle this complex threat in the region. The project had three main aims: (1) clarify the scale and drivers of the wildlife trade through market surveys in Indochina; (2) develop a DNA database for all protected animal species in Indochina for trade monitoring and enforcement; and (3) strengthen existing research in the conservation genetics of lorises, muntjacs, and turtles to identify unique lineages in groups under the highest harvesting pressure.

The research project expanded on U.S. partner Dr. Mary Blair's research project through the development of a biodiversity research network across Vietnam, Laos, and Cambodia for coordinated data collection, DNA database mapping, and capacity building. The project also added in-depth studies of key trade-targeted species beyond lorises, including muntjacs and turtles. Dr. Blair worked closely with the research team on field surveys, genetic analyses of the lorises, and the development of socioeconomic data collection and analysis methods to enable coordination of these methods across the PEER and NSF projects, thus expanding their collective impact.

FINAL SUMMARY OF PROJECT ACTIVITIES

On December 8, 2017, Dr. Le and his co-PIs organized the final workshop on the project, which was held at the Central Institute for Natural Resources and Environmental Studies (CRES) in Hanoi. The workshop was entitled “Wildlife Trade in Indochina: Applications of Research Results to Combating Wildlife Trade,” and during the event project participants presented data and results to an audience including more than 40 different researchers and government and NGO officials. Organizations represented included the Wildlife Conservation Society, Asian Turtle Program, USAID, USAID Saving Species program, the U.S. Embassy, universities, research institutions, and the Vietnamese Ministry of

Agriculture and Rural Development. In addition to the presentations, lively discussions ensued regarding approaches developed during the project for potential applications to enhance wildlife management.

At the time the project's funding support from PEER ended as of February 28, 2018, Dr. Le summarized his team's key accomplishments as follows:

- Eleven papers were published under the project. Of these, ten were published in international journals and one in a Vietnamese journal. Three of the publications were co-authored with the U.S. partner, Dr. Mary Blair of the American Museum of Natural History.
- Nine presentations were given at international and national conferences/workshops.
- A prototype of the DNA database, which integrates sequences of protected vertebrate species in Indochina and modern bioinformatic tools to enhance wildlife trade management, was developed to fulfill the project goal. The Biodiversity Conservation Agency of the Vietnamese Ministry of Natural Resources and Environment, which implements the country's national biodiversity law, is interested in further developing the database to support biodiversity research and conservation in Vietnam.
- The project team organized three workshops, which included more than 80 participants. One training workshop helped building the capacity of more than 30 trainees in forensic science and molecular sequencing to enhance wildlife trade management and biodiversity research.
- Three undergraduates, three Master's students, and one PhD student received training through their participation in the project.
- The PI and the U.S. partner raised more than $300,000 in additional funding to conduct further research activities related to the PEER project.\
- Dr. Le and Dr. Blair are continuing to develop research activities and collaboration and completing additional manuscripts and proposals for submission to various journals and funding agencies to ensure the long-term sustainability of the project.

PUBLICATIONS

Mary E. Blair, Minh D. Le, Gautam Sethi, Hoang M. Thach, Van T. H. Nguyen, George Amato, Mark Birchette, And Eleanor J. Sterling. 2017. The Importance of an Interdisciplinary Research Approach to Inform Wildlife Trade Management in Southeast Asia. BioScience 67: 995–1003. https://doi.org/10.1093/biosci/bix113

Renata F. Martins, Jörns Fickel, Minh Le, Thanh van Nguyen, Ha M. Nguyen, Robert Timmins, Han Ming Gan, Jeffrine J. Rovie-Ryan, Dorina Lenz, Daniel W. Förster, and Andreas Wilting. Phylogeography of red muntjacs reveals three distinct mitochondrial lineages. BMC Evolutionary Biology 17:34. https://doi.org/10.1186/s12862-017-0888-0

Mary E. Blair, Minh D. Le, Hoàng M. Thạch, Anna Panariello, Ngọc B. Vũ, Mark G. Birchete, Gautam Sethi, and Eleanor J. Sterling. 2017. Applying systems thinking to inform studies of wildlife trade in primates. American Journal of Primatology 2017: e22715. https://doi.org/10.1002/ajp.22715

Vinh Quang Luu, Michael Bonkowski, Truong Quang Nguyen, Minh Duc Le, Nicole Schneider, Hanh Thi Ngo, and Thomas Ziegler. 2016. Evolution in karst massifs: Cryptic diversity among bent-toed geckos along the Truong Son Range with descriptions of three new species and one new country record from Laos. Zootaxa 4107(2): 101-140. http://doi.org/10.11646/zootaxa.4107.2.1

Vinh Quang Luu, Truong Quang Nguyen, Minh Duc Le, Michael Bonkowski, and Thomas Ziegler. 2016. A new species of karst-dwelling bent-toed gecko (Squamata: Gekkonidae) from Khammouane Province, central Laos. Zootaxa 4079 (1): 087–102. http://doi.org/10.11646/zootaxa.4079.1.6

Minh Le, Fernando Penaloza, Renata Martins, Thanh V. Nguyen, Ha M. Nguyen, Dang X. Nguyen, Luong D. Nguyen & Andreas Wilting (2016) Complete mitochondrial genomes of the Laotian Rock Rat (*Laonastes aenigmamus*) confirm deep divergence within the species. Mitochondrial DNA Part B 1(1): 479-482. http://dx.doi.org/10.1080/23802359.2016.1186520

VIETNAM, CAMBODIA, AND LAOS - PROJECT 3-100: BUILDING A MEKONG RIVER GENETIC BIODIVERSITY RESEARCH NETWORK

PI: Vu Ngoc Ut, Can Tho University, with Co-PIs Dang Thuy Binh, Nha Trang University; Chheng Phen, Inland Fisheries Research and Development Institute; So Nam, Mekong River Commission; and Latsamy Phounvisouk, Living Aquatic Resources Research Centre

U.S. Partner: Kent Carpenter, Old Dominion University (Funded by the National Science Foundation)

Dates: December 2014 – September 2018

PROJECT OVERVIEW

The Mekong River Basin (MRB) in Southeast Asia has long been known for its rich aquatic biodiversity. Millions of people rely on the products of the river, which includes not only fish but also other aquatic animals and plants for their livelihoods and food security. With globalization and the rapid land use changes in Southeast Asia, a majority of the MRB's biodiversity is under threat. Five partner institutions – The Inland Fisheries Research and Development Institute of Cambodia, the Living Aquatic Resources Research Center of Lao PDR, Ubonrachthani University of Thailand, Nha Trang University (NTU) and Can Tho University from Vietnam — undertook a study on the population genetics of 8 important and representative fish species of the Mekong River and in the process, built a strong biodiversity research network among scientists from Cambodia, Laos, Thailand and Vietnam. An understanding of these genetic relationships will enable targeted protection of general areas in the MRB and ensure that specific habitat requirements are conserved.

Initial results showed that the genetic diversity depended on the main river and its tributaries. In order to maintain the diverse network, fragmentation due to dam projects needs to be mitigated. Furthermore, it was found that the Khone Falls may act as a natural barrier preventing fish from migrating upstream. Further and revised results will be presented after additional sequencing

FINAL SUMMARY OF PROJECT ACTIVITIES

In 2015, the partner institutions selected eight species for collection at a variety of sites across Cambodia, Vietnam and Laos, with sampling taking place across the year. The research team underwent training on sequencing alongside US partners from ODU and Texas A&M. In 2016, sampling sites were revisited and the PEER grantees met to discuss initial findings and data analysis training. Ubonrachthani University joined the partnership and additional sites in Thailand were added. In 2017, researchers attended an international conference on conservation genetics in the MRB, which included participation of Myanmar and Vietnamese government agencies and other regional and international scientists. The team finalized sampling for the last year of the project and sent samples to Texas A&M for final analysis. This last batch included five species sampled from the Mekong Delta and Laos to complete the data set of eight species along the Lower Mekong River.

In June 2018, the research team, other PEER project grantees, and additional researchers attended a final presentation workshop on the results of the study. In particular, they discussed how to strengthen the research network and planned additional work on their selected species: *Pangasius conchophilus, Trichopodus trichopterus, Ompok bimaculatus, P. macronema, P. larnaudii, P. krempfi, Labeo chrysophekadion*, and *Macrognathus siamensis*. Workshop attendees also took a field trip to Kampong Phlouk Fisheries Community, one of the floating villages on Tonle Sap Lake in Cambodia, where they discussed fishing techniques and community fisheries management practiced in the village. As a result of the PEER project findings, the Mekong River Commission expressed strong interest in the study's implications for upstream dam construction. Findings from this PEER Cycle 3 project also served as the basis for a PEER Cycle 6 project (6-435) that involved most of the same partners. Data collected under Cycle 3 was used for publications from the Cycle 6 team as well.

VIETNAM - PROJECT 2-544: EVALUATING THE SUSTAINABILITY OF GROUND WATER RESOURCES: ACADEMIC AND SCIENTIFIC GAPS

PI: Pham T.K. Trang, Hanoi University of Science
U.S. Partner: Benjamin Carlos Bostick and Alexander Van Geen, Columbia University (Funded by the National Science Foundation)
Dates: August 2013 – December 2016

PROJECT OVERVIEW

Arsenic contamination is heterogeneous but widespread in the Red River and Mekong River deltas of Vietnam, where more than 10 million people depend on arsenic-impacted aquifers for drinking and irrigation water. Many of these wells are private tube wells with dangerous levels of arsenic. The Vietnamese researchers conducting this project have been documenting the extent and nature of this contamination for many years in collaboration with scientists from around the world.

Development and urbanization have facilitated the installation of numerous domestic water supplies that draw heavily upon low-arsenic parts of the aquifer. These wells provide safe drinking water but have drastically changed the regional hydrology and are beginning to draw contaminated water into previously uncontaminated areas. The long-term sustainability of these precious water supplies needs to be established. To address this need, the project team sampled these and other groundwater resources regionally around the Hanoi area. The work involved training young scientists and incorporating a comprehensive suite of quality parameters that are indicative of both current and future risks, increasing local capacity to evaluate these resources, and providing the information needed to effectively recommend solutions for the sustainable use of aquifers. Capacity building was carried out through a series of training courses addressing critical knowledge gaps in evaluating water quality, the effects of arsenic in the environment, and potential remediation options.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team first sampled existing wells in the southeast quadrant of Hanoi and regionally, including more rural areas presumably less affected by pumping near Hanoi. They measured the concentration of many chemical constituents in groundwater, as well as the isotopic composition of groundwater, to determine its origin. The results showed groundwater is not derived from surface water in most places in the Hanoi area, providing an indication that pumping is changing the aquifer considerably.

The researchers also documented stark contrasts in groundwater bromide levels on different sides of the Red River, indicating that the river forms an effective boundary to the impacts of Hanoi pumping. They found arsenic levels are higher on the western bank of the Red River than adjacent eastern bank shorelines, suggesting that the arsenic could be redistributed from other aquifers with arsenic already in them or could be “new” in the sense that it could have been released from sediments due to chemical changes induced by pumping.

Based on their regional survey, researchers selected two sites for well drilling to study what is in groundwater at a specific depth. These areas were selected because they were both believed to be older, Pleistocene sediments that appear to behave differently than others. Most Pleistocene aquifers contain oxidized (red) sediments and little or no measurable arsenic in the groundwater. Both sites had aquifer arsenic concentrations considerably higher, in some cases more than 20 times the drinking World Health Organization's water standard of 10 micrograms per liter. By collecting sediment from these two sites, researchers found they had been considerably altered by reacting with groundwater containing arsenic and dissolved organic carbon and suggests the changes induced by groundwater pumping are more extensive than previously recognized.

The project completed its scientific goals of mapping of groundwater composition, documentation of sediment stratigraphy, and evaluation of the sustainability of water resources in the regions studied. Researchers received two additional grants for their work on arsenic in groundwater during the PEER project period, including an approximately $360,000 grant from the European Union, and they disseminated their results through several academic papers and a documentary produced by Vietnam National Television.

The PEER project supported several graduate studies, including a Master's thesis completed as part of the project, and built capacity by training students and staff in field research, x-ray fluorescence (XRF), and data input and management. The U.S. partner Dr. Benjamin Bostick taught a two-week short course on the intersection of biology, chemistry and earth sciences for more than 40 participants at the Hanoi University of Science.

PUBLICATIONS

Athena A. Nghiem, Yating Shen, Mason Stahl, Jing Sun, Ezazul Haque, Beck DeYoung, Khue N. Nguyen, Tran Thi Mai, Pham Thi Kim Trang, Hung Viet Pham, Brian Mailloux, Charles F. Harvey, Alexander van Geen, and Benjamin C. Bostick. 2020. Aquifer-scale observations of iron redox transformations in arsenic-impacted environments to predict future contamination. Environmental Science and Technology Letters 7(12): 916–922 https://dx.doi.org/10.1021/acs.estlett.0c00672

Mason O. Stahl, Charles F. Harvey, Alexander van Geen, Jing Sun, Pham Thi Kim Trang, Vi Mai Lan, Thao Mai Phuong, Pham Hung Viet, and Benjamin C. Bostick. 2016. River bank geomorphology controls groundwater arsenic concentrations in aquifers adjacent to the Red River, Hanoi, Vietnam. Water Resources Research 52: 6321-6334. https://doi.org/10.1002/2016WR018891

VIETNAM - PROJECT 2-496: TECHNICAL DEVELOPMENT AND FIELD-TESTING OF A SELF-CONTAINED, INEXPENSIVE WAVE ENERGY CONVERTER DEVICE

PI: Tho H. Nguyen, Tan Tao University
U.S. Partner: Brian Bingham, University of Hawaii (Funded by the National Science Foundation)
Dates: August 2013 – July 2015

PROJECT OVERVIEW

This project sought to further the technical development of an inexpensive, long-term-field-deployable wave energy converter device (named the SEAWEED for "self-efficient, adaptable wave energy extraction device"). The primary purpose of the SEAWEED is to provide for the basic electrical needs of people living in underdeveloped and remote coastal communities in Vietnam and around the world. Wave energy converter technologies exist around the world today, mostly via large-scale projects requiring high amounts of government and corporate resource commitments and capital investments. This leaves a gap where underdeveloped and remote communities around the world are yet able to benefit from this source of energy. This research project focused on developing the SEAWEED by increasing its mechanical and electrical efficiency through design and testing, reducing the cost of the device through testing various material or component supplementations, exploring potential capability expansion and uses (for example, as an ocean sensor platform), and conducting long-term field testing to explore the feasibility of widespread application.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the final year of his project in 2015, Dr. Nguyen and his team focused on five primary activities: (1) continuation of the technical research with field tests and transition to adoption; (2) community outreach; (3) establishment of a website and community data repository; (4) education, training, and workshops; and (5) policy advocacy. As they continued field testing and refinement of the SEAWEED device, the team continued to experience minor technical issues associated with long-term field deployment, as they had expected. That is, while the prototype works well in short-term testing and in a controlled environment, the device experienced minor issues in long-term deployment tests. Maintenance and design improvements were therefore the primary research and development activity this past year. The team now has two prototype designs of the SEAWEED that are optimized for two types of waves associated with different types of shores—shallow sloped beaches and deep sloped rocky shores. In seeking opportunities for pilot adoption and scale up of the SEAWEED, they were pleased to find interest and initial success with the tourism industry. The device has been adopted at one ocean resort as part of its green energy campaign. The Vietnam Ministry of Science and Technology is also interested in further investigating the SEAWEED as part of its wave energy research track.

Building off the success of their outreach activities in the first year, the group expanded outreach activities and created more opportunities for student engagement in 2015. The SEAWEED project continues to serve as the flagship research activity for Tan Tao University outreach and recruitment, and the SEAWEED PR team regularly travels to local junior high and high schools to present their popular “Infoshare” program. The SEAWEED project also connects with other local and international NGOs in the region on hosting research seminars and getting team members involved in community projects. To promote access to information, the SEAWEED project team created the globalcitizenscientists.org website as a data collection portal and repository. They have subsequently broadened their effort on the database to serve the research community in Vietnam (vietdata.org). The Vietdata project is in collaboration with a network of Vietnamese scholars in the United States (led by UC Davis) to establish a common space for data sharing. This database has been seeded with SEAWEED-related data (e.g., hydrology and weather) and was presented to the Lower Mekong research community and U.S. government agencies in November 2015. The plan is to develop and grow the database to serve as the repository for the research community in the entire Lower Mekong region.

Although this project has ended and the PI Dr. Nguyen is currently based in the United States, the efforts facilitated with PEER support have continued. Dr. Nguyen collaborated with scientists in the United States and Mekong countries to apply for and win an NSF Research Coordination Network (RCN) grant. The RCN program focuses on enabling researchers from multiple disciplines to collaborate to address a grand challenge. For this RCN grant, led by Dr. Michael Ceballos, the researchers aim to coordinate U.S.-Mekong research collaborations to address issues related to Food, Energy, and Water. The grant is entitled “RCN UBE: MIRC Food, Energy, Water, and Ecosystems Resources.” Back in Vietnam, the PEER team’s primary goal for the next few years is to scale up the uses of the SEAWEED. The SEAWEED proof-of-concept was established through revisions and extensive field-testing, and they now have several reliable working prototypes. They aim to find sponsors to replicate these prototypes and deploy them in rural, remote, underdeveloped communities as intended. One promising industry they are targeting is large-scale industrial parks in Vietnam. Initial conversations with relevant representatives provide grounds for hoping that the team will receive support to scale up the SEAWEED. They are also looking to expand application of the SEAWEED internationally. Connections have been established with researchers in Myanmar, and with their support the team hopes to conduct feasibility testing of the SEAWEED on that country’s southern coast.

VIETNAM - PROJECT 2-007: CONSERVATION GENETICS FOR IMPROVED BIODIVERSITY AND RESOURCE MANAGEMENT IN A CHANGING MEKONG DELTA

PI: Dang Thuy Binh, Nha Trang University
U.S. Partner: Kent E. Carpenter, Old Dominion University (Funded by the National Science Foundation)
Dates: August 2013 – June 2018

PROJECT OVERVIEW

This PEER project leveraged and extended an existing National Science Foundation (NSF)-supported investigation into the origins of marine biodiversity in southeast Asia into the estuarine and freshwater biomes of the Mekong Delta. Connectivity of populations across and within the Mekong Delta is shaped by the complex and dynamic physical processes of the Mekong River Basin, with the basin outflow and complex branches potentially serving as a barrier to gene flow of marine populations, similar to what has been observed for the Amazon River. The project examined fine-scale population connectivity of three fish species (marine, estuarine, and freshwater) across the Mekong Delta using advanced genomic methodologies, as the start of a long-term research program to investigate processes that promote lineage diversification across the delta. The project also provided a basis to examine genetic adaptation of populations to the changing conditions caused by damming, development, agriculture, and climate change. One of the species studied is considered Near Threatened on the International Union for Conservation of Nature Red List (IUCN 2012), and the population information gained in this study will be applicable to its conservation and biodiversity conservation in general in the Mekong Delta. The project also provided training to Vietnamese researchers.

FINAL SUMMARY OF PROJECT ACTIVITIES

Based on the results of three species representatives for three habitats in the Mekong Delta (fresh water, brackish water and saltwater), Dr. Binh and her colleagues demonstrated that the species exhibited population homogeneity in the delta and showed a connection to the Tonle Sap in Cambodia. Historical migration data indicated that the species *Polynemus melanochir* can be separated by two rivers (Mekong and Basac River at the Mekong Delta), while *B. micropepis* shows a free migration route. The *P. melenochir* population is also small in effective population size, indicating that they are facing a changing environment at the delta.

The PI and her team also conducted an expanded multi-national sample collection and data analysis campaign in the Sekong Basin, including field work in the Serepok and Sesan Rivers. U.S. partner Dr. Kent Carpenter accompanied them on some of the field work. This sample collection and genetic analysis helped produce policy suggestions regarding the master plan for dams in the 3-S Basin area. Thanks to supplemental support provided by USAID through PEER, Dr. Binh, Dr. Carpenter, Dr. Chris Bird of Texas A&M University, and other colleagues worked together to analyze additional data and submit their recommendations to the Natural Heritage Institute, an international NGO partially funded by USAID to evaluate proposed and existing hydropower projects in Laos and Cambodia that could impact local fisheries.

As part of this PEER project, the researchers developed a functional laboratory for advanced genomics at Nha Trang University and established a Biodiversity and Conservation Research Team. With support from a PEER Evidence to Action supplement, they collaborated with a local TV station to create a video about their work. Multiple graduate and doctorate students contributed to this research, including two who defended their theses during the project. Dr. Binh and her colleagues subsequently received funding in PEER Cycles 3 and 6 to expand the scope of their research.

PUBLICATIONS

Dang Thuy Binh, Le Phan Khanh Hung, Truong Thi Oanh, Luong Thi Tuong Vi. 2015. Preliminary taxonomic review of wrasses species (*Labridae*) from Vietnam with an integration of morphological and molecular data. Journal of Fisheries Science and Technology, Nha Trang University, Special issue: 16 – 22, ISSN 1859 – 2252.

Oanh Truong Thi, Quyen Vu Dang Ha, and Binh Dang Thuy. 2015. Phylogenetic Relationships of Emperors (*Lethrinidae*) and Snappers (*Lutjanidae*) in Vietnam based on Mitochondrial DNA Sequences. Proceedings of the International Conference on Biological, Environment and Food Engineering (BEFE-2015) May 15-16, 2015, Singapore.

Vu Dang Ha Quyen, Thai Thi Lan Phuong, Truong Thi Oanh, Tran Linh Thuoc, and Dang Thuy Binh. 2015. Phylogenetic Relationships of Freshwater Fish in Vietnamese Mekong. Proceedings of the International Conference on Biological, Environment and Food Engineering (BEFE-2015) May 15-16, 2015, Singapore.

Dang Thuy Binh and Doan Vu Thinh. 2015. WebGIS for Reef Fishes Biodiversity at Nha Trang and Cam Ranh Bays in Khanh Hoa Province, Vietnam. Proceedings of the International Conference on Biological, Environment and Food Engineering (BEFE-2015) May 15-16, 2015, Singapore.

Truong Thi Oanh, Doan Vu Thinh, and Dang Thuy Binh. 2015. Distribution and phylogenetic relationships of snappers (*Lutjanidae*) based on mitochondrial DNA sequences. Journal of Fisheries Science and Technology, Nha Trang University, Special issue: 160 – 166, ISSN 1859 – 2252.

Thai Thi Lan Phuong and Dang Thuy Binh. 2015. Goby species diversity in Vietnam based on morphological and genetic characteristics. Journal of Fisheries Science and Technology, Nha Trang University, Special issue: 141 – 148, ISSN 1859 – 2252.

Vũ Đặng Hạ Quyên, Đặng Thúy Bình, Trương Thị Oanh, Thái Thị Lan Phương. 2014. DNA barcoding of freshwater fish in the Mekong Delta. Journal of Science, Can Tho University, Special issue: Aquaculture and Fisheries (1): 123 – 131, ISSN 1859 – 2333.

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Nguyen Thi Anh Thu, Dang Thuy Binh, and Phan Dung. 2014. Researching on venom glands' composition and modeling three-dimensional structure of toxin protein in *Conus tessulatus* [in Vietnamese]. Journal of Science, Can Tho University, Special Issue: Aquaculture and Fisheries, Vol. 1.

Nguyen Thi Anh Thu, Dang Thuy Binh, and Chau Thi My Linh. 2014. A study on genetic structure of giant clam (*Tridacna* spp.) (*Tridacninae*) population in south central and southern Vietnam's coast [in Vietnamese]. Tap Chi Sinh Hoc [Biology Magazine] 2014, 36(1se): 189-194.

A study on population genetic structure of *Sardinella gibbosa* Bleeker, 1849 (*Clupeiformes: Clupeidae*) in the coastal area of Vietnam. 2014. Dang Thuy Binh, Nguyen Thi Bao Chau, and Bui Kim Ly. Tap Chi Sinh Hoc [Biology Magazine] 2014, 36(1se): 180-188.

VIETNAM - PROJECT 1-319: RESEARCH AND CAPACITY BUILDING ON REDD+, LIVELIHOODS, AND VULNERABILITY IN VIETNAM: DEVELOPING TOOLS FOR SOCIAL ANALYSIS OF DEVELOPMENT PLANNING

PI: Le Thi Van Hue, Central Institute for Natural Resources and Environmental Studies of Vietnam National University; with Co-PIs Nguyen Viet Dung, Pannature--Center for People and Nature Reconciliation; and Tran Huu Nghi, Tropenbos International Vietnam

U.S. Partner: Pamela McElwee, Rutgers University (Funded by the National Science Foundation)

Dates: June 2012 – December 2015

PROJECT OVERVIEW

Forecasted global climate changes have the potential to exacerbate existing social vulnerabilities, especially in poorer developing countries, and communities' and individuals' ability to cope with these future changes are often conditioned on their ability to access and mobilize natural resources. At the same time, new global policies would pay countries for "avoided deforestation" through forest conservation efforts known as Reduced Emissions from Degradation and Deforestation (REDD+) to sequester carbon and contribute to climate change mitigation.

However, as access and use rights to forests change under REDD implementation, this may render some households and communities *more* vulnerable to the effects of climate change in the long term if REDD policies reduce their adaptive capacity by restricting access to natural resources. Thus, an understanding of the potential outcomes of carbon-credit policies on land use decision-making is necessary before such large-scale global programs get more fully underway.

This study built upon an early REDD development site in Vietnam and explored several questions regarding this new policy. The PEER-supported project, involving three Vietnamese institutions, expanded an existing project to new field sites and additional data collection on environmental conditions. To promote capacity building with local policymakers and NGOs on key REDD issues, short training courses and national workshops were organized.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers collected basic information and undertook preliminary field research on several field sites, including Kien Giang, Kon Tum, Dien Bien and Hoa Bin. PEER team members met with different groups of stakeholders to inform them about the project activities and explore opportunities for cooperation in the field of climate change and local livelihood research work.

Dr. Hue and her colleagues also collected data for land use maps for research sites, covering 1990 through 2010, relying on satellite and remotely sensed data. Early in the project, the research team took part in a training workshop on research methodologies to help them better understand statistical analysis of survey data and index development techniques. They also hosted a workshop on the development of a Provincial REDD+ Environmental and Social Index (RESI), providing them an opportunity to consult experts, management authorities/agencies, research institutes and NGOs on their opinions of how an index for social and environmental impacts of REDD and what indicators and criteria would be suitable for the provincial level. Nineteen key indicators were identified by the workshop participant and were included in the final field research surveys.

The PEER team organized a two-day training course for local officials at the commune level and rangers of the Bi Doup Nui Ba National Park and Lac Duong district on "Local Livelihoods and Forest Protection in the Context of Climate Change," and an extended training course "Social and Environmental Safeguard: Developing Tools for Monitoring PES/REDD Project for Success." Participants in the latter spent six days learning to design surveys for their research, spent six days in the field in Hoa Binh and then had three months to carry out their own research and write reports under the supervision of CRES research team members.

Finally, the researchers carried out field surveys, focus group discussions, 100 household interviews and key informant interviews. A final workshop introduced the RESI framework, discussed the outcomes of the pilot assessment in Son La, Dien Bien, Kon Tum and Kien Giang provinces and the ability to apply the index in the process of developing and monitoring the Provincial REDD+ Action Plan.

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EUROPE AND EURASIA

ARMENIA

Armenia - Project 9-252: Assessment of geothermal energy resources and natural hazards in Armenia
PI: Khachatur Meliksetian, Institute of Geological Sciences, Armenian National Academy of Sciences
U.S. Partner: Peter La Femina, The Pennsylvania State University (funded by the National Aeronautics and Space Administration)

Armenia- Project 4-230: Sustainable Fisheries for Enhanced Water Resources in Armenia (SFEWRA)
PI: Vardan Urutyan, International Center for Agribusiness Research and Education
U.S. Partner: Stephen Schoenholtz, Virginia Water Resources Research Center (funded by the United States Geological Survey)

Armenia - Project 2-323: Volcanic hazard assessment of Ararat Valley, Armenia
PI: Khachatur Meliksetian, Institute of Geological Sciences, Armenian National Academy of Sciences
U.S. Partner: Charles Connor, University of South Florida (funded by the National Science Foundation)

GEORGIA

Georgia, Armenia, and Azerbaijan - Project 3-161: Active geodynamics of the Caucasus region
PI: Tea Godoladze, Ilia State University, with co-PIs Arkadi Karakhanyan, Institute of Geological Sciences, Armenian Academy of Sciences; and Fakhraddin Abulfat oglu Kadirov, Institute of Geology, Azerbaijan National Academy of Sciences
U.S. Partner: Robert Reilinger, Massachusetts Institute of Technology (funded by the National Science Foundation)

Georgia - Project 1-170: Discovering potential seismic sources in the Caucasus using virtual-reality based data analysis and development of a cyber-enabled geosciences workforce in Georgia
PI: Mikheil Elashvili, Ilia State University
U.S. Partner: Louise Kellogg, University of California, Davis (funded by the National Science Foundation)

KOSOVO

Kosovo - Project 9-176: Phytochemical, biological and toxicological evaluation of hop (Humulus lupulus L.) from populations growing wild in Kosovo
PI: Avni Hajdari, University of Prishtina
U.S. Partner: Cassandra Quave, Emory University (funded by the National Institutes of Health)

SERBIA

Serbia - COV-183: Mitigating effects of COVID-19 on small-scale dairy farmhouse producers through education and training initiatives to improve food safety and their access to online distribution platforms
PI: Nada Smigic, University of Belgrade
U.S. Partner: Jovana Kovacevic, Oregon State University (funded by United States Department of Agriculture/ National Institute of Food and Agriculture)

ARMENIA

ARMENIA - PROJECT 9-252: ASSESSMENT OF GEOTHERMAL ENERGY RESOURCES AND NATURAL HAZARDS IN ARMENIA

PI: Khachatur Meliksetian, Institute of Geological Sciences, Armenian National Academy of Sciences

U.S. Partner: Peter La Femina, The Pennsylvania State University (Funded by the National Aeronautics and Space Administration)

Dates: April 2021 – April 2024

PROJECT OVERVIEW

Armenia is a landlocked country in the South Caucasus region, located between Iran, Georgia, Azerbaijan, and Turkey, with a population of about 3 million. Several active faults and potentially active and active volcanic systems exist in the country, and many earthquakes have been recorded. Past experience in Armenia shows that social stability and economic development are intimately tied to natural hazards; for example, the 1988 Spitak earthquake killed 25,000 people and led to economic collapse. The geology of Armenia is a potential source of hazards, but it also represents potential for geothermal energy and hydropower, an important resource given that much of Armenia's current energy production is from imported fossil and nuclear fuels.

The research team of the Institute of Geological Sciences of the Armenian National Academy of Sciences in Yerevan (IGS ANAS) has experience in studying geology, volcanology, potential hazards, and geothermal energy in Armenia, but they lacked experience and knowledge in quantitative computational models of these processes and the study of geothermal systems linked with volcano-tectonic interactions. Overall, this PEER project was designed to provide a pathway to better tie years of geological research to hazard assessments and exploration of the geothermal energy potential of Armenia. The team sought to develop recommendations for the Government of the Republic of Armenia regarding further exploration and use of geothermal energy resources, as well as for local policymakers regarding natural hazards and volcano monitoring.

FINAL SUMMARY OF PROJECT ACTIVITIES

Over its three-year term, the project focused on assessing Armenia's geothermal energy potential, including the development of a voluminous project database integrating geological, geophysical, volcanological, tectonic, seismic, satellite, and geochemical data. The researchers collected satellite data from NASA and the European Space Agency—particularly infrared and gravity satellite data with focus on geothermal energy resources—for further analysis of geothermal anomalies.

The team's field work included volcano-tectonic mapping, sampling for geochemistry and 40Ar-39Ar dating, CO_2 surveys, and processing of seismic data aiming to develop ambient noise tomography in areas with potential for large scale geothermal power. They installed three new seismic stations in the Gegham volcanic ridge to study seismic swarms and geothermal activity of the area.

The team identified four new potential geothermal sites—Arpa-Sevan, Spitaksar, Hankavan, and Ashock—for further large-scale investigations that may lead to exploration drilling. They also developed policy recommendations in collaboration with government officials to guide Armenia's growth in renewable energy and built academic collaborations with universities in the United States and the United Kingdom, as well as local institutions like the American University of Armenia. The PEER team organized a webinar on geothermal energy potential in the South Caucasus and presented their project at two national conferences, one that they organized at the Institute of Geological Sciences of the Armenian National Academy of Sciences and the other convened by the Young Scientists Union of Armenia. In addition, they presented three papers at the 2023 General Assembly of the European Geosciences Union.

PUBLICATIONS

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Edmond Grigoryan, Khachatur Meliksetian, Hripsime Gevorgyan, Ivan Savov, Gevorg Navasardyan, Marina Bangoyan, and Tatevik Boyakhchyan. 2023. Tephrochronology and geochemical correlation of Middle Pleistocene distal tephra deposits in Armenia. Abstract for the European Geosciences Union General Assembly 2023, EGU23-15716. https://doi.org/10.5194/egusphere-egu23-15716

ARMENIA- PROJECT 4-230: SUSTAINABLE FISHERIES FOR ENHANCED WATER RESOURCES IN ARMENIA (SFEWRA)

Pi: Vardan Urutyan, International Center for Agribusiness Research and Education
U.S. Partner: Stephen Schoenholtz, Virginia Water Resources Research Center
(Funded by the United States Geological Survey)
Dates: October 2015 – June 2019

PROJECT OVERVIEW

This project addressed the issues of depleting artesian water resources in the Ararat Valley. An increasing numbers of fish farms in the valley have substantially decreased the level of artesian water in the area. Although profitable in current market conditions, these fish farms operate primarily using inefficient water technologies. The first step in the project was to analyze targeted fish farms in the Ararat Valley to determine the current production models being used and recommend appropriate best practices for water-efficient aquaculture. The researchers also studied the potential for improving discharge water distribution efficiency and discharge water quality for targeted fish farms to agricultural plots in the Ararat Valley. After analyzing the current regulatory framework, the team produced recommendations for improved policy for water usage in fish farm production systems and for better management of discharge water. Throughout the process, they engaged key stakeholders to ensure their input was included in the study and to inform them of recommended policies and actions.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which began in October 2015 and received a PEER Evidence to Action supplement in August 2017, was concluded as of June 30, 2019. However, the recipient organization used its own funds to organize an official opening event on October 7 at the fish farm that benefited from a new semi-closed Recirculation Aquaculture System, installed thanks to PEER. USAID Armenia Mission Director Deborah Grieser, Armenian government officials, representatives from the education sector, members of international and local organizations, and the project beneficiaries were present. During the opening event, SFEWRA project manager Lusine Tadevosyan described how the upgraded system works and how water is reused several times. The new system not only conserves water but also ensures that the water ultimately released is cleaner than that coming from conventional systems.

The main development impacts of the project center around its contribution to sustainable water use practices by Ararat Valley fish farms through the introduction of water-efficient farming models, such as closed or semi-closed recirculation systems, which ensure the restriction of water exchange and increase in stocking density. The project was also notable for its success in building partnerships within the sector through networking with several stakeholders, such as NGOs, government institutions, and two relevant projects directly funded by USAID—Participatory Utilization and Resource Efficiency of Water (PURE-Water) and Advanced Science and Partnerships for Integrated Resource Development (ASPIRED).

The following specific results were achieved during implementation of the project:

- Fifteen water-efficient and environmentally friendly business and operations models were developed for the fifteen beneficiary fish farms involved in the project. The proposed models include a technical description of water-efficient fish farm models, including description of the Recirculating Aquaculture System (RAS) model; Nitrogen management in RAS; calculation of Ammonia, Nitrate, and Nitrite optimal levels in the proposed system; proposed volume of water supply; the number of stocks to be kept under the model; necessary financial investments and cost-benefit analysis, etc.

• Thanks to the PEER Evidence to Action supplement, one beneficiary fish farm was upgraded from its existing production model into the intensive, water-efficient model. As a result, the fish farm uses 10 l/s groundwater (instead of 30 l/s water, as 20 L/s water is cleaned in mechanical and biofiltration units and recirculated back into the system). It now produces approximately 10 tons of fish annually. As a result of the upgrade, the fish farm re-uses the water four times over, increasing water efficiency greatly. In addition, the aquaponics system installed on the farm allows the farmer to generate additional revenue by producing and selling greens.

• Project team members participated in eight international and local conferences to present their research papers and results and made one study visit to the United States.

• Five manuscripts were developed, of which one was published in *Groundwater for Sustainable Development*, two in the *Bulletin of Armenian National Agrarian University*, one (in Armenian) in the *Bulletin of National University of Architecture and Construction of Armenia*, and one submitted and pending publication at the journal *Aquaculture*.

• Four public outreach and dissemination events were organized.

• Recommendations were developed and presented to the Ministry of Economy (Agriculture Department), and several technical presentations were made to the Ministry of Agriculture, USAID Mission, PURE-Water project staff, and other stakeholders.

PUBLICATION

Natella Mirzoyan, Narek Avetisyan, Hovhannes Mnatsakanyan, and Lusine Tadevosyan.
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ARMENIA - PROJECT 2-323: VOLCANIC HAZARD ASSESSMENT OF ARARAT VALLEY, ARMENIA

PI: Khachatur Meliksetian, Institute of Geological Sciences, Armenian National Academy of Sciences
U.S. Partner: Charles Connor, University of South Florida (Funded by the National Science Foundation)
Dates: September 2013 – August 2016

PROJECT OVERVIEW

Armenia is situated in a region of copious Quaternary-Holocene-Historical volcanism, and its capital, Yerevan, is located in the Ararat Valley, adjacent to the foothills of the Gegham upland and the Aragats and Ararat volcanoes. Geologic evidence indicates the possibility of future volcanic eruptions from one or more of these volcanic systems. When such eruptions occur, Yerevan and surrounding areas will be at significant risk from a variety of volcanic phenomena and accompanying seismic activity, yet prior to this project, there had been no analyses of this risk.

This project aimed to undertake systematic geological and probabilistic studies to link geologic observations of the products of volcanic eruptions (volcanic ash deposits, lava flows, and pyroclastic density currents) with numerical simulations of volcanic eruptions. Previously work by the PEER team has shown magmas in this region erupt at higher temperature and with fewer volatiles than elsewhere on Earth, due to the plate tectonic setting. These differences must be accounted for in hazard models. The team aimed to develop a robust hazard assessment for the Ararat Valley, including Yerevan, and to improve all natural hazard assessment in Armenia, and make Armenia a regional locus for this type of natural hazard assessment.

One of the major tasks for this project was to incorporate research into Armenian volcanism into an NSF-funded project on cyberinfrastructure, sharing the U.S. partner’s volcanic hazard modeling codes with the Armenian team and training their personnel, including young scientists, to use and apply the codes for assessing volcanic hazards in Armenia. VHub research tools were used to simulate specific phenomena, such as volcanic ash fallout and lava flows, used to estimate the probability that such phenomena would affect the Ararat Valley.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Meliksetian and his colleagues developed a volcano database of the region, including geologic data on the extent, timing, and nature of past volcanic activity in the region. The team added in new data to the database from field work, field mapping of volcanic centers, tephra fallout deposits, ignimbrite units, and lava flows, including data on their thickness, volume estimate, extent, viscosity, and argon-argon dating. The researchers developed a conceptual model of volcanism in the site region, based on state-of the-art geochemical and petrologic studies, new geochemical data, as well as information about the tectonic setting and geologic history. They also undertook detailed analyses of the recurrence rate and potential magnitude of each volcanic phenomena, including tephra fallout and lava flows, that may impact the infrastructure of the region of the Ararat valley.

From these analyses, the PEER team developed recommendations for Armenian policymakers concerning volcanic hazards in the region. These recommendations included public education and outreach based on project results, enhanced volcano monitoring, including the need for international collaborative efforts to monitor the Ararat volcano system, and development of guidelines for emergency response to volcano crises.

Team members made four visits to the United States to receive training and collaborate with U.S. partner Dr. Charles Connor during the PEER project period, and one team member, Davit Manucharyan, was subsequently accepted into a PhD program at the University of South Florida under Dr. Connor's supervision, graduating in 2019.

The researchers presented their findings in peer-reviewed papers, in technical presentations at international scientific conferences, including at the European Geosciences Union General Assembly, and at the invitation of International Atomic Energy Agency (IAEA) for a workshop in Manila to discuss hazards for nuclear installations. The team received an additional $26,000 USD grant from the State Committee of Science of the Republic of Armenia to continue their work. In 2021, Dr. Meliksetian was awarded a new PEER grant under the program's Cycle 9 to assess geothermal energy resources and natural hazards in Armenia.

PUBLICATIONS

Hripsime Gevorgyan, Christoph Breitkreuz, Khachatur Meliksetian, Arsen Israyelyan, Yura Ghukasyan, Jörg A. Pfänder, Blanka Sperner, Daniel P. Miggins, and Anthony Koppers. 2020. Quaternary ring plain- and valley-confined pyroclastic deposits of Aragats stratovolcano (Lesser Caucasus): Lithofacies, geochronology and eruption history. Journal of Volcanology and Geothermal Research 401: 106928. https://doi.org/10.1016/j.jvolgeores.2020.106928

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Hripsime Gevorgyan, Alexander Repstock, Bernhard Schulz, Khachatur Meliksetian, Christoph Breitkreuz, and Arsen Israyelyan. 2018. Decoding a post-collisional multistage magma system: The Quaternary ignimbrites of Aragats stratovolcano, western Armenia. Lithos 318–319: 267-282. https://doi.org/10.1016/j.lithos.2018.07.024

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Ivan Savov, Khachatur Meliksetian, Charles Connor, Arkadi Karakhanian, Patrick Sugden, Gevorg Navasardyan, Ralf Halama, Osamu Ishizuka, Laura Connor, and Sergei Karapetian. 2016. Evolution of Pleistocene to Holocene eruptions in the Lesser Caucasus Mts: Insights from geology, petrology, geochemistry and geochronology. Geophysical Research Abstracts 18, EGU2016-6377.

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I. Neill, Kh. Meliksetian, M.B. Allen, G. Navasardyan, and K. Kuiper. 2015. Petrogenesis of Mafic Collision Zone Magmatism: The Armenian Sector of the Turkish-Iranian Plateau. Chemical Geology 403: 24-41. https://doi.org/10.1016/j.chemgeo.2015.03.013

Hetu Sheth, Khachatur Meliksetian, Hripsime Gevorgyan, Arsen Israyelyan, and Gevorg Navasardyan. 2015. Intracanyon Basalt Lavas of the Debed River (Northern Armenia), Part of a Pliocene–Pleistocene Continental Flood Basalt Province in the South Caucasus. Journal of Volcanology and Geothermal Research 295: 1-15. https://doi.org/10.1016/j.jvolgeores.2015.02.010

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Ivan Savov, Khachatur Meliksetian, Ralf Halama, Gevorg Navasardian, Chuck Connor, Massimo D'Antonio, Samuele Agostini, Osamu Ishizuka, Sergei Karapetian, and Arkadi Karakhanian. 2014. Collision zone magmatism aids continental crustal growth. Geophysical Research Abstracts 16, EGU2014-2235.

GEORGIA

GEORGIA, ARMENIA, AND AZERBAIJAN - PROJECT 3-161: ACTIVE GEODYNAMICS OF THE CAUCASUS REGION

PI: Tea Godoladze, Ilia State University, with Co-PIs Arkadi Karakhanyan, Institute of Geological Sciences, Armenian Academy of Sciences; and Fakhraddin Abulfat Oglu Kadirov, Institute of Geology, Azerbaijan National Academy of Sciences
U.S. Partner: Robert Reilinger, Massachusetts Institute of Technology (Funded by the National Science Foundation)
Dates: November 2014 – May 2017

PROJECT OVERVIEW

Continental collisions have particular societal importance, as historically the most destructive earthquakes in terms of the loss of life and property have occurred along continental collision zones and the associated zones of deformation in the Earth's outer shell. Only two active continent-continent collisions occur today: India-Eurasia and Arabia-Eurasia (AR-EU). The Greater Caucasus represents the northern extent of the deformation between the Arabian and Eurasian plates.

The project sought to clarify understanding of dynamics of continental deformation in order to estimate and mitigate earthquake hazards in this rapidly developing region. During the PEER grant, the researchers used available GPS data and installed additional permanent GPS stations in Georgia and Armenia, significantly improving monitoring of the region. Almost all of Georgia is now covered by the GPS point grid, providing a valuable dataset for further research.

The PIs used GPS observations from this project to publish findings on the Lesser–Greater Caucasus collision area and suggested a reevaluation of seismic hazards in the area around Tbilisi.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project team further developed the Global Navigation Satellite System in Georgia, installing 7 new permanent GPS stations and 51 new benchmarks, covering almost all the central part of the Caucasus region**.** The GPS data will help characterize active faults of the region and serve as an input for Georgia's national seismic hazard maps.

The PI was also part of teams awarded three new related grants, more than $300,000 USD in total, from the U.S. Department of Energy, the U.S. National Science Foundation and the Georgian Science Foundation. The grants involve further research on seismic hazard assessment in the Caucasus and Rapid Moment Tensor solutions.

The project also included cross-regional collaboration with the Institute of Geology of Armenia, the Institute of Geology of Azerbaijan, and the Institute of Earth Sciences at Ilia State University of Georgia, along with U.S. partner institution MIT to conduct geodetic monitoring and enhance researchers' capabilities in data analysis, modeling, and interpretation.

In addition to ongoing research grants, the PEER team developed a productive collaboration with Kandili Observatory in Turkey and expects to conduct a joint field survey with them in the future. The team conducted a workshop to discuss their results, hosting scientists and students from Armenia, Azerbaijan, Georgia, Turkey, Taiwan, and Russia, and a member of the project team presented a poster at AGU's Fall meeting in 2016.

In November 2017, co-PI Arkady Karakhanyan passed away unexpectedly. He was succeeded as director of the Institute of Geology by his colleague, PEER PI Khachatur Meliksetian.

PUBLICATION

Sokhadze, G., M. Floyd, T. Godoladze, R. King, E. S. Cowgill, Z. Javakhishvili, G. Hahubia, and R. Reilinger. 2018. Active convergence between the Lesser and Greater Caucasus in Georgia: Constraints on the tectonic evolution of the Lesser–Greater Caucasus continental collision. Earth and Planetary Science Letters 481: 154-161. https://doi.org/10.1016/j.epsl.2017.10.007

GEORGIA - PROJECT 1-170: DISCOVERING POTENTIAL SEISMIC SOURCES IN THE CAUCASUS USING VIRTUAL-REALITY BASED DATA ANALYSIS AND DEVELOPMENT OF A CYBER-ENABLED GEOSCIENCES WORKFORCE IN GEORGIA

PI: Mikheil Elashvili, Ilia State University
U.S. Partner: Louise Kellogg, University of California, Davis (Funded by the National Science Foundation)
Dates: June 2012 – May 2017

PROJECT OVERVIEW

In much of the developing world, including Georgia, active faults with the potential to produce devastating earthquakes have yet to be identified, as illustrated by the frequent occurrence of such events on previously unidentified faults. Discovering and characterizing these potential seismic sources is an essential first step towards increasing disaster resilience.

In particular, planning for and managing the impact of earthquake disasters requires knowing the location and three-dimensional (3D) geometry of active faults that may rupture to produce an earthquake, as well as the type, magnitude, and frequency of ruptures they are likely to produce. This project aimed to increase disaster resilience and thus promote sustainable development in Georgia by discovering potential seismic sources in the Caucasus through the use of new virtual reality (VR)-based methods of data analysis. In particular, these researchers used the new virtual-globe application *Crusta* to map active faults and folds based on their distinctive expression in the landscape. Using the application *Visualizer,* they also aimed to determine the subsurface geometry of potential seismic sources. The PEER project team subsequently tested their VR-based observations by conducting pilot field studies of active faults near the capital city of Tbilisi to determine fault geometries and slip directions, as well as preliminary slip rates and earthquake histories.

This project sought to improve the skills of Georgian researchers and students through mentor-based education and research in collaboration with their U.S. partners.

FINAL SUMMARY OF PROJECT ACTIVITIES

Faculty and students at Ilia State University (ISU) learned how to use the VR-based software tools by receiving training at KeckCAVES (the W.M. Keck Center for Active Visualization in the Earth Sciences) at the University of California, Davis. ISU has also incorporated advanced visualization tools in their undergraduate and graduate courses. A differential GPS system and Quad-copter drone for aerial visualization were introduced as practical tools in several courses and are widely used by students at different levels.

The PEER team continued an investigation of active faults through field work at the fault scarp near the Tbilisi-Gori highway, between the villages of Okami and Igoeti. This previously unknown fault was discovered by the project team in an area with terrain that is less folded and unseparated, thus outcrops in the region are very rare. In addition, researchers identified a thrust fault in middle of a trench that cut through all soil layers, except the first.

The team also made progress towards constructing 3D models of the Bronze Age settlement Tells in the Kolkheti lowland, an area that shows traces of having undergone dramatic changes in the environment during the past millennia. Researchers were able to use drone-mounted photography to create a digital elevation model, using six Ground Control Points to achieve a high degree of precision.

In the Shiraki plain, the team was able to reconstruct the paleoenvironment of the area and identify traces of natural catastrophes and their effect on the early formations in the Southern Caucasus.

The researchers presented some of their work at the 2016 American Geophysical Union Fall Meeting**.** The PEER team developed new collaborations with researchers and students at Bridgewater State University in Massachusetts, including submission of a joint proposal for a National Science Foundation International Research Experiences for Students (IRES) project. The team also made contact with ATel LLC, a company that specializes in development of advanced tools for e-learning.

PUBLICATIONS

G. Sokhadze, M. Floyd, T. Godoladze, R. King, E.S. Cowgill, Z. Javakhishvili, G. Hahubia, and R. Reilinger. 2018. Active convergence between the Lesser and Greater Caucasus in Georgia: Constraints on the tectonic evolution of the Lesser–Greater Caucasus continental collision. Earth and Planetary Science Letters 481: 154-161. https://doi.org/10.1016/j.epsl.2017.10.007

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KOSOVO

KOSOVO - PROJECT 9-176: PHYTOCHEMICAL, BIOLOGICAL AND TOXICOLOGICAL EVALUATION OF HOP (*HUMULUS LUPULUS L.*) FROM POPULATIONS GROWING WILD IN KOSOVO

PI: Avni Hajdari, University of Prishtina

U.S. Partner: Cassandra Quave, Emory University (Funded by the National Institutes of Health)

Dates: April 2021 – October 2023

PROJECT OVERVIEW

Hop is an economically important plant species used in both the pharmaceutical and food industries. Hop raw material usually is provided from cultivars derived from hybridization, a process that decreases genetic variability. While the raw material from wild populations is not used by industry due to its high variability in chemical composition, wild hop germplasm and genetic diversity from under-utilized origins can serve as new reservoirs of genetic material useful for improving crop production. Wild hops have the potential to reveal unique sources of novel bioactive compounds.

This PEER project investigated the genetic and chemical potential of wild hops by applying phytochemistry and molecular biology techniques in assessing the biological activities and toxicological effects of the hop. The team assessed genetic diversity and chemical variability of wild hop specimens that can serve in the future as a new gene pool for improvement of hop cultivars, as well as a potential source of novel chemical entities for future food and drug development. The project team sought to break down barriers between fieldwork and lab work, as well as between disciplines, by integrating tools from multiple disciplines and fostering sustainable uses of natural resources.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers undertook an intensive literature search to identify potential hop populations in Kosovo and compiled a list of possible sites for hop collection. The PEER team's fieldwork resulted in the collection of plant material from 21 selected populations and provided training for five graduate and doctoral students.

The PEER team also participated in a training workshop for DNA analysis and established a methodology for studying the genetic population of hop using STR markers. The graduate and doctoral student researchers undertook a variety of analyses of the hop samples, including hop DNA extraction and DNA fragment analysis; chemical analysis of the constituents of hop essential oil; analysis of volatile organic compounds (VOCs); experiments in extracting VOCs; evaluation of non-VOCs compounds among wild hop populations; antioxidant activity testing; and assessment of the cytotoxic and genotoxic properties of water-based and crude hop extracts using the Allium test model.

The PhD and Master's students in the PEER team undertook much of this analysis as part of their thesis work, and these young researchers subsequently presented their findings in technical presentations at five conferences.

In addition to the planned activities within the scope of this project, the PEER team conducted an ethnobotany expedition in the Has region, situated along the border between Albania and Kosovo. The team successfully collected understudied medicinal plants for scientific analysis and documented traditional food and health practices to inform future laboratory research. Moreover, the team investigated the medicinal plant trade, changes in plant usage and collection, and their material culture, with a particular focus on rye used in roofing and for nutritional purposes. The results of this field visit were presented at the American Association of Geographers 2023 Annual Meeting.

In terms of outreach and collaboration, in addition to strengthening collaboration with Emory University and the University of Gastronomic Sciences, the project activities facilitated new partnerships with Florida Atlantic University. The team also conducted online consultations with the USAID office in Prishtina to identify beneficiaries focused on medicinal and aromatic plants within the Agriculture for Growth and Rural Opportunities program. The goal was to establish new cooperation and synergize USAID activities in Kosovo. To further enhance collaboration with local companies working with medicinal and aromatic plants, the team organized a meeting with NGOs to discuss the potential services the lab could provide for local companies and explored possibilities for cultivating hops. The researchers shared their new methods and results with a local brewery and met representatives of NGOs, aiming to link scientific research with economic development. In addition, to ensure the long-term impact of the project, they incorporated the field guidelines for plant collection, laboratory protocols, standard operating procedures, and methodologies for chemical, molecular, and toxicological analyses into course curricula at the University of Prishtina.

PUBLICATIONS

Avni Hajdari, Kujtesa Gashi, Blerta Salihu, Sunmin Woo, Behxhet Mustafa, Albiona Spahiu, Bledar Pulaj, Cassandra L. Quave. 2023 Assessment of phytochemical composition and antioxidant activity variability in wild populations of *Humulus lupulus* L. in Kosovo. Preprint available at SSRN. http://dx.doi.org/10.2139/ssrn.4589167.

Sarah Shabih, Avni Hajdari, Behxhet Mustafa, and Cassandra L. Quave. 2022. Medicinal plants in the Balkans with antimicrobial properties. Chapter 3 in Medicinal Plants as Anti-Infectives, Academic Press, pp. 103-138, ISBN 9780323909990. Editor: François Chassagne. https://doi.org/10.1016/B978-0-323-90999-0.00013-6.

Blerta Salihu, Bexhet Mustafa, Bledar Pulaj, and Avni Hajdari. 2022. Chemical composition of the essential oil of hops (*Humulus lupulus* L.) growing wild in Kosovo. Macedonian Pharmaceutical Bulletin 68 (Supplement 2): 67 – 68. https://doi.org/10.33320/maced.pharm.bull.2022.68.04.028

SERBIA

SERBIA - COV-183: MITIGATING EFFECTS OF COVID-19 ON SMALL-SCALE DAIRY FARMHOUSE PRODUCERS THROUGH EDUCATION AND TRAINING INITIATIVES TO IMPROVE FOOD SAFETY AND THEIR ACCESS TO ONLINE DISTRIBUTION PLATFORMS

PI: Nada Smigic, University of Belgrade

U.S. Partner: Jovana Kovacevic, Oregon State University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Dates: November 2022 – April 2024

PROJECT OVERVIEW

Small-scale dairy producers (SSDPs) in Serbia were disproportionately affected by the COVID-19 pandemic. Due to the lockdowns and inability to sell their products through typical distribution channels, such as open markets and restaurants, these communities have struggled to make sales and stay in business. During the pandemic, Serbia witnessed the emergence of new online food distribution channels, increasingly accepted by consumers, mainly due to their convenience. While larger, well-established businesses have pivoted to new markets, SSDPs face significant challenges in adapting and meeting the standards required for online sales.

The goal of this project was to support Serbian SSDPs' longevity and resilience by helping them produce foods of high quality and safety during the COVID-19 pandemic, as well as enabling them to expand their distribution channels to online platforms. The project was conducted in two phases, focused on research and training. During the research phase, the team identified challenges faced by SSDPs throughout the production and distribution stages and investigated the quality and safety of dairy products produced by SSDPs through microbiological and physico-chemical analyses to assess their suitability for online sales. The training phase was aimed at improving SSDP's knowledge and compliance readiness with region-specific and customized training tailored to SSDPs, including basic quality and food safety preventive controls and key requirements for online product sales.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers interviewed representatives of online platforms and conducted questionnaires with 58 SSDPs. They sampled 302 dairy products to analyze their microbiological quality and test for the presence of *l. monocytogenes* and indicator microorganisms. The platforms emphasized the need for SSDPs to acquire tools and resources to ensure compliance with food safety and quality standards and highlighted the critical need for cold chain transport solutions to ensure consistent product quality. By identifying the differences between the SSDP clusters, researchers could tailor the training program to the specific characteristics and knowledge gaps within each group.

From these findings, the PEER team created a 20-page brochure of practical information, aligned with the identified knowledge gaps, that would directly benefit small dairy processors, such as farm registration, hygiene standards, food labeling, cheese production, quality control, online customer requirements, and food transport. Printed copies were distributed to SSDPs during in-person training sessions. The researchers also developed social media profiles on Facebook and Instagram to engage stakeholders.

The curriculum material was carefully developed and included a mixture of lectures, case studies, and practical examples, complemented by demonstrations of various rapid tests to assess hygiene and quality in dairy products and refined based on feedback from the U.S. partner. The PEER team held In-person training sessions with a total of 43 SSDPs across four events. It was a great challenge to attract female dairy producers, as only 58% of the participants were women, although the proportion should be 70%. This discrepancy highlights the prevailing gender inequalities in rural Serbia, where women are often confined to traditional roles, hindering their educational endeavors.

The participants completed a pre-test and a post-test following the in-person training sessions, as well as anonymous questionnaires. The most common feedback emphasized a desire for further training opportunities in the future, indicating participants' confidence and eagerness to continue their education. Belgrade and Niš performed exceptionally well with post-tests of over 80%, possibly due to a higher proportion of highly educated participants. Conversely, participants from Zaječar performed worse on both tests, but showed a significantly higher average knowledge increase, emphasizing the importance of targeting efforts at specific population groups, such as women with low levels of education. After the face-to-face training sessions, a significant proportion (≈20%) of participants were in constant contact with members of the project team. They sought advice on various topics such as infrastructure improvements, technological advances, standardization of production processes, transportation of dairy products, and the importance of maintaining a cold chain.

The PI and team received two grants, worth a total of $495,000, for new research. They presented their findings at the 2nd International Symposium of Biotechnology, International Dairy Expert's Symposium, Black Sea Association of Food Science and Technology Congress, and the International Association for Food Protection. The PEER team also developed an eLearning training on the Moodle platform, which includes 12 comprehensive lessons and covers a variety of topics that are crucial for milk production and dairy product distribution. The training material is presented in Serbian to meet the language needs of the target group in the region. This e-learning training will last beyond the funding period of the project and serve as an invaluable educational resource.

PUBLICATIONS

Z. Miloradovic, J. Kovacevic, J. Miocionovic, I. Djekic, N. Kljajevic, and N. Smigic. 2024. E-commerce readiness and training needs of small-scale dairy processors in Serbia: Understanding barriers and knowledge gaps. Heliyon 10(6): e27442. https://doi.org/10.1016/j.heliyon.2024.e27442

B. Aleksic, B. Udovicki, J. Kovacevic, Z. Miloradovic, I. Djekic, J. Miocinovic, N. Tomic, and N. Smigic. 2024. Microbiological assessment of dairy products produced by small-scale dairy producers in Serbia. Foods 13(10): 1456. https://doi.org/10.3390/foods13101456

Z. Miloradovic, J. Kovacevic, J. Miocinovic, I. Djekic, and N. Smigic. 2024. Empowering small-scale dairy processors: a comprehensive analysis of training impact and participant feedback. Proceedings of the 2nd International Symposium on Biotechnology: 329-335. http://dx.doi.org/10-46793-sbt29-43

LATIN AMERICA

BOLIVIA

Bolivia - Project 1-358: The fateof enteric pathogens in fluids, fields, and food products: on-farm solutions for the safe reclamation of water and nutrients from sewage
PI: Maria de la Mercedes Iriarte Puña, Centro de Aguas y Saneamiento Ambiental, Universidad Mayor de San Simon
U.S. Partner: James Mihelcic, University of South Florida (funded by the National Science Foundation)

BRAZIL

Brazil - COV-177: Fishing for a "new normal": potential effects of the COVID-19 pandemics on vulnerable fishing communities in the Brazilian Amazon
PI: Renato Silvano, Universidade Federal do Rio Grande do Sul
U.S. Partner: Henry Huntington, Huntington Consulting (funded by National Science Foundation)

Brazil - Project 9-326: Biodiversity correlates of sustainable value chain expansion in the Brazilian Amazon: Developing combined environmental DNA (eDNA) and camera trapping protocols to assess vertebrate diversity in managed Brazil nut forests
PI: Pedro Galetti, Federal University of São Carlo ((original PI Ludmilla Aguiar), with co-PI José Luiz de Andrade Franco, University of Brasilia/Foundation for Scientific and Technological Enterprises U.S. Partner: Kirsten Silvius, Virginia Polytechnic Institute and State University (funded by the United States Department of Agriculture/ Forest Service)

Brazil - Project 5-589: Integrating dimensions of microbial biodiversity across wetlands and land use types to understand methane greenhouse gas cycling in tropical forests
PI: Jose Mauro Moura, Universidade Federal do Oeste do Pará
U.S. Partner: Jorge Rodrigues, University of California Davis (funded by the National Science Foundation)

Brazil - Project 5-9: History and diversification of floodplain forest bird communities in Amazonia: towards an integrated conservation plan
PI: Camila Ribas, Instituto Nacional de Pesquisas da Amazônia, Ministry of Science, Technology and Innovation
U.S. Partner: Joel Cracraft, American Museum of Natural History (funded by the National Science Foundation)

Brazil - Project 4-478: Mapping and conserving butterfly biodiversity in the Brazilian Amazon
PI: Andre Freitas, Universidade Estadual de Campinas
U.S. Partner: Keith Willmott, University of Florida (funded by the National Science Foundation)

Brazil - Project 4-461: Capacity building for participatorymonitoring of changing forests in sustainable use areas of the Southwestern Brazilian Amazon
PI: Sabina Ribeiro, Universidade Federal do Acre
U.S. Partner: Stephen Perz, University of Florida (funded by the National Science Foundation)

Brazil - Project 4-445: Functional diversity of interrelated photosynthesis and water use of Central Amazonian trees
PI: Tomas Domingues, University of Sao Paulo
U.S. Partner: Pierre Gentine, Columbia University (funded by the National Aeronautics and Space Agency)

Brazil - Project 4-299: Monitoring the disturbance of microbiota in Amazonian soils during the conversion of forest to pasture and its consequences on cattle health
PI: Ederson Jesus, Embrapa (Brazilian Corporation of Agricultural Research)
U.S. Partner: James Cole, Michigan State University (funded by the National Science Foundation)

Brazil - Project 4-209: Lidar remote sensing of Brazilian Amazon forests: analysis of forest biomass, forest degradation, and secondary regrowth

PI: Jean Ometto, Instituto Nacional de Pesquisas Espaciais
U.S. Partner: Michael Keller, USDA-Forest Service (funded by the National Aeronautics and Space Agency)

Brazil - Project 4-123: Where is my turtle? Quantifying biodiversity impacts of hydroelectric expansion and river use changes in the Brazilian Amazon

PI: Darren Norris, Federal University of Amapá
U.S. Partner: James Gibbs, SUNY College of Environmental Science and Forestry (funded by the National Aeronautics and Space Agency)

Brazil - Project 4-82: Linking sustainability of small-scale fisheries, fishers' knowledge, conservation, and co-management of biodiversity in large rivers of the Brazilian Amazon

PI: Renato Silvano, Federal University of Rio Grande do Sul
U.S. Partner: Kirk Winemiller, Texas A&M University (funded by the National Science Foundation)

Brazil - Project 3-198: Biodiversity And Socioeconomic Impacts Of Palm Oil Bioenergy Development In The Brazilian Amazon

PI: Rodrigo Medeiros, Conservation International do Brasil, with co-PI Luciano Montag, Universidade Federal do Pará
U.S. Partner: Kathleen E. Halvorsen, Michigan Technological University (funded by the National Science Foundation)

Brazil - Project 3-188: Biodiversity conservation and scientific capacity development in the Brazilian Amazon using ants as bioindicators and ecosystem health indicators

PI: Rodrigo Feitosa, Universidade Federal do Paraná
U.S. Partner: Kenneth G. Ross, University of Georgia, Athens (funded by the National Science Foundation)

Brazil - Project 3-121: Biodiversity and climate change in the "Arc of Deforestation" of Brazilian Amazon

PI: Guarino Colli, Universidade de Brasília, with co-PIs Ben Hur Marimon Junior, Universidade do Estado do Mato Grosso, and Fernanda Werneck, Instituto Nacional de Pesquisas da Amazônia–INPA
U.S. Partner: Barry Raymond Sinervo, University of California, Santa Cruz (funded by the National Science Foundation)

Brazil - Project 2-515: Epiphyllic communities on leaves at tropical forests: causes and consequences for leaf functioning at different scales

PI: Bruno Henrique Pimentel Rosado, Centro de Gestão de Pesquisa, Desenvolvimento e Inovação – CGPDI
U.S. Partner: Scott Saleska, University of Arizona (funded by the National Science Foundation)

Brazil - Project 2-503: Mycota associated to native *Hevea spp.* in the Brazilian Amazon region

PI: Aristóteles Góes-Neto, Centro de Excelência em Bioinformática, Fundação Oswaldo Cruz (Fiocruz)
U.S. Partner: Priscila Chaverri, University of Maryland (funded by the National Science Foundation)

Brazil - Project 2-435: Biodiversity and adaptations of CYP enzymes in the Amazon *Loricariidae* fishes

PI: Thiago Parente, Fundação Oswaldo Cruz (Fiocruz) (formerly at Universidade Federal do Rio de Janeiro)
U.S. Partner: Mark Hahn, Woods Hole Oceanographic Institution (funded by the National Science Foundation)

COLOMBIA

Colombia - Project 9-269: Inclusive economic growthfor sustainable peace? Assessing development mechanisms and conservation efforts in post-conflict Colombia
PI: Laura Bernal-Bermúdez, Pontificia Universidad Javeriana
U.S. Partner: Tricia Olsen, University of Denver (funded by the National Science Foundation)

Colombia - Project 9-116: Climate mitigation potential of Colombia's lowland peatlands: distribution, emission factors and conservation priorities
PI: Juan Benavides, Pontificia Universidad Javeriana
U.S. Partner: Erik Lilleskov, US Forest Service

Colombia - Project 8-221: Incorporating relationships betweenecosystem integrity and people's livelihoods for conservation action planning in tropical dry forest
PI: Susana Rodríguez-Buriticá, Alexander von Humboldt Biological Resources Research Institute, in partnership with the Universidad Nacional de Colombia
U.S. Partner: Andrew Hansen, Montana State University (funded by the National Aeronautics and Space Administration)

Colombia - Project 8-214: Voluntary geographic redistribution of Venezuelan immigrants in Colombia
PI: Gina Galindo-Pacheco, Universidad del Norte
U.S. Partner: Jens Hainmueller, Stanford University (funded by the National Science Foundation)

Colombia - Project 8-166: A database of field-based radar images to assist in the safe removal of landmines in Colombia
PI: Roberto Bustamante Miller, Universidad de los Andes
U.S. Partner: Sarah Kruse, University of South Florida (funded by the National Aeronautics and Space Administration)

Colombia - Project 8-41: Recommendations for decision makers with concerns on forest fire policies
PI: Dolors Armenteras, Universidad Nacional de Colombia
U.S. Partner: Jennifer Balch, University of Colorado, Boulder (funded by the National Science Foundation)

Colombia - Project 7-275: Implementation of essential biodiversity variables for biodiversity assessment and monitoring at the subnational level in Colombia
PI: Maria Londoño, Instituto de Investigacion en Recursos Biologicos Alexander von Humboldt
U.S. Partner: Victor Gutierrez-Velez, Temple University (funded by the National Aeronautics and Space Administration)

Colombia - Project 5-331: Degradation of tropical forests in Colombia: impacts of fire
PI: Dolors Armenteras, Universidad Nacional de Colombia
U.S. Partner: Jennifer K. Balch, University of Colorado, Boulder (funded by the National Aeronautics and Space Agency)

Colombia - Project 4-70: Satellite-based estimations of river discharge into the Cartagena Bay, Caribbean Colombia: capacity building to mitigate sources of upstream runoff and associated risks of pollution
PI: Juan D. Restrepo, Universidad EAFIT
U.S. Partner: Robert Brakenridge, Dartmouth Flood Observatory (DFO), CSDMS, INSTAAR, University of Colorado (funded by the National Aeronautics and Space Agency)

Colombia - Project 2-487: Integrated humanitarian logistics system for developing countries
PI: Victor Cantillo, Universidad del Norte
U.S. Partner: José Holguin Veras, Rensselaer Polytechnic Institute (funded by the National Science Foundation)

Colombia - Project 2-65: Ecosystem response to climate change in the mountain wetlands
PI: Juan Castaño, Universidad Tecnológica de Pereira
U.S. Partner: Jay Martin, The Ohio State University (funded by the National Science Foundation)

Colombia - Project 1-31: Impacts of climate change on tropical wetlands: tracking the evolution of two Andean lakes and a floodplain cienaga in Columbia
PI: Julio Eduardo Cañón, Universidad de Antioquia
U.S. Partner: Francina Dominguez, University of Arizona (funded by the National Science Foundation)

DOMINICAN REPUBLIC

Dominican Republic - Project 9-410: Resiliency analysis for the development of microgrid architecture against climate-driven events in the Dominican Republic's electric systems
PI: Ramón Emilio De Jesús Grullón, Pontifica Universidad Catolica Madre y Maestra
U.S. Partner: Hashem Nehrir, Montana State University (funded by the National Science Foundation)

Dominican Republic - Project 9-210: Creating knowledge on cocoa pollinators in agroforestry systems of the Dominican Republic for improving plantation management practices
PI: Colmar Serra, Pontifica Universidad Catolica Madre y Maestra
U.S. Partner: Justin Runyon, United States Forest Service (fundedby the United States Department of Agriculture/ Forest Service)

Dominican Republic - Project 7-434: Technology and citizen science for creating a solid and participatory biodiversity information system in Hispaniola
PI: Yolanda Leon, Instituto Tecnológico de Santo Domingo
U.S. Partner: John Lloyd, Vermont Center for Ecostudies (fundedby the United States Department of Agriculture/ Forest Service)

Dominican Republic - Project 5-400: Development and use of the i-Tree tool to explore the potential for urban green infrastructure as an adaption strategy to climate change resilience in the city of Santo Domingo
PI: Solhanlle Bonilla Duarte, Instituto Tecnológia de Santo Domingo (INTEC)
U.S. Partner: Gerald Bauer, US Forest Service, International Institute of Tropical Forestry (funded by the United States Department of Agriculture/ Forest Service)

Dominican Republic - Project 2-270: Temperature profile of the ocean seabed, from the city of Puerto Plata, Dominican Republic, and preliminary designfor a commercial exploitation of cold water to supply for a central air conditioning system
PI: Eduardo David Sagredo Robles, Universidad Tecnológica Santiago
U.S. Partner: Naphtali David Rishe, Florida International University (funded by the National Science Foundation)

ECUADOR

Ecuador - Project 1-384: REDD based forest expansion, food consumption, and reduced emissions agricultural policies (REAP) in the Ecuadorian Amazon
PI: Carlos Mena, Universidad San Francisco de Quito
U.S. Partner: Thomas Rudel, Rutgers University (funded by the National Science Foundation)

Ecuador - Project 1-108: Long-term sustainability of water resources and biodiversity under scenarios of climate change in the Napo watershed, Ecuador
PIs: Juan Manuel Guayasamin, Universidad Tecnológica Indoamérica, and Andrea Encalada, Universidad San Francisco de Quito
U.S. Partner: LeRoy Poff, Colorado State University (funded by the National Science Foundation)

EL SALVADOR

El Salvador - Project 5-58: Data sciences training and research to address crime and insecurity in El Salvador
PI: Oscar Picardo, Universidad Francisco Gavidia
U.S. Partner: Carlos Castillo-Chavez, Arizona State University (funded by the National Science Foundation)

El Salvador - Project 1-354: Demonstrating the integration of ground-based monitoring and satellite remote sensing for forecasting landslides and flooding hazards in volcanic terrains
PI: José Fredy Cruz, Universidad de El Salvador
U.S. Partner: John S. Gierke, Michigan Technological University (funded by the National Science Foundation)

HAITI

Haiti - Project 6-18: Students with disabilities and pedagogical practices of teachers in the schools in three Regions of Haiti
PI: Rochambeau Lainy, Groupe d'Initiative pour l'Etude de la Cognition du Langage, de l'Apprentissage et des Troubles (GIECLAT)
U.S. Partner: Nathalis Wamba, Queens College (funded by the National Science Foundation)

Haiti - Project 4-245: Exploring sustainable solutions aimed at redressing environmental disasters in Haiti
PI: Rene Jean-Jumeau, Universite Quisqueya
U.S. Partner: Jerry Bauer, International Institute of Tropical Forestry (funded by the United States Department of Agriculture/ Forest Service)

MEXICO

Mexico - Project 3-129: Poverty and climate change in Mexico: the implications of mitigation policy, climate impacts, and development pathways for household welfare
PI: Landy Sanchez, El Colegio de Mexico
U.S. Partner: Brian O'Neill, National Center for Atmospheric Research (funded by the National Science Foundation)

Mexico - Project PP-10: NSF-PIRE collaboration: sustainability evaluation of jatropha oil production in Yucatan, Mexico
PI: Julio Sacramento-Rivero, Universidad Autonoma de Yucatán
U.S. Partner: Kathy Halvorsen et al., Michigan Technological University (funded by the National Science Foundation)

NICARAGUA

Nicaragua - Project 2-459: Marine biodiversity initiative for Central America: international partnership for research and training on marine biodiversity and genomics
PI: Jorge Alberto Huete-Pérez, Universidad Centroamericana
U.S. Partner: Martin Polz, Massachusetts Institute of Technology (funded by the National Science Foundation)

PERU

Peru - Project 9-229: Multi-scale, interdisciplinary integrated analysis of societal and ecosystem values of Peruvian Amazon peatlands
PI: Sandra Ríos Cáceres, Instituto del Bien Común, with co-PI Aoife Bennett
U.S. Partner: Hinsby Cadillo-Quiroz, Arizona State University (funded by the National Science Foundation); and Victor Gutiérrez-Vélez, Temple University

Peru - Project 9-124: Improving sustainability and resilience of Peruvian Amazon systems through silvopastoralism
PI: Carlos Gomez, Universidad Nacional Agraria La Molina
U.S. Partner: Heathcliffe Riday, U.S. Dairy Forage Research Center, U.S. Department of Agriculture – Agricultural Research Service

Peru - Project 8-161: A wood species identificationtool to aid in compliance and enforcement of Peruvian timber regulations
PI: José Ugarte Oliva, Instituto Tecnológico de la Producción - CITEmadera
U.S. Partner: Michael Wiemann, U.S. Forest Service, Forest Products Laboratory

Peru - Project 8-235: Impacts of alluvial mining in the Madre de Dios Basin: physical effects and mitigation planning
PI: Mónica Moreno Brush, Universidad de Ingeniería y Tecnología
U.S. Partner: Eddy Langendoen, United States Department of Agriculture/ Agricultural Research Service

Peru - Project 7-355: Numba Wachokkeri: Empowering indigenous peoples toprotect their forests with cutting-edge technology
PI: Sidney Novoa, Asociación para la Conservación de la Cuenca Amazónica (ACCA), and Carlos Saito Villanueva, Pontificia Universidad Catolica del Peru (PUCP)
U.S. Partner: Eben Broadbent, University of Florida (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Peru - Project 6-330: Preventing lead exposure of Peruvian children from mining and battery recycling with a new field test kit
PI: Johny Cesar Ponce-Canchihuamán, Universidad Peruana Cayetano Heredia & the Center for Research in Environmental Health (CREEH Perú)
U.S. Partner: Alexander van Geen, Lamont-Doherty Earth Observatory of Columbia University (funded by the National Science Foundation)

Peru - Project 5-259: AGUA-ANDES: ecological infrastructure strategies for enhancing water sustainability in the semi-arid Andes
PI: Bram Willems, Centro de Competencias del Agua - CCA
U.S. Partner: Andrea Gerlak, University of Arizona (funded by the National Science Foundation)

Peru - Project 4-116: Tropical montane forests and climate change in the Peruvian Andes: micro-environmental, biotic, and human impacts at the tree line
PI: Norma Salinas, Pontificia Universidad Catolica del Peru
U.S. Partner: Miles Silman, Wake Forest University (funded by the National Science Foundation)

Peru - Project 3-127: Glacier retreat and water resource sustainability in the Peruvian Andes: informing adaptation strategies through collaborative science
PI: Cirilo Lagos, Instituto Geofisico del Peru
U.S. Partner: Bryan G. Mark, The Ohio State University (funded by the National Science Foundation)

Peru - Project 2-359: Strengthening resilience of Andean river-basin headwaters facing global change
PI: Bram Leo Willems, Universidad Nacional Mayor de San Marcos
U.S. Partner: Christopher Scott, The University of Arizona (funded by the National Science Foundation)

Peru - Project 2-228: Impact of transboundary biomass burning pollution transport over the Central Andes of Peru
PI: Luis Suarez, Instituto Geofisico del Peru (formerly at Universidad Continental)
U.S. Partner: Detlev Helmig, University of Colorado at Boulder (funded by the National Science Foundation)

Peru - Project 1-353: Building Peruvian capacity for monitoring and modeling the effects of climate change on the Coropuna Glacier and associated watersheds in Arequipa, Peru
PI: Roberto Zegarra Balcazar and Felio Carderon La Torre, (former PIs Karen Kraft and Julio F. Alegría), AEDES - Asociación Especializada para el Desarrollo Sostenible
U.S. Partner: Joerg Schaefer, Columbia University (funded by the National Science Foundation

BOLIVIA

BOLIVIA - PROJECT 1-358: THE FATE OF ENTERIC PATHOGENS IN FLUIDS, FIELDS, AND FOOD PRODUCTS: ON-FARM SOLUTIONS FOR THE SAFE RECLAMATION OF WATER AND NUTRIENTS FROM SEWAGE

PI: Maria de la Mercedes Iriarte Puña, Centro de Aguas y Saneamiento Ambiental, Universidad Mayor de San Simon
U.S. Partner: James Mihelcic, University of South Florida (Funded by The National Science Foundation)
Dates: June 2012 - May 2014

PROJECT OVERVIEW

Domestic sewage is a crucial water and nutrient source for agriculture in water-scarce regions like Cochabamba, Bolivia, irrigating over 2,000 hectares of crop fields. However, this wastewater contains high concentrations of enteric pathogens, posing serious health risks to farmers, their families, and consumers. Current policies regulate wastewater quality at the municipal treatment plant level, but pathogen reduction can also occur post-treatment and on farms through measures like on-farm water storage, indigenous farming techniques, strategic irrigation, and crop-washing, making sanitation a more community-managed process.

This project measured concentrations of human pathogens causing diseases such as cryptosporidiosis, giardiasis, and helminthiasis in water, soil, and crop samples from six community farms using wastewater for irrigation. The team quantified differences in pathogen concentrations with and without on-farm health protection measures. The CASA team developed expertise in detecting these pathogens in environmental samples, led the laboratory analysis, and provided graduate students with field sampling experience. The U.S. partner at USF assisted with designing data collection and sampling techniques and collaborated academically with Bolivian counterparts to publish results.

In the Rocha River area, pathogen incidence was very high in river water but much lower in irrigation wells used by farmers. Enteric viruses were absent in the irrigation wells but present in high concentrations in the river. Parasite levels in well water exceeded WHO limits for irrigation use, highlighting the need for effective health protection measures.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team has presented their results at several conferences as well as workshops to disseminate their research results to local community stakeholders.

Among the recommendations offered was limiting the contamination of wells by animal waste, installing a series of stabilization ponds to store the irrigation water and providing treatment via sedimentation of parasites, and exposure to UV rays from the sunlight. At the plants, their recommendations included the installation of bar screens to prevent solids from entering the lagoons, and general maintenance under a monitoring program for both plants.

At the workshop in Punata, discussion with the community members focused on improvements that could be made to the treatment plant, and representatives of the water company affirmed their commitment to improving the treatment plant, with technical support from the university.

At the workshop in Arani, the team presented the results collected to farmers and irrigators who used the treated wastewater, as well as representatives from the mayor's office. Community members said they generally perform maintenance activities without any technical guidance and that the research team's support and guidance was very helpful. The representatives from the mayor's office noted that aside from the planned improvements to the treatment plan, their office has approved the construction of a new treatment plant in a lower area of the municipality. At the workshop near the Rocha River, PEER grantees presented their results to a group of majority-female farmers.

The research contributed to five students' theses and a partner researcher USF was invited by the Center to help deliver a short course entitled, "Introduction to quantitative microbial risk assessment for water reuse in agriculture."

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BRAZIL

BRAZIL - COV-177: FISHING FOR A "NEW NORMAL": POTENTIAL EFFECTS OF THE COVID-19 PANDEMICS ON VULNERABLE FISHING COMMUNITIES IN THE BRAZILIAN AMAZON

PI: Renato Silvano, Universidade Federal do Rio Grande do Sul
U.S. Partner: Henry Huntington, Huntington Consulting (Funded by the National Science Foundation)
Dates: April 2023 – March 2024

PROJECT OVERVIEW

The people of the Brazilian Amazon were hit hard by the COVID pandemic, especially those living in small, vulnerable, and usually remote communities relying heavily on natural resources, such as small-scale fishers. There is a need for more empirical data on the pandemic effects on fishing communities in the Amazon and elsewhere, especially in developing countries where research capacity is limited. The goal of this PEER project was to conduct a broad and interdisciplinary analysis of the multiple pandemic effects on riverine fishing communities in the Brazilian Amazon, including the potential cascading effects on food provisioning, local economies, and aquatic biodiversity. This research was grounded in fishers' knowledge and individual interviews with households (men and women) to provide first-hand quantitative data to evaluate how the pandemic has affected fishers' livelihoods, fisheries, and biodiversity. The study focused on the rivers Tapajos, Tocantins, Trombetas, and Negro, which differ regarding the presence of protected areas, local biodiversity, and intensity of environmental degradation.

The PI Dr. Silvano and his team evaluated indicators related to fisheries, economics, food security, and the incidence of COVID. The project included a gender component, as the researchers conducted targeted interviews to compare COVID impacts on men versus women. The project sought to build upon the results from a PEER Cycle 4 project concluded in 2018 by the PI, which provides a pre-COVID database of interviews with fishers and records of fish landings in the Brazilian Amazon, to be compared with the post-COVID data from the current effort. The results highlighted fishers' perceptions and concerns regarding the pandemic to inform policy actions and mitigation measures, either implemented or planned.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team included 13 researchers (4 men and 9 women) from the Federal University of Rio Grande do Sul (UFRGS) and two collaborators from two other Brazilian universities. During the 11 months of data collection, the researchers interviewed 705 individuals in 44 communities in four rivers in the Brazilian Amazon about fisheries and pandemic effects. While communities differed on the impact of the pandemic of fisheries, life, and work capacity, they generally expressed lower to no impacts on the availability of food. The researchers made a more detailed analysis comparing gender perceptions on pandemic effects on life and food provision in the Tapajos River, through the paired comparison of 178 interviews with 89 men and 89 women living in the same houses (husband and wife). This comparison showed that both genders shared the same perceptions and trends on how the pandemic affected their lives but not on food provision. A higher percentage of women reported effects on both life and food provision, which indicated that women may be more aware about negative effects from the pandemic.

The team also analyzed changes in two fisheries indicators, through a comparison of interviews in this time period, versus interviews done in the same communities prior to the pandemic. They asked fishers to estimate the amount (in biomass) of fish caught in a regular fishing trip, at the moment of interview (2022 and 2023), and during the pandemic period. The team then compared these data to the same estimates these fishers made in previous interviews, from before the pandemic (2016 to 2018). The biomass of fish harvested in a typical fishing trip was lower during the pandemic but similar during the periods from before and after the pandemic, indicating that even if the quantity of fish caught decreased during the pandemic, it recovered afterwards. Other indicators suggested the decrease in the biomass of fish harvested during the pandemic was possibly related to a decrease in fishing effort or fishing intensity.

The fishers provided information on abundance trends of 61 fish species (or species groups) for the three rivers. Most fishers mentioned that fish abundance was unchanged since the pandemic in the Tapajos and Trombetas rivers and for the whole dataset, whereas most fishers cited a decreased fish abundance in the Tocantins River.

The researchers disseminated their findings through posters delivered to leaders and schools in 13 communities in the Tapajos River, as well as on social media. The PI shared findings at a research conference in Seattle and in the the fishing village of Cordova, Alaska, while visiting the U.S. partner Dr. Henry Huntington in March 2024. Publications on this research are forthcoming and the team plans to present their findings at the Brazilian Society of Ethnobiology conference and the American Fisheries Society (AFS) in Honolulu.

Dr. Silvano and two of his team members participated in USAID research-to-action plan training, and the PI received two additional grants worth more than $70,000 in this period, from University of Alberta, Canada, as part of the Ărramăt project, and from Brazilian governmental institution Conselho Nacional de Desenvolvimento Científico e Tecnológico.

BRAZIL - PROJECT 9-326: BIODIVERSITY CORRELATES OF SUSTAINABLE VALUE CHAIN EXPANSION IN THE BRAZILIAN AMAZON: DEVELOPING COMBINED ENVIRONMENTAL DNA (EDNA) AND CAMERA TRAPPING PROTOCOLS TO ASSESS VERTEBRATE DIVERSITY IN MANAGED BRAZIL NUT FORESTS

PI: Pedro Galetti, Federal University of São Carlos (Original PI: Ludmilla Aguiar), with Co-PI José Luiz De Andrade Franco, University of Brasilia/Foundation for Scientific and Technological Enterprises
U.S. Partner: Kirsten Silvius, Virginia Polytechnic Institute and State University
(Funded by the United States Department of Agriculture/ Forest Service)
Dates: May 2021 – April 2024

PROJECT OVERVIEW

DNA metabarcoding of environmental DNA (eDNA)—simultaneously identifying multiple species using short sections of DNA from soil or water samples— holds great promise for biodiversity research, but these tools have not been fully refined for assessing animal community structure in general and terrestrial vertebrate communities in particular. eDNA work is more advanced for aquatic than terrestrial systems, facilitated by DNA's more rapid dispersal in water. This PEER project used camera trapping and sign and visual encounter survey, simultaneously with eDNA sampling from soil and water and invertebrate DNA (iDNA) and sampling from insect blood-meals, to describe the species composition of mammal communities associated with Brazil nut (*Berhtolletia excelsa*) rich forests. This work was designed to address the still-open question of whether Brazil nut harvest and management practices affect vertebrate communities and species abundance.

Wild-harvested Brazil nuts are an internationally traded food commodity and a key source of income for traditional and indigenous peoples. Brazil nuts are Brazil's single most valuable non-timber forest product. Understanding the impacts on biodiversity and ecosystem function of nut-biomass extraction and other types of anthropogenic disturbance during the harvest is essential to ensure the ecological sustainability of the resource and provide an important marketing tool, assuring consumers that Brazil nuts from the Brazilian Amazon are harvested using ecologically and socially sustainable approaches.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team began by carrying out a pilot experiment at Terra Ronca State Park, investigating the mammal community from eDNA and iDNA samples with metabarcoding sequencing to reproduce an ongoing experiment with the RT-PCR approach. They collected water samples and bulk samples of mosquitoes and flies from insect traps and used the RT-PCR procedure to determine the presence of Panthera onca. The samples' row sequences were processed with bioinformatic tools, which showed 33 mammal species. This pilot phase allowed researchers to adjust their methods for their planned field expedition.

The researchers also joined project partner Fundação Vitória Amazônica (FVA) to visit Brazil nut producing communities in Jaú National Park and Unini River Extractive Reserve. They presented their PEER project at eight community meetings of traditional ribeirinho families living on both banks of the

Unini River. After each meeting, the team held conversations with individuals identified as among the most active Brazil nut harvesters in each community.

The PEER team organized a ten-day field expedition to the Amazon with all researchers from the project, including U.S. and local NGO partners. At the Tapiira community, local residents from all the visited communities met and researchers trained 13 pre-selected residents on participating in the project as parabiologists, engaging the local community in participating in the research. At the end of the course, four pairs of parabiologists were selected to be responsible for three transects near their home community. The team established 12 transects along the Unini River, where local parabiologists installed camera and fly traps and collected data on sightings and vestiges of vertebrates for a month. To monitor the work carried out by the parabiologists, a member of the PEER team traveled back twice to the area, gathering fly samples and data collected by the parabiologists, as well as collecting water samples for environmental DNA analysis.

In addition, soil collection took place under a complementary project that seeks to expand the amount of environmental data collected at the study sites: “Biodiversity and Ecosystem Function in Brazil-nut rich forests in the Unini River basin”. A total of 125 soil samples were collected and shipped to laboratories at the ESALQ school at the University of São Paulo, where they were analyzed for soil and microbial community structure by project collaborators.

One difficulty with the eDNA and iDNA approaches is the lack of a complete reference database on target species sequences, especially from areas of high diversity, such as Amazonia. Part of the PEER team worked on construction of a library of sequences with two minibarcodes (12S and 16S) used in the metabarcoding approach for mammals, and produced reference sequences for about 60 mammal species, which will be deposited in the NCBI database.

The researchers recorded 74 mammal species throughout all sampling methods. While findings are still preliminary, they have concluded that for short survey periods of less than 3 months, DNA methods are highly complementary to the traditional transect and camera trap methods used to detect medium and large terrestrial vertebrates and will add taxa to any such survey. For longer term surveys (a year or more), the traditional methods would likely be sufficient for the targeted medium-to-large mammal taxa. For small mammals, which are usually detected with physical trapping, DNA methods are highly complementary to transect-and camera-trap based surveys that do not include traditional methods for capturing small mammals.

The team project partner Fundação Vitória Amazônica received an additional grant of $104,000 to support the PEER Project work, as well as the complementary work on soils and soil microbes. The team presented findings from the pilot experiment at XI Brazilian Congress of Mammalogists in 2022 and further manuscripts on the larger project are forthcoming.

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BRAZIL - PROJECT 5-589: INTEGRATING DIMENSIONS OF MICROBIAL BIODIVERSITY ACROSS WETLANDS AND LAND USE TYPES TO UNDERSTAND METHANE GREENHOUSE GAS CYCLING IN TROPICAL FORESTS

PI: Jose Mauro Moura, Universidade Federal do Oeste do Pará
U.S. Partner: Jorge Rodrigues, University of California, Davis (Funded by the National Science Foundation)
Dates: December 2016 – October 2022

PROJECT OVERVIEW

Deforestation is among the most important alterations occurring in tropical systems and is responsible for unprecedented losses of plant and animal biodiversity. However, little is known about the impact of land use change and seasonal inundation of wetlands on microbial biodiversity, especially in the tropics. In previous research, Dr. Moura and his colleagues discovered that soil microbial biodiversity in Amazon rainforest soil is homogenized and reduced by forest-to-agriculture conversion. However, it remains unknown how such changes in microbial biodiversity affect ecosystem functions. This challenge is paralleled by our need to understand, and ultimately manage, the problem of global climate change. This project addresses the intersection of these two questions in the context of biodiversity conservation by asking: "how does the interaction between soil microbial and forest tree biodiversity control cycling of the powerful greenhouse gas methane along gradients of land use and seasonal water inundation in Amazon forests?" To predict the future of methane as a driver of climate change in this system, the researchers will combine novel gas flux measurement instrumentation with cutting-edge molecular microbial ecology. They will address biodiversity and environmental controls on methane production from tropical regions by measuring methane fluxes from a variety of potential sources, including surfaces of tree stems and leaves, soil, and water in forested and deforested areas, as well as upland and wetland areas. Detailed inventories of biodiversity of methane-active vegetation and microbial communities will be performed in the Santarem region of Brazil.

The goals of the project are to advance biodiversity conservation science in Amazônia by (1) quantifying methane-cycling microbial diversity as a function of land use and seasonal inundation, (2) quantifying interactions between methane-cycling microbes and methane cycling, and (3) incorporating knowledge of interactions between methane-cycling microbes and plants into conservation and management plans for mitigating the climate impact of methane emissions. Collaborators from the United States will work with the Brazilian team to analyze and integrate results and ultimately create a model to predict the response of methane cycling to land-use change. This model will not only be useful to a wide community of researchers but will also inform stakeholders and local policy administrators on protecting local biodiversity. The project's focus on microbial biodiversity as a driver of methane cycling through the twin lenses of land use change and tropical wetlands (the largest natural sources of microbially produced methane to the atmosphere in the world) links development-associated anthropogenic land use change to both biodiversity conservation and climate change feedback. The project will thus bring new knowledge from a novel field (conservation biology for microbes) to our understanding of the impacts of development. Results from this project will provide a basis to inform policy development to simultaneously address problems of biodiversity conservation and management of key economic resource for riverine communities.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the course of the project, the team carried out measurements of CH4 fluxes and the tree diameter increment and biomass from litter traps. Dr. Moura's group took regular monthly measurements of methane (CH4) fluxes at their various sites (Varzeas, Arapixuna stream, Salvação, Juá, Terra Preta, Capoeirão, Mata Ciliar, Buriti, Savanna, Pasture, and Primary and Secondary Forest). They also measured tree diameter increments, collected and analyzed biomass from litter traps, tracked daily rainfall data, and collected soil samples to evaluate soil moisture content. The team conducted seasonal characterization of biophysical parameters and aboveground biomass estimation of a floodplain forest fragment using lidar remote sensing. Comparison was done between the structure, biomass and growth dynamics of secondary terra firme forest and lowland forest in the district of Arapixuna, Santarém, Pará. Floristic composition and structure of the natural regenerative layer in a lowland forest in the district of Arapixuna, Santarém, Pará were performed.

The final six months of the project also allowed time for the field campaigns for two Master's degree dissertations from students working on the project team. One of the students evaluated the effect of induced ground heating conditions on greenhouse gases (CO2 and CH4) fluxes on a variety of Amazon ecosystems, while another student analyzed and compared the floristic composition, structure, and dynamics of the natural regenerative stratum of two types of floodplain forest, located in the Arapixuna and Pixuna do Tapará communities near Santarém, Pará.

According to the PI, this PEER project served a model for the research the team intend to develop for the DOE project to study methane emissions on Amazon wetlands (Varzeas).

In efforts to demonstrate to the community research this project accomplished at the Arapixuna 's sites, the project team presented the results to the children of Arapixuna's elementary school. The team developed a variety of activities for elementary school students which entailed science workshops connected to arts for 5-14 year old children. Workshops focused on sharing information on the composition of rainforest flora, ecological strategies of floodplain vegetation, the role of the forest in the water cycle. According to Dr. Moura, during the conversation about water cycle the children became more familiar with leaf structures and water transportation in the trees. The team members took the children to field campaigns in the forest they already knew very well, however from another-more well informed - perspective. Over the 5 years of this PEER project implementation, ten art workshops in Ecology and Botany themes were held with students between 5 and 14 years old, reaching a total of 300 riverine children. 25 graduate and undergraduate students from UFOPA were involved in the activities. According to Dr. Moura, a combination of science and art enabled students to connect concepts from science classes with the broader environment surrounding their community, hopefully awakening a sense of action towards preserving their riverside ecosystem.

In terms of lessons learned by the river to understand the processes on dry and flooded periods, the project PI Dr. Moura stated that the exchange between community members and scientific knowledge producers is crucial for the development of sustainable strategies that maintain these communities and their traditional practices.

PUBLICATIONS

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BRAZIL - PROJECT 5-9: HISTORY AND DIVERSIFICATION OF FLOODPLAIN FOREST BIRD COMMUNITIES IN AMAZONIA: TOWARDS AN INTEGRATED CONSERVATION PLAN

PI: Camila Ribas, Instituto Nacional de Pesquisas da Amazônia, Ministry of Science, Technology, and Innovation

U.S. Partner: Joel Cracraft, American Museum of Natural History (Funded by the National Science Foundation)

Dates: December 2016 – November 2019

PROJECT OVERVIEW

This research project is crucial as Amazonian countries focus on building hydroelectric dams, significantly impacting biota specialized in flooded habitats through habitat loss, fragmentation, and changes in sediment dynamics. These habitats have a unique, complex, and poorly understood history. Although birds are well-studied vertebrates, their assemblages in flooded habitats have been minimally explored using molecular techniques. Recent studies revealed substantial cryptic diversity and endemism, challenging the assumption that these species have high dispersal ability and lack genetic structure. This poses a major threat to Amazonian biodiversity within developmental plans for energy generation. Dr. Ribas and her colleagues aimed to generate a multidisciplinary dataset, including genomic, ecological, and spatial data, to advance knowledge on the evolution of Amazonian flooded habitats and their biota, and provide information for assessing the impact of proposed hydroelectric dams and identifying conservation priority areas. This was to be accomplished in collaboration with Dr. Cracraft's NSF-funded project, which focused on reconstructing the history and evolution of Amazonian biota and its environment.

Hydroelectric energy generation, considered clean and renewable, often overlooks the long-term irreversible impacts of dams on Amazonian flooded habitats. With 121 established and 303 planned dams in the Amazon region, mostly in Brazil, immediate attention is needed. Among the largest planned dams, Santo Antônio and Jirau (Madeira River) and Belo Monte (Xingu River) are already built or nearing completion. Most planned dams will use the "run of the river" system, permanently flooding large areas and disrupting the hydrologic cycle, which can result in significant species loss in flooded habitats and impact interconnected upland biota. To assess these impacts, it is essential to understand the history and distribution of flooded habitats' biological diversity and the importance of the hydrological cycle. Dr. Ribas assembled a multidisciplinary team to study population genomics, ecological affinities, biological diversification, and species distribution patterns of flooded habitat birds. They aimed to relate these patterns to the spatial distribution and chronology of flooded habitats, sediment dynamics, and hydrology of threatened Amazonian basins. This interdisciplinary approach was expected to produce and disseminate data and integrative analytical methods to inform environmental impact assessments for future developmental projects in Brazil.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project combined data collection and analysis from various disciplines to achieve integrative results, with significant impacts on policy and planning. One key outcome was the support for student projects, which helped develop new researchers in Amazonia. The project supported data collection for 14 graduate students, 10 from Amazonian research institutions, building their skills in a region that is poorly understood, greatly threatened, and in need of more locally based scientists.

Mapping different Amazonian habitats is challenging due to homogeneous relief, habitat heterogeneity and seasonality, lack of field data, and intense cloud cover. Dr. Ribas and her colleagues aimed to update the 1995-1996 map of Amazonian wetlands by Hess et al., refining it with ALOS/PALSAR images and developing a habitat classification scheme. They collected ground data in joint field expeditions and created a platform for gathering ground truth information. Classification covered central Amazonia and expanded further despite challenges like hiring technicians for remote sensing analyses and Dr. Silva's institutional change in 2019.

The team compiled occurrence data for bird species in seasonally flooded habitats, analyzing distribution, diversity, and endemism patterns. These results informed environmental impact assessments for dams in the Xingu and Branco rivers, influencing planning for hydropower production in Amazonia. Genomic data for 40 species were obtained, revealing threatened taxa and showing that Eastern Amazonian populations are smaller and less diverse than Western ones, indicating a higher extinction risk.

Basic analysis of dam impacts was delayed due to difficulties in obtaining precise information on dam locations and heights. This data will be needed for final planning, which Dr. Ribas and her group still plan to implement with governmental agencies. The team employed Passive Acoustic Monitoring (PAM) to generate data on habitat use for bird species. This method provided insights into species' habitat affinities and usage, with significant data obtained from sites along the Madeira and Xingu rivers.

The project proposed areas of endemism (AoE) for Amazonian birds in flooded forests, differing from those for upland forest birds. This regionalization highlights areas of conservation priority and considers the revised taxonomy from the genomic analyses. The team also integrated genomic data with sedimentary chronology to understand the evolution of bird populations in relation to the temporal dynamics of flooded habitats, producing significant studies on Amazonian habitat evolution and the effects of dams on sedimentary dynamics.

Although the PEER project has ended, Dr. Ribas and her colleagues plan to continue collaborating with their USG-supported partners and other researchers to analyze and publish their data. They also aim to work closely with indigenous and river-dweller communities in the Xingu River basin, using scientific data to support better planning and management of their territories. Future research will combine existing datasets with refined climate information and insights from local communities on species' responses to environmental changes. This approach ensures that local researchers have the experience to discuss impacts, rather than being merely research subjects.

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BRAZIL - PROJECT 4-478: MAPPING AND CONSERVING BUTTERFLY BIODIVERSITY IN THE BRAZILIAN AMAZON

PI: Andre Freitas, Universidade Estadual de Campinas

U.S. Partner: Keith Willmott, University of Florida (Funded by the National Science Foundation)

Dates: January 2016 – December 2019

PROJECT OVERVIEW

The Amazon hosts some of the world's most diverse biological communities, including butterflies. Recent expeditions by Dr. Freitas and collaborators have discovered numerous poorly known or undescribed species. Although involved in several butterfly classification and evolution projects, the Amazon remains poorly understood compared to other Brazilian regions due to its vast size and transport challenges. This lack of knowledge hinders conservation efforts for most butterfly species. In this project, the Brazilian team collaborated with a National Science Foundation-supported project at the Florida Museum of Natural History to study euptychiine butterflies, a diverse group in Amazonian forests. The project aimed to sample new regions, build collections, and enhance research and conservation capacity for Brazilian Amazonian butterflies. Researchers compiled data from literature, databases, and museum specimens to improve knowledge of butterfly distribution, targeting poorly known groups or those with restricted distributions. Up to eight expeditions to poorly sampled or unexplored areas of the Brazilian Amazon were planned, with approximately 20,000 specimens to be collected, processed, and databased. Mitochondrial cytochrome C oxidase 1 (COI) genes were sequenced for some specimens to identify cryptic species.

Deforestation, oil and gas exploitation, and climate change threaten Brazilian Amazon biological communities. Butterflies serve as indicators of biodiversity and ecosystem health, climate change monitors, and key species in biodiversity conservation. Butterfly distribution data can identify priority areas for Amazonian biodiversity conservation, similar to efforts in temperate countries. As the Brazilian Amazon plays a crucial role in controlling South American and global climate, this data also provides a baseline for measuring future climate change. The project aimed to build research capacity on Brazilian Amazonian butterflies by training graduate students and a postdoc, and by strengthening collaborations among researchers and students in Brazil and with foreign institutions. The project also enhanced major Brazilian butterfly collections with new material, archived tissue samples for DNA study, and databased specimens, creating substantial collections and online resources for future taxonomic, biogeographic, and conservation research.

FINAL SUMMARY OF PROJECT ACTIVITIES

Now that this project has concluded as of the end of 2019, PI Dr. Freitas emphasizes that the financial support provided by PEER was crucial for facilitating the collection of new data from remote, under-sampled regions in the Amazon. The team visited 67 localities during the project, gathering data they will continue to study in the coming years. By February 2020, they had published 17 papers describing more than 20 new taxa (species and genera) based on morphological and molecular data. They have achieved a better understanding of some diversification processes in the Amazon region, including the roles of large rivers and hybrid zones. Involving all students in project activities also led to the development of outreach projects. Finally, the project strengthened existing international collaboration with the U.S. partner and initiated new collaborations.

During the final year of the project in 2019, postdocs Leila T. Shirai and Jessie P. Santos received training from NSF-funded collaborator Dr. Keith R. Willmott in using a Microsoft Access database for recording butterfly specimen data. This relational database contains 17,218 locality records and 28,412 Neotropical butterfly species-group names. Dr. Freitas and colleagues completed a compilation of records from multiple databases, resulting in 27,332 locality records for 36,203 Brazilian butterfly specimens, including 752 species from 170 genera.

Over the four years of the project, morphological research on key butterfly genera contributed to eight research papers. These activities were facilitated by PEER funds, which allowed Dr. Freitas to acquire a stereomicroscope for his lab. The data gathered will result in additional publications, including taxonomic revisions and descriptions of new taxa. Main researchers involved in these studies included Dr. Mario Marín, Dr. Eduardo P. Barbosa, and Dra. Thamara Zacca, assisted by undergraduate student Julia Ramos and Master's student Tamara Aguiar.

The molecular team sequenced DNA for more than 800 specimens, continuing to use the data in ongoing projects on the systematics and evolution of Neotropical butterflies. An ongoing molecular study of Heliconius hermathena, a sand forest specialist, is advancing based on data from eight populations. The first publication describing a new subspecies is completed, and two additional genomic studies are underway, one in collaboration with Dr. Marcus Kronforst (University of Chicago). All these studies involve collaboration with Dra. Karina Silva-Brandão (Center of Molecular Biology - Unicamp).

Mario Marín continued broad-scale sequencing of Pareuptychia specimens, including those recently collected in Amapá, Roraima, Amazonas, and Pará, with most of the material coming from field trips supported by this project. He is also sequencing Taygetis specimens from several Amazon localities to unveil species complexes in collaboration with Keith Willmott. Leila T. Shirai prepared a genetic diversity bank with tissues from 2,300 butterfly specimens collected in the central Amazon, to be used in ongoing projects in Dr. Freitas's lab and in a collaborative project between Unicamp, Harvard University, and the University of York.

The PI and his group published 17 papers and described more than 20 new taxa, including a new subspecies of Heliconius hermathena from South Pará State, based on morphological and molecular data. Studies in collaboration with postdocs Thamara Zacca, Eduardo Barbosa, and Mario Marín focused on poorly known satyrines and included several published and submitted papers, including broad taxonomic revisions of key genera of Satyrinae butterflies with descriptions of several new taxa. During the project, six students from Unicamp participated as instructors training local people in sampling protocols for residents and future implementers of the "Biodiversity Monitoring in Conservation Units" program in the Cabo Orange National Park and Tumucumaque National Park. With support from the National Geographic Society, the team appeared in a documentary to be released in 2020 and produced several other videos available on their YouTube page. During the expedition to Tefé and Iranduba (September-October 2018), a television crew accompanied the team to record a Brazilian TV program called "Profissão Reporter," illustrating the challenges faced by researchers in Brazil.

Dr. Freitas and the colleagues collaborated with the Brazilian Biodiversity Monitoring Program in several Amazon Conservation Units. In August 2017, they took part in an expedition to Tumucumaque Mountains National Park, aiming to survey the entire butterfly fauna and develop a species list. Over a week, they collected butterflies with entomological nets along monitoring transects, with substantial logistical assistance from the local monitoring team. They helped the monitoring crew with species identification and provided relevant information about the butterfly fauna. Biological material from this expedition is still being identified, and several undescribed Satyrini species will be described in future publications.

Overall, the data gathered during the four years of the project are now an invaluable source of information for better understanding the Amazon region, especially in previously unsampled areas. Several new taxa have already been described, and additional new species are being studied for future descriptions. The project also strengthened collaboration with Dr. Keith Willmott of the University of Florida. In 2020 and beyond, they will continue studying the collected material, with support from the Brazilian National Council for Scientific and Technological Development. The PI has also submitted a proposal to the São Paulo Research Foundation (FAPESP) to study the evolution of Amazonian butterflies.

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BRAZIL - PROJECT 4-461: CAPACITY BUILDING FOR PARTICIPATORY MONITORING OF CHANGING FORESTS IN SUSTAINABLE USE AREAS OF THE SOUTHWESTERN BRAZILIAN AMAZON

PI: Sabina Ribeiro, Universidade Federal do Acre
U.S. Partner: Stephen Perz, University of Florida (Funded by the National Science Foundation)
Dates: October 2015 – January 2021

PROJECT OVERVIEW

Biodiversity in the Brazilian Amazon is the focus of numerous research initiatives, but significant knowledge gaps remain. The proposed project responds to several scientific priorities with regard to our understanding of forests in the Amazon. Forests in the southwestern Brazilian state of Acre are exceptionally biodiverse, but we still have limited information about many species. Further, climate change and extreme climatic events pose threats to forests, which require monitoring efforts that include fieldwork. The research team on this project aimed to revisit established botanical plots to evaluate forest dynamics in terms of carbon stocks and biodiversity. This effort builds on previous work with National Science Foundation funding and under the RAINFOR program, both of which use established protocols. The team also aimed to establish new botanical plots to fill coverage gaps in forest types underrepresented in existing plots. In both types of plots, they aimed to add data collection protocols designed to detect changes in vegetation due to climate change, including tree mortality, seedling recruitment, and canopy gaps. These data collection protocols were anticipated to permit more robust analyses in response to a suite of pressing scientific questions about forests in the Amazon. The revisits would allow analysis of forest dynamics, particularly by comparing carbon stocks and species composition over time. The new plots would expand forest coverage and plot sample size, providing a more representative picture of forests in Acre. Finally, the additional protocols were anticipated to evaluate changes in forest structure and species composition in the context of debates over the implications of climate change for Amazonia.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project had two main objectives: (1) to improve understanding of forest biodiversity and carbon stocks, and (2) to improve the capacity of stakeholders to use that knowledge for sustainable forest management. To meet the first objective, Dr. Sabina Ribeiro and her team remeasured six RAINFOR permanent plots located in the eastern portion of the state of Acre, Brazil. As most of these plots were established in the 1990s, they were able to evaluate how forest dynamics, species composition, and forest carbon were affected by the 2005 and 2010 Amazon droughts. They also studied the primary modes of tree mortality in these plots and the degree to which severe droughts increased the mortality rates of species with economic value. For that effort, two Master's students from the graduate courses in Forest Science (Mr. Égon Castro) and Ecology and Natural Resources Management (Ms. Angélica Maciel) at UFAC were included in the PEER project. These studies resulted in three articles in proceedings: two for the XXV IUFRO World Congress: Forest Research and Cooperation for Sustainable Development and one in the 2nd Rabeco (Reunião da Associação Brasileira de Ciência Ecológica e Conservação) and 6th SET (Simpósios de Ecologia Teórica). The team also produced a manuscript that was submitted to the journal Forest Ecology and Management in late 2021, based on research done for Égon's dissertation.

The researchers also established two new permanent plots in the CMER. Those plots serve to enhance the forest monitoring network in Acre, a state that is highly biodiverse and has different forest types but still lacks vegetation field data. These new plots (CUM-01 and SIB-01) were also incorporated in the ForestPlots.net repository. Additional data collection protocols to assess the impacts of drought were included in the six remeasured plots. The team performed measurements on necromass (dead biomass), canopy openness, and natural regeneration to refine forest dynamics analyses and improve estimates of carbon stocks.

To disseminate the results of their work, the PEER team also presented several workshops about forest health. Some were part of the Conference Viver Ciência: Educação e Saberes Amazônicos (Living Science: Education and Amazonian Knowledge. There, Dr. Foster Brown, Dr. Sabina Ribeiro, Dr. Fernando Schmidt and his graduate students, and Ms. Fiama Lima offered three workshops about forest health. The topics included discussions of how forest health may respond to climate change (FB, RS), the use of permanent plots to monitor forest health (SR, FL) and the use of ants as bioindicators of forest biodiversity and functioning (FS, graduate students). The audience for the conference included teachers and students ranging from elementary schools to university undergraduates. Dr. Sabina Ribeiro and two undergraduate students from UFAC also presented two workshops about forest health in the state public school "Escola Presbiteriana João Calvino". Around 80 students, ranging from the 6th to the 12th grades, attended the workshop.

This PEER project also had a strong social component (second objective) that featured work with communities in the CMER to build their capacity to monitor their forests. Communities in the CMER have noted changes in their forests due to drought, and they face challenges in the monitoring and management of their forests. However, communities are also reconsidering forest culture and looking for other livelihood activities due to the fall of rubber prices and variations in the productivity of Brazil nut trees. As a result, forests in the CMER are being cleared, mostly for livestock. Communities in the CMER therefore prioritize partnerships that can bring them economic benefits. This carries the key implication that projects focusing on conservation goals are increasingly resisted by CMER communities. To address these issues, Dr. Ribeiro and her group sought to reconcile conservation and development via forest monitoring, an essential step in payments for ecosystem service (PES) programs that focus on carbon sequestration. They therefore designed a capacity-building program to implement a forest health monitoring program with CMER communities. Their approach was to train people in the use of technologies that involve skills not only necessary to participate in monitoring forest health, but which are also valuable in the job market. Hence, while their focus was on supporting a forest monitoring program, the training had applications to information management, a valued skill set in urban labor markets. At the same time, training in forest monitoring helped participants in rural communities to identify the linkages between forest health and local livelihoods and global climate. This allowed participants to quantitatively relate carbon stored in biomass to potential incomes from PES as a component of local livelihoods. The team faced several challenges in working with communities in the CMER, which can be summarized in three categories: (1) understanding community political cultures and practices; (2) organizing logistics to access communities in the CMER; and (3) managing expectations of community members about benefits. These challenges, as well as the adaptive strategies they adopted and their outcomes, are discussed in detail in a paper they published in the journal Ecology and Society (https://doi.org/10.5751/ES-11665-250305).

Although the project ended as of January 31, 2021, Dr. Ribeiro will continue her research with the two permanent plots established under the PEER project, and she plans to establish more plots in the state of Acre. She wants to continue working with forest carbon stock, forest dynamics, and scientific knowledge dissemination to traditional communities. She also wants to further study the sustainability of forest management in the Brazilian Amazon. Dr. Ribeiro plans to continue to establish international partnerships to foster science development and human resources training in the state of Acre and in the MAP region (Madre de Dios-Acre-Pando). Dr. Ribeiro plans to continue studying forest dynamics in mature and secondary forests in the state of Acre, with emphasis on carbon stock and tree mortality. Currently, she is part of the project titled PROcess-based management of DIversity Generates sustainabilitY - PRODIGY, leaded by German universities, in which she participates in a sub-project leaded by Dr. Galia Selaya. They plan to study woody plant species traits and ant assemblies in the southwestern Amazonia as bioindicators of forest health and tipping points.

EVIDENCE TO ACTION SUPPLEMENT

In 2018, Dr. Ribeiro was awarded a PEER Evidence-to-Action (EtoA) Supplement to broaden capacity building activities on her project by including students from rural areas and by expanding the geographic scope of our educational activities beyond the CMER. They incorporated the project “Forest Health” as a complementary activity in the Asas da Florestania or “Wings of Forest Citizenship” program of the Government of the State of Acre. This project allowed children and teenagers to better understand environmental issues in terms of forest health and to learn skills required for forest monitoring and sustainable forest management (SFM). That in turn can foster the development of positive attitudes towards the forest while inculcating skills necessary for SFM, now and in the future. To achieve this goal, the team created a learning kit containing materials and a book with dynamics for different knowledge areas to be used by students from the 6th to the 12th grades. The book (ISBN 978-85-60775-06-4) served as a guide for teachers on how to implement the dynamics inside classrooms to facilitate collaborative learning. Learning kits on Forest Health were disseminated in 10 municipalities in Acre (45% of all municipalities), encompassing the five regional divisions of the state of Acre (upper Acre, lower Acre, Juruá, Purus, and Tarauacá-Envira). In order to facilitate the implementation of the project in rural schools, the PI and her colleagues trained teachers, supervisors, and pedagogical coordinators in these municipalities on how to apply the kits in the classroom. They initially trained 49 teachers, supervisors, and pedagogical coordinators from the various municipalities in a one-day workshop in 2018. Due to political changes in the Government of Acre, they had to offer the training again to 68 participants in 2019. This time the trainings occurred in different locations and times. In total, 338 students from 20 rural schools located in 10 municipalities in Acre (two per municipality) participated in the Forest Health project. Of this total, 220 students were in middle school and 118 were in high school. A manuscript focusing on the activities developed under the project was in preparation as of late 2021.

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BRAZIL - PROJECT 4-445: FUNCTIONAL DIVERSITY OF INTERRELATED PHOTOSYNTHESIS AND WATER USE OF CENTRAL AMAZONIAN TREES

PI: Tomas Domingues, University of Sao Paulo
U.S. Partner: Pierre Gentine, Columbia University (Funded by the National Aeronautics and Space Agency)
Dates: November 2015 – July 2022

PROJECT OVERVIEW

This project was intended to generate novel understanding on the diversity of plant traits related to water use and photosynthesis. The functional diversity present in a given community is a key dimension of biodiversity that effectively modulates how forests respond to disturbances, such as logging, precipitation, and temperature extremes or the increase in carbon dioxide concentration. It also determines the extent of the feedback between forest and climate, therefore informing us on possible consequences of forest mortality or land use change. To better predict the resilience of the forest and its capacity to provide ecosystem services, it is essential to evaluate the current spectrum of functional diversity, still a major unknown component in biodiversity research. Dr. Domingues and his colleagues set out to use a new approach looking at the carbon and water cycles as fundamentally coupled at both the leaf and tree level. In order to achieve a qualitative and quantitative assessment of water and carbon strategies by Amazonian trees, they planned to continuously monitor both the transport of water in tree trunks and the continuous expansion and contraction of the tree's bole diameter, which relates to water storage, mobilization of photosynthetic products, and growth. This was complemented by leaf-level measurements of photosynthetic apparatus and hydraulics to comprehend the individual link of photosynthesis with water usage. This novel dataset was intended to demonstrate the coupling between transport of water and carbon within trees and how it relates to forest productivity. The new data was intended to be applied to broader scales by using land-surface and ecosystem models to simulate the interaction between forest and atmosphere at different scenarios of functional diversity.

The proposed research intended to shed light on the role of biodiversity not only in maintaining and improving quality of life for inhabitants of the Amazon region but also for improving water security in other areas. By characterizing current variability in water and carbon use strategies expressed by Amazonian trees, it is possible to assess how much biodiversity loss within this group is tolerable, without seriously compromising ecosystem functioning. The information generated by this project was intended to help in evaluating ecosystem integrity in areas where disturbance has already occurred. This research was also intended to aid in guiding species selection for vegetation restoration efforts.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project supported extensive field work in the Amazon that, in addition to the many research outputs, provided valuable hands-on training for students to develop their skills in tropical ecophysiology. The PI Dr. Domingues notes that the financial support provided by PEER enabled several students to start their careers studying the tropical rainforest biome. His team included 12 students (four postdocs, a PhD student, four Master's students, two undergraduates, and a technician), 75% of whom were female. One highlight of the project was the successful PhD thesis defense of Dr. Maquelle Garcia, who worked on the PEER project since its early days, beginning as a Master's student and completing her PhD research with PEER support. She had her first manuscript published by the Journal of Experimental Botany (see citation below) and had two more manuscripts in preparation at the time of the final report on the project. Maquelle accepted the offer of a postdoctoral position in the United States beginning in January 2022.

Thanks to PEER funds, Dr. Domingues and his team obtained several key pieces of equipment, including a gas exchange monitoring system, a portable photosynthesis measurement device, and 100 high-precision automated dendrometers. One important aspect of this project involved monitoring a large number of tree species (about 100) to determine their water use behavior. Through transpiration, trees transfer large amounts of water from the soil to the atmosphere. This transpired water helps maintain high precipitation rates within the Amazon, but it also exports some moisture to other regions of South America. The PEER team used their new automated high precision dendrometers (also called "tree huggers") to gather useful data efficiently. The quality of their work has been reflected in several publications in high-impact journals. A list of the most recent major publications associated with PEER support is included below.

Although the PEER project has ended, Dr. Domingues and his group will continue their work in the Amazon, working in partnership with colleagues from other Brazilian universities through their involvement in the AmazonFACE program (https://amazonface.unicamp.br/en/).

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BRAZIL - PROJECT 4-299: MONITORING THE DISTURBANCE OF MICROBIOTA IN AMAZONIAN SOILS DURING THE CONVERSION OF FOREST TO PASTURE AND ITS CONSEQUENCES ON CATTLE HEALTH

PI: Ederson Jesus, Embrapa (Brazilian Corporation of Agricultural Research)
U.S. Partner: James Cole, Michigan State University (Funded by the National Science Foundation)
Dates: October 2015 – December 2019

PROJECT OVERVIEW

Pandemics of "swollen face," a bacterial-origin periodontitis disease that afflicted ruminant livestock, were correlated with deforested areas in Brazil (Döbereiner et al., 2000). This disease, also known as "lumpy face," was commonly reported in Brazil during the 1960s and 1980s. Recently observed cases had been noted in sheep and goat flocks in the Amazon, exhibiting the same epidemiological conditions and characteristics as those observed in bovines. In such circumstances, the disease had destroyed up to 90% of the affected herds.

Dr. Jesus and his project collaborators hypothesized a link between the "swollen face" disease and shifts in the soil microbial communities as a consequence of deforestation and pasture introduction. This hypothesis was based on previous evidence showing that the disease was triggered by deforestation, which in turn led to significant changes in the soil communities, favoring specific populations such as actinomycetes. The team's Phase I objective was to characterize correlations between the soil environment, changes in the microbial community due to deforestation, and the occurrence of this disease. Once they identified more specific correlations, in Phase II they experimentally tested hypotheses generated through isolating key microbes and using both culture-dependent and independent techniques. Answering these questions was important to advance toward a cure for the disease and to design monitoring methods and alternative management strategies to reduce its incidence. Additionally, confirming the link between the occurrence of diseases, deforestation, and changes in biodiversity contributed to the delineation of policies to hinder deforestation and promote biodiversity conservation. As part of the effort, Dr. James Cole, a U.S. Government-supported partner, provided training and support with bioinformatic analysis of the datasets, sharing analytical tools he used in his own research.

The world's growing population and their increasing demand for animal protein had raised concerns over the pressure to create new pastures to meet this demand, especially in countries like Brazil, which was the world's leading beef exporter. New pastures were created at the expense of native lands, including the Brazilian Amazon. In fact, pasture introduction was the major driver of deforestation in the region, and alternatives to reduce this pressure were needed. Within this context, the project contributed information to support policymakers in their decisions, as well as to create alternatives for the sustainable management of pre-existing pasture lands. The results of this project also contributed to designing sustainable, innovative management systems, such as the integrated crop-livestock-forest system, which had been recognized by the FAO, the Ministry of Agriculture of Brazil, and Embrapa as an alternative to stimulate the use of pre-existing pasture lands, guarantee food and agricultural security, and discourage the deforestation of new areas for agriculture and livestock production.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project concluded at the end of September 2021 after six years of dedicated efforts by the PI Dr. Ederson Jesus and his colleagues. Dr. Jesus reports that they achieved all their Phase I objectives on the project, including (1) carrying out a prospecting survey of livestock swollen face disease in regions threatened by deforestation; (2) characterizing the pasture systems; and (3) applying multivariate methods to identify variables correlated with occurrence of the disease. All field collection and DNA sequencing activities were completed, and although the project has ended, the researchers continue to prepare additional manuscripts and student dissertations. Members of all three subgroups working on the project (Embrapa Agrobiologia, Embrapa Solos, and UNESP) have integrated their data, drawn some conclusions about some of the patterns found, and raised new hypotheses to be tested in the future. Regarding Phase II on the project, the researchers concluded the field experiment and laboratory activities. Co-PI Dr. Iveraldo Dutra and his team did a careful evaluation of animal health and sampled soil and grasses during the field experiment in Araçatuba. They finished DNA extraction from the soil and animal samples and expect to have sequence data to analyze in early 2022.

Several expeditions were carried out during the project, including five trips for soil characterization and microbiological sampling in five municipalities. Soil physical, chemical, and microbiological attributes were measured for at least 92 sampling points, which also included the examination of litter bacterial communities in the forest. Fifteen soil profiles were examined, providing a comprehensive survey of soils in the studied farms. More expeditions were carried out for veterinary work, including 14 expeditions to farms and four slaughterhouses in eight municipalities in the Amazon region. A total of 334 animals were examined on rural properties, and samples of subgingival biofilm from 54 animals and ruminal fluid from 22 animals were collected. These samples were sent for 16S rRNA gene sequencing and the results evaluated by bioinformatics analysis.

The prevalence of periodontal lesions in cattle in the evaluated areas ranged from 10.4% to 71.4%. These results show that periodontal diseases are common in cattle herds, but their occurrence is still neglected. The publication of these data will help to show that periodontal diseases are an extremely relevant health problem for livestock. The sequencing results show that there are differences in the composition between the dental microbiomes of healthy and sick animals, both for cattle, sheep, and goats. These results will contribute to the identification of potential pathogens and will help in the development of control and prevention measures for periodontal diseases in ruminants.

Regarding the relationship between the soil environment, microbiota, and animals, as reported in the previous sections, Dr. Jesus and his colleagues were able to identify soil, microbiological, and forage variables linked to a higher incidence of periodontitis. The results give support to a multifactorial relationship with the environment, with changes also observed at the level of microbial communities. As previously mentioned, their preliminary assumption is that the highest alpha and gamma diversities associated to a greater number of modularity classes in network analysis, indicates that the microbiota of high-severity level (HSL) pastures are reflecting intense environmental stress, characterizing its dysbiosis. This is a hypothesis that should be tested in the future, and the researchers expect to confirm it in their analysis of sequencing data coming from Phase II. The hypothesis that Actinobacteria may be involved was also supported by their higher abundance and the higher abundance of Streptomycin synthesis genes in HSL pastures. Based on these results, the team identified potential factors related to the incidence of the disease. The results point to new hypotheses that will help advance the comprehension of the interaction between the soil environment and the periodontal disease. Now that the researchers finally have results that can help in understanding the link between periodontal disease in cattle and their environment, these results will be important to guide future studies aiming at improving management practices to reduce the impacts of the disease. Dr. Dutra's team has made significant progress in understanding the microbiome related to the disease itself, and that will contribute to the identification of potential pathogens and help in developing control and prevention measures.

Although the PEER project has ended and his primary U.S. partner Dr. James Cole has retired, Dr. Jesus will be continuing to collaborate with U.S. co-partner Dr. Adina Howe of Iowa State University. In fiscal year 2022, he has been awarded a Joint Genome Institute Community Science Program Annual Grant, funded by the U.S. Department of Energy, to sequence soil metagenomes from forest and pasture soils with a focus on environmental sustainability: https://jgi.doe.gov/our-projects/csp-plans/approved-proposals-fy22/ The major goal is to study the role of microbial communities from soil organic layers of the forest and pasture in nutrient cycling. The project will be carried out in collaboration with Dr. Howe, and the JGI award will pay all sequencing costs and give support with data analysis (an estimated value for these services is approximately US $100,000). Dr. Jesus and his colleagues will sequence 3 Tb of data for 60 metagenomes.

Dr. Dutra's team has established a scientific partnership with a group of researchers from the United Kingdom (University of Glasgow) and Netherlands (University of Amsterdam) established since 2015. These researchers contributed with data analysis and bioinformatics analysis. We have established contact and intend to expand this partnership with researchers from other universities (University of Liverpool and University of Surrey) since we intend to develop an epidemiological study about dental diseases in the United Kingdom. Dr. Dutra's group recently established a connection with researchers from Portugal (University of Évora) with the aim of working to define how diet contributes to the development of periodontal diseases. The researchers are also in contact with ASTRE (Animal, Santé, Territoires, Risques et Ecosystemes), a research unit in Montpellier, France, devoted to the study of the relationships between health and the environment. They remain eager to establish new contacts with other research institutions looking to establish collaborations and develop new projects to advance their findings.

PUBLICATIONS

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BRAZIL - PROJECT 4-209: LIDAR REMOTE SENSING OF BRAZILIAN AMAZON FORESTS: ANALYSIS OF FOREST BIOMASS, FOREST DEGRADATION, AND SECONDARY REGROWTH

PI: Jean Ometto, Instituto Nacional De Pesquisas Espaciais
U.S. Partner: Michael Keller, USDA-Forest Service (Funded by the National Aeronautics and Space Agency)
Dates: November 2015 – March 2021

PROJECT OVERVIEW

Recently, the Earth System Science Center (CCST) at INPE had received substantial funding from the Amazon Fund-BNDES to enhance understanding of land use change and carbon budgets in the Brazilian Amazon. As part of this project, INPE had planned to contract LIDAR (light detection and ranging or laser scanning) remote sensing flights to acquire forest structure information over the Amazon that could be used to enhance our understanding of forest biomass. These data were intended to substantially overcome the current limitations of insufficient and biased sampling of the Brazilian Amazon forest and provide the first large-scale, statistically balanced characterization of forest carbon stocks across the Amazon region. The experimental design aimed not only to estimate carbon stocks across the region but also to identify the proportions of forest that were currently secondary or degraded and thus potentially large carbon sinks in the future. The LIDAR data, calibrated by a network of ground-based forest inventories, was used to achieve three objectives:

1) Reduce the uncertainty in the quantification of the above-ground carbon stocks of the forests of the Brazilian Amazon.
2) Provide improved estimates of carbon emissions from deforestation and avoided carbon loss from reducing deforestation policies in the Brazilian Amazon region.
3) Improve our ability to predict future carbon fluxes in the Brazilian Amazon by quantifying the current biomass status of secondary and degraded forests.

This project aimed to improve the estimation of carbon emissions from deforestation in the Brazilian Amazon and construct a sound basis for future emissions scenarios, considering different options of land use and land cover change. Several strategies, policies, and compensation mechanisms had been proposed to minimize the impact of human actions on the natural forest. Among those, the effective implementation of REDD+, soy and beef moratoria, and the establishment of conservation units benefited from a better calculation of the balance between carbon emission by deforestation and forest degradation, and uptake, by secondary vegetation and mature forest growth. Through capacity-building activities, the project had trained young researchers in LIDAR estimatesof biomass, statistical biomass modeling and mapping, and emissions modeling. The data gathered was intended to become a resource for the Brazilian Ministry of Science, Technology, and Innovation to produce the National Inventories on GHG emissions. The Brazilian Earth System Model, which was under development at INPE and associated universities and research institutes, was also an obvious client of the planned database. Finally, through its leadership in forest monitoring activities, Brazil had the potential to share its knowledge and technologies with neighboring countries, especially those of the Amazonian Cooperation Treaty Organization.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the final year on this project, which ended on March 31, 2021, Dr. Ometto and his team focused on publishing their results and performing extra analysis on lidar data sets and satellite imagery. They expanded the study to include the region bordering the Amazon, entering the Cerrado area in cooperation with another collaborative scientific project. Despite the COVID-19 pandemic situation in Brazil and respecting all security protocols, in late 2020 the researchers were able to carry out field data collection activities in the Amazon and transition areas with the Cerrado as planned. The information collected will be part of a future scientific publication. During this pandemic period, they also took the opportunity to write scientific articles and organize online meetings to discuss partnerships and contributions to other publications. Plans for in-person events, however, were seriously impacted, and no such events could be organized.

The results from this project include 11 published papers so far, as well as a large collection of data available on Zenodo, an Open Access digital repository where researchers from any field of science can share their findings: https://zenodo.org/record/4557390#.YRqi7ohKgn9. In addition, in terms of potential policy impacts, Dr. Ometto reports that the biomass map of the Amazon region produced with the help of PEER funding has been incorporated in several efforts in Brazil beyond the scientific publications mentioned. The PEER team communicated with the Brazilian Ministry of Science and Technology to provide inputs to the Brazilian National Communication to the United Nations Framework Convention on Climate Change. The biomass map was also incorporated into the Emission Model developed by the National institute for Space Research (INPE) and is included in other initiatives like the MapBiomas. Although PEER support has ended, the PI and his colleague plan to continue collaborating with their counterparts in the United States and elsewhere to advance their studies of Amazon forest dynamic, structure, and biomass content, including field recalibration, interpolation, and comparison to other databases (e.g., NASA's Global Ecosystem Dynamics Investigation) and remote platforms.

PUBLICATIONS

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BRAZIL - PROJECT 4-123: WHERE IS MY TURTLE? QUANTIFYING BIODIVERSITY IMPACTS OF HYDROELECTRIC EXPANSION AND RIVER USE CHANGES IN THE BRAZILIAN AMAZON

PI: Darren Norris, Federal University of Amapá
U.S. Partner: James Gibbs, Suny College of Environmental Science and Forestry
(Funded by the National Aeronautics and Space Agency)
Dates: October 2015 – June 2020

PROJECT OVERVIEW

Semi-aquatic species are impacted by hydroelectric developments and river use changes, and to engage multiple stakeholders (from children to local landowners to electricity companies) Dr. Norris and his colleagues chose to focus on conservation of the river turtle Podocnemis unifilis within a unique socioeconomic development scenario (Amapa State). P. unifilis represent provisioning (food, source of income) and cultural services for Amazon populations (Vogt 2008), and unlike charismatic mammal species like the Giant Otter (Michalski et al. 2012), river turtles do not generate negative perceptions in local human populations (Norris & Michalski 2013). Additionally, river turtles depend on both terrestrial (nesting) and aquatic (feeding/reproduction) environments, which provides multiple opportunities for achieving engagement, research, and biodiversity conservation objectives. In sum, river turtles are thus ideal biodiversity conservation "flagship" species that deliver important ecosystem services and elicit strong affinity in people for the conservation of wild species and their habitats. However, no previous study has robustly quantified a P. unifilis population. A variety of approaches have been used but none incorporate detectability. As such, previous studies only provided estimates of minimum or maximum numbers, which are not suitable for comparison (Norris et al. 2011) and are not associated with population parameters required to inform conservation actions. By integrating data from multiple techniques this project team aimed to provide a robust assessment of P. unifilis movements and demographics. The project also integrated participation of local schools, regional postgraduate courses, lecturers, researchers, students, and people from riverine communities to transfer knowledge and help to create and foster new practices.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team, alongside local community members, participated in 34 field visits accumulating a total of 8606 km of river-based boat surveys that resulted in 868 detections of individual turtles along the rivers. Over the PEER project period, researchers also monitored 384 nesting areas over the course of five months each year to collect data on the number of turtle nests, and hatchling success. From those 384 nesting areas, they selected a subset of 29 for more intensive monitoring and development of community-based management actions. These actions focused on protecting nests from losses due to predation (e.g., lizards and birds) and flooding.

During the 2019-2020 turtle nesting season, team members successfully installed a river level monitoring system and were able to avoid the most serious nest flooding impacts. Together with the local communities, they took preventive actions so that no eggs were submerged in 2019, in contrast to the devastating losses suffered during the previous year's nesting season. The new technology provided reliable real-time data that helped avoid the flooding and loss of hundreds of eggs and saved more than 200 hatchlings.

Results from the PEER project were shared through several publications, dozens of technical presentations, and conferences. The team developed extracurricular activities for children from three local schools, using conservation of the tracajas as learning inspiration, and helped clean beaches around the reservoir formed by the dam, which are used by both people and turtles.

The PI contributed to a "Green List" Assessment of the turtle species Podocnemis unifilis for inclusion and evaluation by the International Union for Conservation of Nature (IUCN). This was carried out in collaboration with Dr. Molly Grace at the University of Oxford (UK). A Green List assessment is an optimistic vision of species conservation that presents a road map on how to preserve a species and facilitate its recovery.

The research has also contributed to several National Biodiversity Targets for Brazil and informed mitigation strategies to reduce biodiversity losses following the construction of the dam. This includes a proposal for the restoration of turtle nesting areas that is included in the ongoing licensing renewal process for the dam operator.

PUBLICATIONS

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BRAZIL - PROJECT 4-082: LINKING SUSTAINABILITY OF SMALL-SCALE FISHERIES, FISHERS' KNOWLEDGE, CONSERVATION, AND CO-MANAGEMENT OF BIODIVERSITY IN LARGE RIVERS OF THE BRAZILIAN AMAZON

PI: Renato Silvano, Federal University Of Rio Grande Do Sul

U.S. Partner: Kirk Winemiller, Texas A&M University (Funded By The National Science Foundation)

Dates: October 2015 – June 2018

PROJECT OVERVIEW

The occurrence and efficacy of local co-management initiatives to promote biodiversity conservation or sustainable use of natural resources were largely unknown for most of the Brazilian Amazon, especially in the less productive black and clear water rivers. This project took a multidisciplinary approach through an integrated analysis of fishers' local ecological knowledge, fishing dynamics, and fish ecology to evaluate potential ecological and socioeconomic outcomes of co-management systems in clear and black water rivers. The researchers addressed the following main research questions:
(1) Did fishing communities that were organized in some form of co-management system (for example, inside extractive reserves) have higher fishing yields, abundance of fish, and fish diversity?
(2) Did the outcomes and problems related to co-management differ between clear and black water rivers? (
3) How did fishing intensity and co-management influence the abundance of frugivorous and detritivorous fishes and their functional roles in these two river systems?
(4) Did fishers' knowledge provide data about temporal trends on fish abundance, fish ecology, and main fish species caught that supported fishers' food security?

Dr. Silvano and his team studied four fishing communities inside and four outside Extractive Reserves (RESEX) in the clear water Tapajós River and in the black water Negro River, and all results were compared between these two rivers and between communities with (inside the RESEX) and without (outside the RESEX) established co-management systems. The collaboration with the U.S. partner and his group complemented the project goals regarding fish ecology; comparison of fish abundance, composition, and diversity among fishing communities and between rivers; and analysis of the structure of fish communities. The planned analysis improved understanding on potential drivers (ecological or economic) of unsustainable fishing practices that undermined conservation efforts.

The results of this research provided invaluable empirical information that was previously lacking to promote governance and guide conservation policies aimed at Amazonian aquatic ecosystems. The project team's results helped policy makers, government technicians, and natural resource managers to devise measures to alleviate the environmental pressures and to reconcile biodiversity conservation with fisheries sustainability. Findings from this project were transferred to managers of the two studied Extractive Reserves, and the local communities were informed about project results during a workshop at the end of the project and through the publication of a book for laypersons. The knowledge and training provided to fishers, the participation of managers from the Brazilian Institute of Biodiversity Conservation, and the possible engagement of local associations enabled the continuity of resource monitoring and improvement of management activities after this project ended. This research thus enhanced the resilience of the studied communities by building the capacity of local people to manage their resources, to negotiate with other stakeholders, and to cope with future changes in resources or the environment, such as dams or climatic alterations affecting the flooding regime.

FINAL SUMMARY OF PROJECT ACTIVITIES

During this project, which was completed at the end of June 2018, the PI Dr. Silvano and his team made nine fieldtrips (four to the Rio Negro and five to the Tapajos) to gather data on fish and fisheries and to organize meetings with people from the communities participating in the research. They carried out 64 collections of fish, 32 in each river, corresponding to two samples in each of the eight studied communities in each river during two seasons (high and low water). All told they collected and measured 12,437 individual fish in both rivers, some of which were brought to their lab to be identified and to be preserved as voucher specimens. Although the final number of fish species should be confirmed soon after being double-checked by an ichthyologist specialist on Amazon fishes, as of September 2018 the researchers had already confirmed the occurrence of 192 fish species, 111 species in the Tapajos and 144 species in the Negro (some fish species occur in both rivers). During the fieldtrips the team also took more than 2,000 photos of individual fish of all collected species, to record them with their live, natural coloration. These data will be part of a book that Dr. Silvano and his colleagues are compiling, to be published by Springer later in 2018. Data on the fish sampled will provide information about the occurrence and abundance of fish species that are important for commercial or food purposes, besides allowing comparisons of fish abundance among communities located inside and outside the extractive reserves. Fish samplings could also provide useful data about some fish biological parameters, such as length-weight relationships, which can be included in fisheries modeling. These biological data are currently scarce for most fish species from the Amazon Basin, especially in less studied clear and black water rivers.

In addition to collecting samples themselves, the project team also implemented a participatory monitoring program in which some fishers voluntarily recorded their fish landings five days per month over a twelve-month period from July 2016 to June 2017 in the Tapajos and from August 2016 to July 2017 in the Negro. A total of 130 fishers from both rivers participated in this monitoring activity, recording 3,760 fish landings in total that were suitable for analyses (after excluding incomplete or inaccurate data). These data on fish landings provide information about fishing effort, fish species most exploited for food or sale, fish sizes, and spawning activity for some fish species, among other information. During this voluntary monitoring, each fisher entered his or her data on paper forms that were later collected by the researchers. This process helped to involve more fishers in the research and provided some capacity building among the studied communities. However, participation was variable, as not all fishers were able to record their fish landings consistently and diligently on a voluntary basis. Another caveat of this method was the long time and continuous effort required to collate and digitize all data recorded by fishers. To address this issue, Dr. Silvano and his colleagues also conducted a pilot project on monitoring of fisheries by data collectors in each studied community who recorded data on mobile phones through the ODK technology. This pilot project was conducted in three communities of the Tapajos River during three months and showed promising results. The ODK monitoring seems to present a promising option for recording fish landings in remote communities and in a faster way, as it does not require paper and data could be readily downloaded to a worksheet. Therefore, the project helped both the researchers and participating people from the involved communities to develop and to improve their knowledge and skills regarding monitoring of use of natural resources.

The project also involved a considerable volume of interviews with members of local fishing communities. The researchers made a total of 565 interviews in 16 communities on the Tapajos and the Negro in the original project, plus 171 more in a pilot add-on activity, expanding the research to the protected area located on the opposite bank of the Tapajos (National Forest) and to communities located along the banks for approximately 150 km further upstream, as far as the community of São Luiz do Tapajos and the city of Itaituba. These interviews addressed several aspects of fishers' knowledge, environmental changes, fishing dynamics, and socioeconomic issues. The complete database of interview responses could facilitate comparisons not only among communities located inside and outside the protected area, but also along a longitudinal gradient on the Tapajos, which might be useful to evaluate potential future impacts of planned dams to be built upstream, near São Luiz do Tapajos.

Based on their interviews and other data, the project team produced 155 GIS-based maps indicating locations of spawning sites, migration routes, and preferred fishing grounds of selected fish species according to fishers' knowledge. These maps (104 at the community scale, 12 for the entire river, and 39 aggregating data for each studied fish) could be useful to identify and hence protect important habitats for fish reproduction, especially in co-management initiatives at the community level. The researchers also collected and compiled actual and estimated fish size measurements, which could be used to evaluate fishing pressure and the health of fish stocks in the studied rivers. In addition, they collaborated with their U.S. partner's lab to conduct stable isotope analysis of more than 140 fish tissue samples, with more than 200 others still being processed. These analyses should support at least two papers in collaboration with the U.S. partner.

In addition to 21 meetings with the studied fishing communities, Dr. Silvano and his team met three times with Brazilian government officials in charge of the management of protected areas where people reside, such as the two studied Extractive Reserves. During these meetings they highlighted their PEER project results and suggested potential applications to address current problems affecting local fisheries or to support management initiatives. As of September 2018, the PI and his research team had made 31 presentations (oral or poster) on their PEER results in in six countries, and they organized a photo exhibit on their Amazon exhibitions that has been shown in Porto Alegre, Brasilia, Tampa, and Halifax. On the education side of the project, PEER funds supported the successful completion of four MSc. dissertations through the Post Graduate Program in Ecology at UFRGS. These include (1) Small-scale fisheries of frugivorous fish in clear and black water rivers of the Brazilian Amazon, by Paula Nagl (August 2017); (2) Influences of fishing pressure and protected areas on fish communities in two tropical rivers, by Pedro P. Nitschke (May 2018); (3) Fishers' knowledge identifies potential socio-ecological impacts downstream of proposed dams in the Tapajós River, Brazilian Amazon, by Anne Runde (November 2018); and (4) Interactions between fishes, fishermen, and ecosystem services in black and clear water rivers of the Brazilian Amazon Basin, by Astrid Tatiana Romero Martinez at the Pontificia Universidad Javeriana in Bogota, Colombia (March 2019).

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BRAZIL - PROJECT 3-198: BIODIVERSITY AND SOCIOECONOMIC IMPACTS OF PALM OIL BIOENERGY DEVELOPMENT IN THE BRAZILIAN AMAZON

PI: Rodrigo Medeiros, Conservation International Do Brasil, With Co-Pi Luciano Montag, Universidade Federal Do Pará

U.S. Partner: Kathleen E. Halvorsen, Michigan Technological University (Funded by The National Science Foundation)

Dates: October 2014 – June 2019

PROJECT OVERVIEW

This research project focused on biofuel development impacting forested systems, one of the most controversial types of energy development at the time (NRC-NAS 2011). The research was expected to advance sustainability science and further understanding of the impacts of palm oil biofuel development on socioecological systems in Brazil. Clean renewable energy policies, biodiversity conservation, and economic development are often studied, but typically in isolation. Utilizing an in-depth case study approach, the project fully integrated social and ecological scientific methods. The main benefits of this research were: (1) understanding rural community-level socioecological impacts of palm oil expansion; (2) designing policy measures that promoted continuous social inclusion and biodiversity-friendly palm oil production; (3) developing new sustainability science indicators and metrics using results from the socioeconomic and biodiversity studies; and (4) increasing the research capacity of Pan American partner institutions for graduate and postgraduate student education specializing in sustainability issues.

The results of this research project had important consequences for the long-term sustainability of biofuel feedstock, human communities, and biodiversity conservation. The project's final results were shared at relevant national and international conferences and also with key regional and local stakeholders in efforts to improve small landholders' economic benefits from palm oil and facilitate the inclusion of marginalized groups in the palm oil sector. Policy recommendations from this research assisted Brazilian government institutions in policy development to increase local and national socioeconomic benefits, promoting energy independence and small landholder's inclusion, while minimizing impacts on existing biodiversity, hence achieving sustainability. The expected project impacts were closely aligned with USAID's interests, particularly in the biodiversity, environment, and agriculture categories, as the project's final goal was to suggest a sustainable and economically viable palm oil agriculture model in Brazil that could be a model for other developing countries in the region. Consistent with USAID's approach, this project took a cross-sector approach addressing major threats to biodiversity conservation, economic growth, and, to a lesser extent, human health and global climate change.

FINAL SUMMARY OF PROJECT ACTIVITIES

Biodiversity Monitoring:

Over five years, Conservation International conducted extensive biodiversity monitoring in the Brazilian Amazon. The team cataloged numerous species across various taxa: 270 birds, 74 fishes, 33 amphibians and reptiles, 32 spiders, 36 bees, 119 ants, 25 flies, and 78 genera of aquatic insects. Notably, 22 species were endemic, rare, or new to science, underscoring the critical importance of continued biodiversity assessments in the region. Comparisons between legal reserve forests and palm oil plantations revealed distinct differences in fauna diversity and abundance, with unique species found in both habitats. The data also confirmed that conserved riparian forests maintain superior environmental quality.

Socioeconomic Analysis:
The socioeconomic study focused on the Tomé-Açú microregion, a significant producer of Brazilian palm oil. Despite high GDP from agricultural commodities, per capita income remained low, with significant unemployment and low educational attainment levels. A survey across 21 communities assessed the local perception of palm oil expansion, revealing mixed impacts on environmental and socioeconomic conditions. While some viewed the expansion positively for economic reasons, concerns about environmental degradation were prevalent, especially among those not directly involved in palm oil farming.

Geodatabase Analysis:
Geodatabase analysis highlighted that 70% of the region is degraded, with ongoing threats from low-productivity agriculture and livestock grazing. Despite this, the 2010 Palm Oil Agroecological Zoning (ZAE) identified suitable areas for cultivation that avoid direct forest displacement. The analysis suggested potential for using degraded lands for palm oil production, aligning with sustainable development goals and forest restoration efforts. Importantly, current legislation and RSPO criteria ensure that new palm plantations do not replace primary forest areas directly.

Impact and Continuation:
The project's findings are critical for informing sustainable land use and conservation strategies in the region. Conservation International plans to continue related efforts with support from Agropalma and is exploring additional projects focused on landscape restoration in the Belém Endemism Center. The comprehensive data collected provides a foundation for ongoing environmental governance and policy development to balance economic growth with biodiversity conservation in the Brazilian Amazon.

BRAZIL - PROJECT 3-188: BIODIVERSITY CONSERVATION AND SCIENTIFIC CAPACITY DEVELOPMENT IN THE BRAZILIAN AMAZON USING ANTS AS BIOINDICATORS AND ECOSYSTEM HEALTH INDICATORS

PI: Rodrigo Feitosa, Universidade Federal Do Paraná
U.S. Partner: Kenneth G. Ross, University of Georgia, Athens (Funded by the National Science Foundation)
Dates: September 2014 – September 2018

PROJECT OVERVIEW

The Amazon remains one of the most biodiverse regions in the world, yet it continues to face threats from human encroachment and global climate change. Historically, biodiversity research has primarily focused on vertebrates, often neglecting other taxa that are arguably more crucial for ecosystem health and function, such as insects. This is particularly true for ants, which are incredibly species-rich, ecologically diverse, and have the highest biomass of any animal group in the Neotropics. Ants act as key ecosystem engineers, encompass various guilds, and are often highly sensitive to environmental changes, making them ideal bioindicators. Using ecologically relevant bioindicators has provided highly sensitive insights into rapid changes in habitat health and ecosystem function. Unfortunately, a taxonomic impediment has limited their use, as many tropical species remain undescribed or new to science, significantly slowing morphological species identification. This research study aimed to address this shortcoming by conducting an inventory of ant diversity using DNA sequence data. The collected samples formed the nucleus for a growing entomology collection at the Universidade Federal do Paraná (UFPR), which was developed into an active research collection to support the study of systematics, biodiversity, and natural history of the ant fauna of the Amazon and Brazil.

Ants include several important tropical agricultural pests and invasive species. Thus, the project was crucial for Brazilian agriculture and food security as it identified potential pest species. Assessing ant biodiversity at various levels and assigning species to functional guilds laid the groundwork for continued monitoring of ecosystem health and biodiversity under climate change and helped inform conservation decisions by enabling rapid and efficient appraisal of ecosystems. The development of inexpensive and rapid genetic identification tools was expected to have an immediate and lasting impact on biodiversity assessment and conservation practices in the Amazon. Coupling genetic and species-level biodiversity assessments with ecological functional information improved the economic valuation and management impact of ecosystems. This strengthened environmental governance and advanced sustainable management of natural resources and biodiversity conservation in the face of environmental and global climate challenges. The use of genetic markers allowed in-depth understanding of pest and bioindicator population genetics and dynamics, important considerations in developing and applying control or conservation management plans. Additionally, the generation of high-throughput DNA barcoding and next-generation population genomic data laid the foundation for cutting-edge science, technology, and innovation in conservation genetics and biocontrol, providing a long-term investment for the PI, Dr. Feitosa, to develop and train genomic capacity in Brazil.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the third quarter of 2018, as the project moved towards completion, Dr. Feitosa and his team carried out two final field expeditions. In July, the PI and three students (Mila Martins, Natalia Lópes, and Alexandre Ferreira) undertook a collecting expedition to the Serra Bonita Reserve, in the state of Bahia, northeastern Brazil. The last expedition took place in late August and marked the first international field trip of the project. Alexandre Ferreira and Maria Fernanda Almeida collected ant specimens at the Station des Nouragues, a scientific reserve of the French National Centre for Scientific Research (CNRS) in French Guiana, near the border with Brazil. Both the Serra Bonita and the Station des Nouragues areas are strategic localities for the broad approach of this project, as they represent distant and physiognomically distinct regions of the Amazon Forest. The specimens collected will allow the team to test the genetic structure of the ant assembly in the Amazon in a more robust way.

During the expeditions, the researchers once again had the opportunity to organize meetings with the leaders of local environmental agencies and small villages to present the project and explain the importance of scientific research for the conservation of natural areas using ants as models. The ant samples recently collected are being processed and will be soon submitted for DNA extraction and analysis. In a parallel action, once again the PI and his group established an agreement with the Curitiba City Hall to develop scientific capacity activities at public primary schools in the city. In particular, they carried out a second edition of the “Scientists Go to School” project, visiting two primary schools in Curitiba, the Ana Hella Primary School and the Madre Teresa de Calcutá Primary School. They developed small workshops and scientific activities with financially vulnerable children (4-10 years old) and demonstrated routine operations from their field work in the Amazon.

To sum up the results and impacts, during the four years of project, which ended as of September 30, 2018, three scientific papers were published and many more are expected in the coming months. Around ten presentations about the project results were made in at least five different international events, and the PI and his team organized one major event, Fomigas do Brasil 2016. They completed six field expeditions to some of the most remote biodiversity host-spots in the Brazilian Amazon. Thousands of ant samples were collected and submitted according to original protocols for processing, DNA extraction, and sequencing using Ultra-Conserved Elements that were developed as part of this project. These samples encompass a considerable number of new species and will be extremely valuable in suggesting interesting questions in ant evolution, ecological importance, and much more broadly. During the project, the researchers conducted a series of meetings and workshops with local agencies and financially vulnerable people at the study sites and primary schools. They also established an extremely advanced research center for the study of evolution, diversity, and taxonomy of ants. A total of 17 young students, 12 of them female, were scientifically trained and developed Master’s, PhD, and undergraduate theses within the scope of the project. Finally, the PI expects that the results will form the basis for a series of public policy recommendations on the collection, comparison, and conservation of the arthropod soil fauna, especially ants. Some of the results of the project are still to be achieved. However, the team’s new collecting protocols and storage techniques have proven to be of essential importance to the development of a standardized methodology to access, collect, process, store, and genetically sequence the most diverse samples of ants. This protocol has the potential to be widely employed in ant surveys at a global scale. In fact, the PI has already proposed a secondary project, “Ant-PELD,” an initiative to collect, process, and sequence ants for all the Brazilian biomes, using the protocol originally created in his PEER project. Meanwhile, the proposed molecular protocol for DNA extraction and analysis for ants using Ultra-Conserved Elements is already a reality not only in the PI’s working group but also in many other myrmecological labs around Brazil. Researchers from different institutions in the country are already sending the PI samples from various localities in order to have the material analyzed in his recently established and upgraded molecular biology lab.

Regarding the facilities of the Zoology Department of UFPR, PEER support made it possible to create a state-of-the-art molecular biology laboratory, as well as a laboratory equipped with the most advanced optical and imaging equipment. This structure already allows students, not only from Dr. Feitosa's group but also from the entire department, to develop high level research in the areas of evolution, morphology, diversity, and insect systematics. Although the project has ended, this infrastructure is permanent and will facilitate scientific production in zoology at UFPR for a long time to come.

It is also noteworthy that the ant collection of UFPR is now one of the most representative in the world, thanks to the specimens collected during field expeditions of the project and the structure of entomological cabinets, draws, boxes and pins obtained. As for the ant species captured so far, Dr. Feitosa and his team are migrating their data to the Brazilian Biodiversity Information and Authorization System - SISBIO (http://www.icmbio.gov.br/sisbio/) and to the Taxonomic Catalog of the Brazilian Fauna – TCBF (http://fauna.jbrj.gov.br/fauna/listaBrasil/PrincipalUC/PrincipalUC.do?lingua=en). Both systems aim to provide an integrated list of valid genera and species found in Brazil by geographic area and biome in order to inform a public strategy document for the conservation of Brazilian biodiversity. Thanks to the PEER project, the group is the main contributor to these databases regarding the ant fauna in Brazil.

PUBLICATION

Marsh, C. J., Feitosa, R. M., Louzada, J., & Ewers, R. M. (2018). Is β-diversity of Amazonian ant and dung beetles communities elevated at rainforest edges? Journal of Biogeography, 45(8), 1966–1979. Portico. https://doi.org/10.1111/jbi.13357

BRAZIL - PROJECT 3-121: BIODIVERSITY AND CLIMATE CHANGE IN THE "ARC OF DEFORESTATION" OF BRAZILIAN AMAZON

PI: Guarino Colli, Universidade De Brasília, With Co-PIs Ben Hur Marimon Junior, Universidade Do Estado Do Mato Grosso, and Fernanda Werneck, Instituto Nacional De Pesquisas Da Amazônia–Inpa

U.S. Partner: Barry Raymond Sinervo, University of California, Santa Cruz (Funded by the National Science Foundation)

Dates: December 2014 – May 2018

PROJECT OVERVIEW

The expansion of agriculture poses serious threats to natural landscapes across the globe, and tropical forests are among the most affected ecosystems. They have declined to about 65% of their original cover worldwide and are expected to continue to dwindle this century. Biodiversity is concentrated in tropical forests, and the combined effects of habitat loss and climate change are presumably the primary drivers of the global biodiversity crisis. To reduce extinction threats due to climate change and the expansion of agricultural frontiers, studies that quantify the extinction risk of populations/species were identified as a high priority. This research project focused on an integrative approach to investigate the ecology, evolution, and conservation of the Amazon-Cerrado transition (ecotone) in Brazil, one of the most critical areas in the "Arc of Deforestation." This region provided a unique model system to investigate the origins and maintenance of high Neotropical biodiversity and the combined effects of climate change and habitat loss on the biota. In this collaborative project, the research team characterized the herpetofauna (amphibians and reptiles) and assessed its vulnerability to climate change and habitat loss. The goals of the project were: (1) to assess whether the biota of the Amazon-Cerrado ecotone was simply a filtered blend of species from the two neighboring biomes, or whether it also harbored unique (endemic) species; (2) to determine the importance of differentiation along this ecotone during evolutionary time and climatic cycles as a source of biodiversity; (3) to predict and test for contemporary extinctions arising from the combined impacts of habitat loss and climate change using ecophysiological models; (4) to identify evolved traits that enhanced the extinction risk induced by habitat loss and climate change; and (5) to assess the role of indigenous land management practices, which resulted in "black earth" (Terra Preta), upon biodiversity levels and extinction risk.

The project was led by an interdisciplinary team of Brazilian and U.S. researchers. The Brazilian team conducted fieldwork at the selected sites to obtain biodiversity data, including species composition and abundances, ecological traits, tissue samples, and ecophysiological data. In the lab, the researchers obtained additional ecophysiological data and molecular data for phylogeographic and phylogenetic analyses. Ultimately, the goal was to develop critical knowledge for scientists, policymakers, and the public to make informed decisions about how human activities are and will influence the biota and biosphere processes. The results of this research project were expected to increase public awareness of the combined impacts of climate warming and habitat loss on biodiversity at the "Arc of Deforestation" and forest-savanna ecotones and aid policymakers and landowners to make informed decisions about the creation and operation of reserves in the region. A webpage was developed to integrate the results from several projects coordinated by the PI. Web-based tools were also created, allowing conservation biologists to upload georeferenced data and obtain extinction forecasts for their species, based on validated extinction models. Data collected during this project also facilitated a more precise calibration of existing global extinction models in under-sampled regions of the world that are at a high risk of biodiversity loss.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER project involving researchers from three Brazilian institutions was completed as of May 31, 2018. There were 69 participants, more than half of them female, and as of January 2019 they had produced 19 publications with PEER support. So far, the PI and co-PIs have obtained more than $400,000 in additional support from Brazilian and U.S. sources to continue and expand their research efforts. Beyond their collaboration with U.S. partner Barry Sinervo of the University of Utah, PEER funds helped them build linkages with several other counterparts in the United States, the United Kingdom, and Sweden. A vast amount of data has been collected and is publicly available for use by other researchers. The data collected by the UNEMAT team is deposited in the database of the Rainfor Project hosted by the University of Leeds (UK): https://www.forestplots.net/en. The DNA data collected by the researchers at INPA are available through GenBank, and phylogenetic trees are posted in Treebase. For geographic, ecological, and morphological data the INPA group uses repositories such as Dryad Digital Repository and the Biodiversity Research Program-PPBio Amazônia Occidental. Supplementary material for the published articles is found on co-PI Dr. Fernanda Werneck's laboratory page and ResearchGate page, among other locations. Following are summaries of project activities for each of the three Brazilian institutions:

UNIVERSIDADE DE BRASÍLIA – UNB

In this collaborative project, the UNB team characterized the plant assemblages and the herpetofauna (amphibians and reptiles) of the Amazon-Cerrado transition in Brazil, the “Arc of Deforestation,” and assessed their vulnerability to climate change and habitat loss. The researchers conducted fieldwork at selected sites to obtain biodiversity data, including species composition and abundances, ecological traits, tissue samples and ecophysiological data. They also obtained ecophysiological and molecular data for phylogeographic and phylogenetic analyses, developing critical knowledge for scientists, policy makers, and the public to make informed decisions about how human activities will influence the biota and biosphere processes. They produced a wealth of data and results that will positively affect biodiversity conservation in the “Arc of Deforestation” of the Brazilian Amazon and on indigenous lands located in the region. Their results, based on demographic, community, genetic, and ecophysiological data and consolidated in several academic publications, highlight the uniqueness of the region, the major threats to its unique biodiversity, and the susceptibility of its biota to the combined threats of local and global anthropogenic changes in the environment. The PI reports that his results are being used by local and federal agencies to inform environmental governance systems for improved biodiversity conservation in the region. He and his team have also promoted the training of a large number of students and scientists on data acquisition and analysis, which should have a lasting impact on biodiversity conservation and natural resource management in the region.

UNIVERSIDADE DO ESTADO DO MATO GROSSO – UNEMAT

Headed by co-PI Ben Hur Marimon Junior, the team at UNEMAT selected, inventoried, and investigated field sites to gather species composition, biomass, and ecophysiological data. The vegetation types between Amazonian Dark Earth forests (ADE) and non-ADE forests were totally defined and the results are being published in a special issue of Frontiers in Ecology and Evolution (Oliveira et al., in press as of January 2019), as well as other publications. Experiments in greenhouses and field work combining a dataset on the hydraulic performance of plants with an anatomic dataset of the main species found in ADE and non-ADE sites corroborate the team’s original hypothesis regarding the high fragility of ADE ecosystems to the environmental changes caused by both land use and climate changes. They have discovered that global climate changes can be reinforced by local changes due to the deforestation of surrounding ADE areas. Their tests investigating the growth performance under treatment of different doses of pyrogenic carbon (PyC) of the main tree species of ADE and non-ADE sites revealed the capability of PyC in conditioning soil and increasing the survival performance of tree species. However, as yet they have no evidence that PyC can prevent plant mortality due to environmental stressors such as temperature and drought, since their results showed higher vulnerability of ADE tree species compared to non-ADE species. Forest inventories combined with ecophysiological data have provided clear evidence of the threat from both climate change (tree blow down, drought, and heat) and land use (selective logging and deforestation). These results highlight the risks of local extinction due to climate and land use factors. These researchers' findings should be useful in guiding the formulation of public policies for sustainable land use in the Arc of Deforestation of Southern Amazonia to prevent local extinctions.

INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA – INPA

This portion of the project had wide scientific impacts, both in the research group led by co-PI Dr. Fernanda Werneck at INPA and in the fields of scientific knowledge in which the project fits (i.e., diversity, effects of climate change, and conservation of Neotropical fauna). Thanks to the resources and opportunities provided by PEER, Dr. Werneck reports that she was able to recruit personnel in Northern Brazil for training at the undergraduate and graduate levels, including several from minority groups. She and her team carried out field expeditions to sample biological, ecological, and evolutionary data in geographical areas considered as gaps in the knowledge of biodiversity. They collected and analyzed molecular data using on modern DNA sequencing techniques, producing dozens of outputs, including articles published in high-impact journals, manuscripts in preparation for publication, dissertations, theses, and reports. In addition, they have disseminated the scientific knowledge generated to the scientific community and governmental and non-governmental agencies active in the area of biodiversity conservation. This outreach was conducted through publications, training courses, public presentations of results, submissions to biodiversity databases, participation in technical advisory meetings on biodiversity conservation, webpage maintenance, and participation in dozens of interviews and news reports. According to Dr. Werneck, the contributions and impacts of this project to the generation and dissemination of scientific knowledge and training of qualified human resources in studies of evolution and conservation of biodiversity were substantial and fostered the consolidation of INPA and her research group as leading reference points for studies on the evolution and conservation of biodiversity.

BRAZIL - PROJECT 2-515: EPIPHYLLIC COMMUNITIES ON LEAVES AT TROPICAL FORESTS: CAUSES AND CONSEQUENCES FOR LEAF FUNCTIONING AT DIFFERENT SCALES

PI: Bruno Henrique Pimentel Rosado, Centro De Gestão De Pesquisa, Desenvolvimento E Inovação – Cgpdi

U.S. Partner: Scott Saleska, University of Arizona (Funded By The National Science Foundation)

Dates: August 2013 – May 2017

PROJECT OVERVIEW

This project focused on improving our knowledge of the basic ecology of forests so we could better understand the response of plant species based on their interaction with epiphylls, identify their role in the carbon cycle at different scales, and anticipate the effects of climate change and different forest management practices on forests and their functioning in ecosystems. The study provided several intellectual gains and broader impacts to scientists, environmental planners, and students. It also provided a missing link in forest carbon models with the potential for a better understanding of atmosphere-vegetation relationships by examining the influence of leaf traits on epiphyllous communities and leaf functioning. Defining the spatial patterns of the influence of epiphyllous communities on leaf functioning among species and sites was important to assess the overall carbon balance at a particular site. With this clearer understanding, more meaningful models of forest carbon processes were formulated that incorporated leaf surface variables and epiphyllous communities.

Dr. Rosado and his team developed basic science investigations with relevant results for development goals and challenges. This goal was reached by stimulating and supporting the development and dissemination of next-generation instrumentation and maintaining and modernizing the shared research and education infrastructure, including facilities and science and technology centers. A major and broad impact of this study on the public was that it provided the basis for new information that enhanced our understanding of carbon fluxes. This was especially important given that Brazil had recently approved a new Forest Code that resulted in escalating deforestation, increasing the urgency to demonstrate the value and functioning of species. Considering the new paradigm of the green economy that now surrounds this discussion, the researchers produced results on biodiversity research combining floristic, metagenomic, and functional ecology to screen forest leaves. They strengthened partnerships with science centers and similar institutions to develop exhibits in science and involve the public in research and education activities. Data were made available in a timely manner by means of databases and digital libraries, and research and education results were presented in formats useful to policymakers and broader audiences.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project ran from August 2013 through April 2017. In his final report, the PI Dr. Bruno Rosado noted the importance of taking microbial aspects into account in trying to anticipate how the Amazon will respond to global change. In the east-central Amazon, Amphyrrox longifolia, is a very abundant and broadly distributed tree species (Tapajós National Forest, Brazil) but the microbiome has been unknown. The PI and his team evaluated the bacterial community structures associated with the phyllosphere, leaf litter, and rhizosphere of this and other plant species in a pristine Amazon forest through high throughput sequencing of the 16S rRNA gene. They also looked at biological nitrogen fixation rates and tree growth rate to determine the effects of epiphylls on tree and ecosystem functioning. The team has several publications in process as of May 2017, but according to the PI they highlight the need to protect environmental conditions that allow the presence of epiphyllous communities and their effects on Amazon forests.

Beyond the scientific findings, many of which are still being analyzed and prepared for publication, Dr. Rosado considers education and outreach to be among the major impacts of his project. The project helped support the research of three Master's students, three PhD students, and one postdoc. In addition, the field course organized in December 2016 served a diverse group of participants. Many of the students in the course were pursuing their own projects related to important aspects associated with social development and environmental management, and many were brought up in the Amazon in families with limited economic resources. The broad audience for the course (including a student from UFOPA, Angélico Nonato, who ran for vice-mayor in the city of Oriximiná, Pará, during the 2016 elections) helped disseminate the knowledge gained in the project more broadly and facilitated application of the findings and research tools to various contexts in the Amazon. For instance, during the small projects that the students had to conduct during the course, applying the knowledge being taught to them, one group proposed a project to evaluate how epiphylls and functional traits could be associated with differences between forests and agricultural areas in the Amazon, for plants co-occurring in both areas, and the ecological implications of such differences.

As for input into government policy, every year the PI and his team must submit a report on their scientific activities in the federal reserves to ICMBio, a Brazilian federal government agency that manages the National System of Conservation Units, including proposing and creating new units and monitoring and protecting existing ones. In this sense, all the results obtained in this PEER project were shared with them, promoting a better connection between the academic research community and natural resource managers and also promoting improved management practices based on the data collected and scientific recommendations made.

Although the PEER grant has now ended, Dr. Rosado has received two grants totaling more than $80,000 from Brazilian science agencies to support his ongoing research. He continues to collaborate with his U.S. PEER partner and with several Brazilian researchers he worked with on the PEER project. He and his colleagues intend to apply for a joint São Paulo Research Foundation (FAPESP)-U.S. National Science Foundation Partnership for International Research and Education (PIRE) award to support their expanded research activities.

BRAZIL - PROJECT 2-503: MYCOTA ASSOCIATED TO NATIVE HEVEA SPP. IN THE BRAZILIAN AMAZON REGION

PI: Aristóteles Góes-Neto, Centro De Excelência Em Bioinformática, Fundação Oswaldo Cruz (Fiocruz)

U.S. Partner: Priscila Chaverri, University of Maryland (Funded by the National Science Foundation)

Dates: August 2013 - August 2016

PROJECT OVERVIEW

This project aimed to characterize the mycota associated with the socially important and economically valuable rubber trees in the Brazilian Amazon region. The focus was on characterizing endophytic and saprophytic fungi that naturally occur in Brazil and comparing fungal diversity with another region of the Amazon basin, the Peruvian Amazon. The goal was to corroborate the hypothesis that fungal endophytes have coevolved with their host plants to protect them from natural enemies.

The endophytic fungi associated with native rubber trees occurring in the Brazilian Amazon were utilized in the biological control of Microcyclus ulei, the agent of South American leaf blight, which is the scourge of rubber trees. This project added more aggregated value to this important tree of the Amazonian forests, reinforcing the need to avoid the potential loss of useful biodiversity due to deforestation and the expansion of agricultural and livestock breeding frontiers in the Brazilian Amazon region.

FINAL SUMMARY OF PROJECT ACTIVITIES

In this project, the PI Dr. Góes-Neto and his team performed a study of the diversity of fungal communities associated to native Hevea brasiliensis (Hb) in the Brazilian Eastern Amazon. The first stage involved isolating, preserving, and identifying endophytic fungi from Hb leaves and sapwood by culturing. The study areas included Anavilhanas National Park (ANP) and Caxiuanã

National Forest (CNF). In the second stage, they determined the Hb foliar mycobiome by amplicon metagenomics (metabarcoding), with the study areas being Caxiuanã National Forest (CNF) and Tapajós National Forest (TNF).

A total of 335 fungal strains (161 from ANP and 174 from CNF) were adequately isolated in pure culture, which at the time of the final report in 2016 comprised the first biotechnological product of this work: a living endophytic fungal culture collection from the rubber trees collected in the these study areas in Eastern Amazonia, which can be a source of potentially new bioactive natural products. The vouchers (testimony specimens) were preserved in sterile distilled water and stored in CCMB (Culture Collection of Microorganisms of Bahia) (UEFS). The second biotechnology product of the project was the genomic DNA bank of all the isolates preserved in the CCMB. This genomic DNA samples, stored in FungiBrBOL (Brazilian Fungi Barcode of Life) gDNA bank, can be further explored to search protein-coding genes that code for new enzymes with possible industrial applications. All the gDNA bank samples were PCR amplified using the selected primary barcode region for fungi (nrITS, nuclear ribosomal internal transcribed spacer) as the target genomic region and sequenced (traditional Sanger sequencing). The third biotechnological product of the project is the set of all sequences that will be further deposited in NCBI Nucleotide database. Initially, OTUs (Operational Taxonomic Units) were assigned to genus-level identification, since many genera are species complexes, which deserve complementary and extensive taxonomic research. The successfully sequenced and analyzed isolates from rubber tree leaves and sapwood of Anavilhanas National Park belong to the Phylum Ascomycota (Subphylum Pezizomycotina) (92.3%) and only 7.7% belong to the Phylum Basidiomycota (Subphylum Agaricomycotina). Similarly to ANP, the successfully sequenced and analyzed isolates from rubber tree leaves and sapwood of Caxiuanã National Forest (CNP) belong to the Phylum Ascomycota (Subphylum Pezizomycotina) (88.9%) and only 11.1% belong to the Phylum Basidiomycota (Subphylum Agaricomycotina).

The researchers found a highly variable fungal diversity in all distinct scales (regional, local, individual). An unexpected result of the foliar mycobiome was the detection and quantification, for the first time, of Pseudocercospora ulei (South American Leaf Blight - SALB agent) in native asymptomatic rubber trees. This opens up the opportunity to produce potentially patentable products to be developed for commercial utilization in partnership with the rubber industry, such as a diagnostic kit for detection and quantification of P. ulei directly from HB tissue samples. The team has also produced approximately 100 lyophilized culture filtrates of CNF endophytic fungi to perform future antagonistic bioassays against P. ulei in partnership of Michelin Plantations in Brazil.

PUBLICATIONS

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PATENT

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BRAZIL - PROJECT 2-435: BIODIVERSITY AND ADAPTATIONS OF CYP ENZYMES IN THE AMAZON LORICARIIDAE FISHES

PI: Thiago Parente, Fundação Oswaldo Cruz (Fiocruz) (Formerly at Universidade Federal Do Rio De Janeiro)

U.S. Partner: Mark Hahn, Woods Hole Oceanographic Institution (Funded by The National Science Foundation)

Dates: September 2013 – December 2016

PROJECT OVERVIEW

CYP1 enzymes are responsible for the biotransformation of natural compounds and anthropogenic pollutants. Typically, reactions catalyzed by CYP1 enzymes lead to detoxification, allowing compounds to be eliminated from the body without causing harm. However, CYP1 enzymes are also known to catalyze bioactivation reactions, in which one of the reaction products is more toxic than its parent compound. The equilibrium between the detoxification (beneficial) and bioactivation (detrimental) roles of CYP1 enzymes had been finely tuned for each vertebrate species over the course of evolution. This PEER Science project was closely aligned with the National Science Foundation-supported work of the U.S. partner, Dr. Mark Hahn, as both involved studying different naturally evolved and selected solutions for the same issue: the balance between detoxification and bioactivation by CYP1 enzymes using fish species as vertebrate models. The adaptation of Killifish, studied by Dr. Hahn, was a well-documented event classified as dramatic, rapid, convergent, and triggered by anthropogenic pollutants that balanced the dual role of CYP1 enzymes at the gene expression level. However, the adaptation of Loricariidae fish was poorly known and likely had the opposite classification: gradual, slow, divergent, and triggered by chemicals naturally present in the fish microhabitat. The goals of this project were to determine whether the adaptations of CYP1 enzymes in Loricariidae fishes were convergent or divergent and how they changed the susceptibility of this species to the toxic effects of petrogenic compounds.

Dr. Parente and his research team sequenced the CYP1 genes of 100 Loricariidae species from the Amazon. These gene sequences were used to determine the enzyme sequences, which were then aligned and compared for amino acid substitutions and interaction with classical CYP1 substrates. Selected Loricariidae species were used for biological assays to evaluate the toxic effects of petrogenic derivatives and their molecular mechanisms of action. Given the current and future prospects for crude oil drilling activities in the Amazon region, it was imperative to understand the metabolism of petrogenic hydrocarbons by Amazonian biota. This was particularly crucial in the case of Loricariidae fishes, as it was already known that these species had CYP1 enzymes with distinct affinity for substrates. It was necessary to determine whether these changes would unbalance the evolved equilibrium of CYP1's dual roles to the beneficial or detrimental side. This knowledge was crucial for better evaluating the risks of oil drilling activities for Amazonian biodiversity.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project was completed as of December 31, 2016, and the PI Dr. Parente reports a wide range of results achieved over its three-year duration. During the first year of the project, he and his team carried out field excursions to the Brazilian Amazon and rain forest areas, resulting in the sampling of more than 300 individual fish belonging to 99 species of Loricariidae and a few other catfish families to be used as outgroups. They extracted total RNA and synthesized cDNA for 56 species, but as stated in their first annual report, “from all the collected species, we could amplify by PCR and sequence by the Sanger method the CYP1A from only seven species.” Thanks to the accessibility of next-generation high-throughput sequencing technology, as well as to the drop in the cost of this sequencing, the PI decided to change the sequencing method from the traditional Sanger to the Illumina HiSeq2500. This, however, was not just a mere methodological change. Instead of sequencing 200 genes, the researchers sequenced the entire set of expressed genes in the liver of 34 species, totaling hundreds of thousands of genes.

The first sequencing batch of transcriptomes was done at the end of the first year of this PEER project, but it was during the second year that most of the transcriptomes were sequenced (a total of 40 liver transcriptomes from 34 species). Six additional non-hepatic transcriptomes were sequenced for the endangered species Hypancistrus zebra. Despite intensive sample preparation and sequencing, the second year was mainly devoted to analyzing the data generated from the first batch of transcriptome sequencing and writing manuscripts describing the results obtained. In this first batch, nine liver transcriptomes belonging to three genera (three fish per genus) were sequenced: Ancistrus spp., Pterygoplichthys anisitsi, and Corydoras nattereri. The team has begun analyzing the transcriptomes of P. anisitsi, with a focus on gene families involved in organismal defenses to chemical threats, the so-called defensome. Although these were their first results, the manuscript describing it was the last one to be published (Marine Pollution Bulletin, 2017) due to the complexity of the data analyses involved. Approximately 5% of the transcriptomic data from the other two species (Ancistrus spp. and C. nattereti) were used to reconstruct their mitochondrial genomes. The manuscripts describing these findings have also been published (Gene, 2015, and Neotropical Ichthyology, 2016).

The third year of the project was marked by intensive data analysis, manuscript writing, and personal developments for all the Brazilian staff directly involved in this project, as natural consequences of the PEER grant. Computational biologist Daniel Moreira was accepted as a PhD student in the graduate program of Systems and Computational Biology at the Oswaldo Cruz Foundation. PI Thiago Parente was accepted as a collaborator professor and received a three-year postdoctoral grant at the same graduate program to act as Daniel’s supervisor. Later, the two undergraduate students in the group, Maithê Magalhães and Paula Andrade, were also accepted at the Master’s level at the same graduate program under Dr. Parente’s supervision. The analyses carried out by each of these three students resulted in manuscripts co-authored with the PI. Two of these manuscripts have been published (Moreira et al., 2016, in Mitochondrial DNA, and Magalhães et al., 2017, in Conservation Genetics).

Although this PEER grant has now ended, the results produced under the project will continue to be analyzed for some years to come. Despite the intense work in data analysis, so far the PI and his team have been able to process the mitochondrial genomes of all sampled species (about 5% of the complete dataset), one gene family in all sampled species (about 1% of the complete dataset), the complete liver transcriptome of one species (about 3% of the complete dataset), and the partial liver and extra-hepatic transcriptomes of four species (about 6% of the complete dataset). By these over-estimated values, only about 15% of the total data produced have been analyzed. Based on previous experience with analyzing the P. anisitsi transcriptome, the PI expects that the on-going analyses and those to come in the near future will be more complex, but they should be even more significant and relevant. As these new results are published, likely in even higher impact journals, Dr. Parente expects to engage the Brazilian environmental authorities more intensively in order to recommend implementation of conservation and pollution monitoring practices. In the meantime, results from this work have contributed to the creation of a new course to be offered in the graduate program of Computational and Systems Biology of the

Oswaldo Cruz Foundation, entitled “Transcriptomes: from reads to results.” It will be offered for 20 graduate students during the second semester of 2017.

The current members of the PEER team have been granted fellowships from Brazilian government agencies in order to continue the work begun under this project. Dr. Parente has a postdoctoral fellowship until May 2019, Mr. Moreira has a PhD fellowship until March 2018, Ms. Magalhães has a Master’s fellowship until March 2018, and Ms. Andrade has a two-year Master’s fellowship that will begin in early 2017. Most of the urgent work is focused on data analysis, so no funds other than these fellowships will be needed. However, several interesting questions have already been raised, so the team is considering applying for additional grants from national and international agencies to fund new experiments over the next years.

COLOMBIA

COLOMBIA - PROJECT 9-269: INCLUSIVE ECONOMIC GROWTH FOR SUSTAINABLE PEACE? ASSESSING DEVELOPMENT MECHANISMS AND CONSERVATION EFFORTS IN POST-CONFLICT COLOMBIA

PI: Laura Bernal-Bermúdez, Pontificia Universidad Javeriana

U.S. Partner: Tricia Olsen, University of Denver (Funded by the National Science Foundation)

Dates: April 2021 – April 2023

PROJECT OVERVIEW

Scholars have sought to understand the impact of peace projects in territories affected by violence, poverty, and inequality, but the evidence base remains weak. This project sought to understand which development pathways are most capable of fostering enduring peace, building inclusive rural development, and promoting environmental sustainability in regions affected by conflict, inequality, and poverty. Using data from Colombia, this project explored the impacts of two development programs: one empowering the private sector (Zones Most Affected by the Armed Conflict, or ZOMAC in Spanish) and one empowering local communities (Development Programs with a Territorial Focus, or PDET in Spanish). Systematic analysis is needed to identify which mechanisms—or combinations of mechanisms—are most effective and where tradeoffs in outcomes may occur. The team's mixed-methods approach provided technical assistance to both public and private institutions in Colombia to promote enduring peace, inclusive development, and environmental sustainability.

This study leveraged differences in these interventions to establish a rigorous evaluation and conduct policy-relevant research and shed light on the environmental footprint of these initiatives. The team also conducted four qualitative case studies to provide contextual evidence for their quantitative findings.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the two-year project, the team undertook research and impact activities to understand and inform the implementation and evolution of two peace and development programs (PDET and ZOMAC) that were designed as a result of the 2016 Peace Agreement with the largest guerrilla group in the country, the FARC-EP. The project team contributed to the evaluation of these programs by building a novel and comprehensive dataset to measure the impact of these programs, as well as models to test for impact.

The researchers also selected four case studies for in-depth research in communities that have received different levels of intervention. Campohermoso (Boyacá) had very similar socioeconomic and violence indicators as some of the PDET municipalities, but it did not receive any intervention because it fell short from the threshold established. Tauramena (Casanare) is a ZOMAC-only municipality. Zambrano (Bolívar) is a PDET municipality with participatory processes and low levels of investment in development projects funded by companies, state entities, or cooperation agencies. El Bagre (Antioquia), now engulfed by high levels of violence because of policies of the new government against illegal mining, is a PDET municipality with high levels of investment of state entities and companies in development projects.

Among their findings were the perception by the communities that after a highly participatory design stage, the implementation stage was appropriated by politicians and technocrats in the capital or at the regional level. Other perceptions identified included low levels of transparency in resource allocation, economic projects that were meant to empower local actors and local economies being rarely funded, conservation policies not being included in the PDET program, and little containment of drug trafficking, which has resulted in increased violence in the territories.

Through mixed methods research, the team developed two policy outputs: a summary with recommendations for policy makers in Colombia (in Spanish), and a policy document in Spanish, English, and French to inform the experiences with peace and development in Colombia and in other countries.

During the course of the project, the researchers established partnerships with other academics in Colombia working on the PDET programs and held an official meeting to discuss their findings with the Agency for the Renovation of the Territory. They also hosted an impact event with 33 attendees from companies, civil society organizations, cooperation agencies, state entities, and academia, where they shared their findings, received feedback, and used a participatory methodology to co-create recommendations to improve the PDET program and the Works for Taxes program.

The project supported the research of a doctoral student, and Laura Bernal-Bermúdez, the original PI of the project, worked on the design of a course for undergraduate students on Peace-Building and Development.

COLOMBIA - PROJECT 9-116: CLIMATE MITIGATION POTENTIAL OF COLOMBIA'S LOWLAND PEATLANDS: DISTRIBUTION, EMISSION FACTORS AND CONSERVATION PRIORITIES

PI: Juan Benavides, Pontificia Universidad Javeriana
U.S. Partner: Erik Lilleskov, U.S. Forest Service
Dates: April 2021 - April 2024

PROJECT OVERVIEW

Peatlands are the most carbon dense terrestrial ecosystems, harboring several times the carbon of non-peatland tropical rainforests per unit area. In addition, they are a major sink for greenhouse gases, with global peatlands storing the equivalent of pre-industrial stocks of atmospheric carbon dioxide in just 3% of the land surface. However, these carbon stocks are vulnerable to land use changes (especially drainage) and consequent decomposition and burning, as well as to the warming and drying impacts of climate change.

Colombia has extensive lowland areas that are known to harbor peatlands, yet very little research has been done to characterize their extent and threats from land use/land cover change, disturbance, and climate change. Global mapping estimates suggest Colombia has about 75,000 km2 of peatlands, second only to Brazil in South America, yet this estimate has not yet been validated by ground truthing Deforestation is also substantial in this region, and both forest fragmentation and fire can have major impacts in the lowlands of Colombia. Because of the lack of information on peatlands, however, the intersections of these land use change and disturbances with peatlands is virtually unknown. This PEER project aimed to fill that gap, using a combination of remote sensing and ground truthing. The team also sought to estimate carbon stocks in these peatlands and gather data on greenhouse gas fluxes.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Benavides and his group developed the first detailed map of peatlands covering a variety of vegetation types in the Amazonian Trapezium region, providing an invaluable tool for the precise identification of wetlands within the Amacayacu National Natural Park and for the formulation of effective conservation strategies. The researchers have identified new types of peatlands with diverse vegetation forms that had not been previously documented and are widespread across the entire Amazon region. These sites, in addition to their ecological richness, pose significant logistical challenges due to their remote location and security concerns associated with accessing them. The team was also able to quantify large soil carbon stocks and the initial CH_4 and CO_2 greenhouse gas fluxes produced by these peatlands under a biogeochemical gradient in the Amazon region of Colombia.

As part of the mapping activities, the team conducted visits to areas such as the Rey Zamuro Reserve located in San Martín, Meta, where extensive palm swamps were found associated with small water tributaries. Other visits were carried out within the Casanare Department on the premises of a civil reserve called La Aurora. The team processed more than 30 cores using the loss ignition methodology to determine carbon percentage and content and bulk density from the samples taken from

Amazonas, Vaupes, and Caquetá. For CO_2 and CH_4 monitoring, field trips were conducted to intensive monitoring sites in Inirida, Leticia, and Puerto Lleras.

The PEER team took part in a one-month laboratory training at the University of Exeter in England to learn about the methodologies used in paleoecology, as well as workshops on methane emission modeling in tropical peatlands and data analysis. Their data and monitoring methodology are now included in the greenhouse gas budgets originating from natural systems in the Colombian Amazon region. By the time of their final report in May 2024, the team had received three additional grants worth a total of $150,000 to continue their work. Publication of their findings is forthcoming.

COLOMBIA - PROJECT 8-221: INCORPORATING RELATIONSHIPS BETWEEN ECOSYSTEM INTEGRITY AND PEOPLE'S LIVELIHOODS FOR CONSERVATION ACTION PLANNING IN TROPICAL DRY FOREST

PI: Susana Rodríguez-Buriticá, Alexander Von Humboldt Biological Resources Research Institute, In Partnership with The Universidad Nacional De Colombia
U.S. Partner: Andrew Hansen, Montana State University (Funded by the National Aeronautics and Space Administration)
Dates: January 2020 – August 2022

PROJECT OVERVIEW

Despite recent improvements in the availability of basic ecological information on Dry Tropical Forest (DTF) remnants in Colombia, high-impact conservation and sustainable land management strategies remain elusive. This is partly due to the lack of a comprehensive narrative connecting ecological knowledge with the economic consequences of DTF degradation. This project addressed two major knowledge gaps about DTF in Colombia. First, there was not a good characterization of DTF ecological degradation; specifically, forest degradation in terms of attributes relevant for ecosystem services (ES) provision. Second, despite previous studies of the ecological and socioeconomic aspects of DTF, no prior effort had aimed to integrate available information to produce a comprehensive understanding of the role of DTF for local communities, as well as the cost-benefits associated with DTF degradation and loss. Analyses of information were limited by project-specific commitments and fell short in using sophisticated analytical tools to construct such a narrative. By translating the ecological impacts of DTF degradation on ES and cost-benefit valuations, the PEER team aimed to provide powerful tools to negotiate DTF protection and restoration at the local levels.

The goal of the project was to integrate scalable information from contrasting DTF territories with nationwide integrity indicators and to improve models for ES supply dynamics and their economic assessments. Site-specific information for the project came from two large ongoing DTF projects supported by other sponsors that explored the links between (1) multi-level biodiversity indicators and DTF degradation in nine watersheds, and (2) DTF degradation, ecosystem processes, and ES supply in four watersheds, with only two providing socioeconomic information. Both projects were based on forest ecological condition assessments that did not incorporate land management history and only considered forest extent, not forest structure or overall integrity.

PI Dr. Rodríguez and her PEER team (1) evaluated the congruence between forest degradation, biodiversity, and ecosystem functioning and ES under contrasting socioecological contexts; (2) assessed the role of landscape management history on the dynamics of forest and ecosystem degradation; and (3) used ecosystem valuation and cost-benefit analyses to assess relationships among alternative management practices. This PEER-supported project updated analyses and models to improve data integration, scalability, and applicability of results to other DTF contexts by using sub-products from several ongoing U.S. Government-funded projects that improved landscape and forest degradation assessments, thereby generating stronger evidence-based, high-impact products with nationwide pertinence.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project undertook a comprehensive review and integration of data spanning 2013 to 2022 from various projects involving the Humboldt Institute focused on dry tropical forests in Colombia. This effort consolidated information on biological composition, structure, and pressure dynamics affecting key forest remnants over time. By analyzing these patterns, the team identified distinct responses of DTF to anthropogenic pressures, categorizing forest remnants accordingly and emphasizing the importance of tailored conservation and restoration strategies. These findings are to be encapsulated in an upcoming book chapter series on DTF, alongside contributions exploring biodiversity impacts, invasive species risks, and acoustic landscape analysis.

Furthermore, the project integrated socioecological and socioeconomic data to assess the impact of forest management practices on DTF integrity at municipal scales, revealing a potential conflict between conservation efforts and local food security. Through Structural Equation Modeling (SEM), the team highlighted municipalities where environmentally friendly practices correlated with better forest conditions, contrasting with areas prioritizing self-supply practices which showed poorer forest integrity.

In addition to ecological assessments, the project modeled scenarios using Python's InVEST package to evaluate ecosystem services like water provision and regulation across DTF territories. Results underscored the critical role of forest cover in maintaining hydric dynamics, particularly during dry periods, and raised concerns about service vulnerability under climate change scenarios.

Ultimately, this project represents a milestone in synthesizing diverse datasets to provide a comprehensive narrative on DTF degradation and its implications for biodiversity and ecosystem services. By linking ground biodiversity data with remote sensing and socioeconomic variables, it advances understanding of DTF dynamics and informs strategic planning for sustainable management and restoration efforts in Colombia.

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COLOMBIA - PROJECT 8-214: VOLUNTARY GEOGRAPHIC REDISTRIBUTION OF VENEZUELAN IMMIGRANTS IN COLOMBIA

PI: Gina Galindo-Pacheco, Universidad Del Norte

U.S. Partner: Jens Hainmueller, Stanford University (Funded by the National Science Foundation)

Dates: November 2019 – February 2022

PROJECT OVERVIEW

The main goal of this project was to develop a tool for identifying potential resettlement locations to be recommended to immigrants coming from Venezuela to Colombia. The recommended locations aimed to optimize the economic integration and well-being outcomes for the immigrants. The methodology was based on a data-driven algorithm developed by the Immigration Policy Lab (IPL) at Stanford University, where U.S. partner Dr. Jens Hainmueller was based. The algorithm analyzed the historic success of economic integration (measured as the likelihood of finding a job) of immigrants at each location and related such success to key characteristics of the immigrants, such as English skills and age. It then predicted the probability of economic integration outcomes for each immigrant in each location in the host country. Finally, the algorithm matched locations with family cases to maximize the total economic integration outcome for the immigrant families, while respecting constraints such as the number of available spots at each location. This was expected to contribute to balancing the distribution of immigrants among locations in Colombia.

Dr. Galindo and her team adapted the algorithm to the Colombian-Venezuelan context, taking into account not only economic integration but also the well-being of immigrants, which implied considering the chances of fulfilling their basic needs, such as medical and educational services, among others. The IPL provided support through all stages of the project to help the Colombian team verify and improve their approaches based on the knowledge and experience their U.S. partner had gained through the application of his methodology in the United States and Switzerland. The project was particularly innovative in its attempt to develop a data-driven matching system for the integration of immigrants coming from and arriving in a developing country. This was particularly relevant since it is estimated that nearly half of all immigrants migrate among developing countries, mostly to neighboring countries. Additionally, even though the problem of resettlement of immigrants had been addressed by several researchers in the past, research had focused solely on refugees, whereas this project focused on Venezuelan immigrants in general.

The Organization of American States had estimated that by the end of 2019 the number of Venezuelan migrants would exceed 5 million, with more than 1 million of them arriving in Colombia, their leading destination. This project sought to create a predictive tool to guide Venezuelan immigrants to the most appropriate locations in Colombia for voluntary resettlement with higher chances of economic integration and well-being. The tool also considered capacities and socioeconomic attributes of localities for better matching of immigrants and localities. The importance of informing settlement choices and guiding the strategic distribution of immigrants was highlighted by “Proyecto Migración Venezuela” (PMV), which was sponsored by Revista Semana and USAID, and international organizations. This type of initiative also attracted the interest of the Colombian government through the Border Management Office (BMO), which operates under the office of the Colombian president. This project was aligned with USAID’s mission of helping people to progress beyond assistance by identifying the locations and attributes that would enable better economic and social development of immigrant families. Furthermore, the project focused on marginalized populations that were vulnerable and required immediate assistance to settle in a new country. The identification of key attributes or drivers that led to immigrants' successful integration was helpful in guiding authorities in the development of specific training and social assistance programs.

FINAL SUMMARY OF PROJECT ACTIVITIES

The aim of this project was to provide guidance about the locations in Colombia where Venezuelan immigrants would have greater chances of economic integration. The PI and her team developed a model that considers diverse characteristics of the Venezuelan immigrants such as job skills, health requirements, and location of relatives or acquaintances, among others. The main objective was to define a path with a higher chance of success for the immigrants and avoid the oversaturation of specific regions that may limit economic and social integration. In the course of the project, which began in November 2019 and ended in February 2022, the PEER team pursued three objectives, which included: (1) identifying key factors of success for immigrants or refugees in Colombia; (2) adapting and validating the data-driven refugee assignment algorithm developed by the Immigration Policy Lab (IPL) at Stanford University to the Colombian context; and (3) proposing strategies to maximize the chances of successful integration of specific immigrant groups, to include vulnerable segments of the population such as women, older people, and others. Finally, the team aimed at sharing their knowledge with stakeholder agencies so they can benefit from the proposed approach and results.

In the course of the project, the team achieved all of their objectives. They were able to Identify key factors of success, which are based on the significant variables in their predictive model. They found gender, education, occupation, age, and time in Colombia to be some of those significant variables. The project also identified key industries and activities that increase and decrease formal employment probabilities. It was possible to identify the types of occupations that favor more socio-economic integration for immigrants, which included real estate, education, and socio-cultural activities.

Working on adapting the algorithm to the Colombian context to estimate where Venezuelan immigrants should be located to maximize their probability of obtaining a formal job presented challenges, which led to key modifications to the algorithm. First, the socioeconomic output was defined as finding formal employment. Second, the project model explicitly accounts for the health and social needs of immigrant families. Third, the project team performed a cluster analysis to assess the capacity of receiving immigrants in each potential location. The model estimates that on average the probability of formal employment will increase by more than 50% if the suggested redistribution is adopted. The project identified locations that should decrease the number of immigrants and determined the destinations where better socioeconomic integration can be achieved in Guajira and Norte de Santander. Also, the algorithm identified locations that still have the potential to absorb immigrants, specifically, Valle del Cauca.

Based on the findings, the PEER team delivered a set of recommendations regarding the origins and destinations for the geographic redistribution of Venezuelan immigrants in Colombia. They also developed a separate analysis for older people, women, and immigrants whose characteristics match with those that have been identified as the least favorable for socioeconomic integration. In this regard, this model predicts that improving the educational level of certain individuals can increase their chances of integration up to 85%. Also, the PEER team was able to connect with governmental and non-governmental organizations. They shared their knowledge and explained their process approach. Moreover, they delivered a set of recommendations that can contribute to improvement of ongoing and future projects.

In terms of development impacts, according to Dr. Galindo, as a result of her PEER project research, her PEER project team was able to provide their set of recommendations with regard to pilot immigrant relocation program led by the UNHCR Colombia team, which is intended to improve their socioeconomic integration. The recommendations are mainly related to the origins and destinations to be prioritized, taking into consideration which locations are least and most preferable for the socioeconomic integration of the immigrants. The UNHCR team compared their selected origins and destinations to the routes (origin-destination) suggested by the algorithm in order to obtain insights. They are also considering origins and destinations that are different from their first approach, but which make sense based on the results from the PEER project. UNHCR is also interested in updating the recommendations by re-adapting the algorithm, while considering additional features that are relevant to the migration process, such as xenophobia and transportation costs.

Now that the project has ended, the team is exploring possibilities to extend their work. With proper credit given to USAID as the funder of their original project, the researchers intend to apply their developed PEER project models and algorithms in outside consulting projects in addition to their ongoing academic research activities.

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COLOMBIA - PROJECT 8-166: A DATABASE OF FIELD-BASED RADAR IMAGES TO ASSIST IN THE SAFE REMOVAL OF LANDMINES IN COLOMBIA

PI: Roberto Bustamante Miller, Universidad De Los Andes
U.S. Partner: Sarah Kruse, University of South Florida (Funded by the National Aeronautics and Space Administration)
Dates: January 2020 – September 2022

PROJECT OVERVIEW

Many of the anti-personnel landmines deployed in Colombian territory are improvised explosive devices (IEDs) of non-standard design and construction. Therefore, traditional detection methods such as metal detectors are not as effective. This PEER project sought to reduce the number of victims of landmines in Colombia by improving the technologies for locating the devices using Ground Penetrating Radar (GPR).

Before this project, there was little available data on GPR for IED detection functioned under the soil and other environmental conditions prevalent in Colombia. Therefore, standard equipment developed by GPR manufacturers was not well-adjusted for field use in the country. Through previous work, the researchers had identified several key pieces of information required to enhance detection with GPR, including radar images of realistic detection scenarios; geological, environmental, and electrical characterization of the fields; and electrical characterization and scattering parameters of the IEDs.

The PI Dr. Bustamante and his team developed a portable field-based GPR for imaging. They also characterized soils and assessed environmental and geological conditions. Working relationships with other NGOs and researchers involved with demining units were also strengthened, with the ultimate aim of the research being to develop these procedures and standards for incorporation into national policies for humanitarian demining. By creating better procedures and providing more information for GPR detection enhancement, this project should facilitate more effective implementation of Colombia’s victims law, thus supporting and providing more secure access to land to develop the rural economy and stabilize conflict areas.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers built a field-based Ground Penetrating Radar (GPR) system for initial use in the laboratory. This work included designing software and hardware of the GPR system and building processing software for the GPR signal, including storing data and basic visualization. They then designed simulation scenarios for the detection of single and multiple objects and evaluated the GPR system and software based on these scenarios. They produced a high quality GPR trace dataset from more than 15 different scenarios and created a public database of GPR field-based measurement for further research.

During their soil characterization studies, the researchers used time-domain reflector (TDR) tools to study differences between measurements and simulations of soil water content. They created a new method, based on simulations, to identify frequency domain response of TDR probes. They also developed a characterization of relative permittivity of soil needed as an input for many imaging algorithms.

As part of the wider work, the researchers implemented migration algorithms to visualize underground objects regardless of their material and machine learning algorithms, some of which show potential to detect and classify landmines in real time. The team produced a document reviewing the current state of Colombia's mine action program, including its history, some statistics, and an in-depth analysis to give insight for its improvement.

The PEER team designed and assembled a portable GPR robot, 3D printing the custom system parts and comprehensively documenting their work for replication by other interested research groups.

The team reached out to NGOs working on demining activities and organized a variety of events, including a Humanitarian Demining course for undergraduates at the Universidad de los Andes and the 2nd International Science and Technology Congress for Mine Clearance. At the latter, 180 attendees, including Colombian National Army personnel, landmine professionals, researchers, and students, discussed and shared research regarding mine action in areas such as unmanned aerial devices, information systems and machine learning.

COLOMBIA - PROJECT 8-41: RECOMMENDATIONS FOR DECISION MAKERS WITH CONCERNS ON FOREST FIRE POLICIES

PI: Dolors Armenteras, Universidad Nacional De Colombia

U.S. Partner: Jennifer Balch, University of Colorado, Boulder (Funded by the National Science Foundation)

Dates: December 2019 – December 2021

PROJECT OVERVIEW

Deforestation in Colombia is still strongly linked to the use or misuse of fires for agriculture and pasture management or directly to occupy land. A six-fold increase in fires has been reported in protected areas across biodiversity hotspots in areas formerly occupied by the Fuerzas Armadas Revolucionarias de Colombia (FARC) guerrillas. Understanding how the transition from conflict to post-conflict is affecting forests remains crucial to mitigating both carbon emissions and biodiversity loss in Colombia. This project sought to impact policy related to fire at the national level and help reduce fire risk in the country. The PI, Dr. Armenteras, and her colleagues aimed to integrate research into support processes for institutions, companies, and local communities that were willing to contribute to the prevention and management of forest fires to reduce risk. This plan was a cross-cutting element to support the management of forest fire risk at local, regional, and national levels. Thanks to a PEER Evidence to Action Supplement on her grant under PEER Cycle 5, Dr. Armenteras and her group worked together with the National Natural Parks of Colombia (PNN), achieving the implementation of a proposal of criteria and indicators to strengthen planning tools for the management of protected areas (PAs), so that the degradation of forests by forest fires could be prevented. This result served as the foundation for the execution of this new PEER Cycle 8 project focused on the development of policies aimed at reducing the risk of fires in the face of climate change. This, in turn, allowed the strengthening of the PNN entity, which favored territorial development and the conservation of biodiversity, thus benefiting the populations surrounding the PAs.

The project began with a critical analysis of policies related to fire management, including laws, decrees, and national plans, followed by an expert workshop to build a SWOT matrix and identify strengths, weaknesses, opportunities, and threats associated with current policies. Likewise, the documents collected were analyzed in detail to identify specific information and policy gaps in protected areas that were required for the design of prevention strategies, fire control, and management of areas affected by fire, particularly national parks. One park was selected for the implementation of a proposed set of indicators to be used as a management tool by park officials. A workshop was held with the community in and around the park to learn more about their perception of the use of fire, forest fires, and the impacts generated by these events. At the national scale, the project also aimed to contribute to the formulation and implementation of forest fire-related policy.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project aimed to integrate politics and planning to advance territorial fire management through governance by December 2021, achieved a series of substantial impacts across Colombia. Their approach involved collaborating closely with local stakeholders and institutions to devise effective strategies for wildfire prevention and management.

One of the project's key achievements was the development of a participative protocol specifically tailored for the Bita River basin in the Orinoquia region. This protocol, created in partnership with Ecolmod, NGOs like Fundación Omacha and Fundación Orinoquia, and the network of Natural Reservoirs of Civil Society, was instrumental in integrating comprehensive fire management practices into the Bita River Management Plan. By engaging local communities and stakeholders in the development process, the protocol not only addressed immediate wildfire risks but also fostered long-term sustainable practices in the region.

In another heavily impacted area, the Farmers Reserve Zone of Sumapaz in Bogotá, the PEER team conducted participatory workshops. These workshops were aimed at understanding local perceptions of fire and its impacts among community leaders. Based on insights gathered, the team drafted a proposal embedded within the Sustainable Development Plan for the Reserve Zone. This proposal outlined strategies for responsible fire use and aimed to reduce the occurrence of wildfires, thus promoting environmental stewardship and community resilience.

Furthermore, the PEER project aligned its efforts with Colombia's broader goals of low-carbon sustainable development in the Orinoquia region. By synergizing with related initiatives such as the "Degradation of Tropical Forests in Colombia: impacts of Fire" project, the team contributed directly and indirectly to reducing greenhouse gas emissions. Collaborations with the private sector, notably with Forest First Forestry Company, were pivotal. This partnership not only secured additional funding but also enabled research into the effects of fire and effective prevention strategies, crucial for minimizing losses in the forestry sector.

At a national level, the PEER team's impact extended into legislative arenas. They conducted a thorough review of Colombia's existing laws, norms, and policies related to wildfires. This review identified strengths and gaps, which informed the drafting of bill proposals, including the influential Bill 221 of 2019 and the National assessment plan for wildfire prevention and control. Their efforts also resulted in the inclusion of a new article focused on wildfire prevention within Bogotá's strategic development plan, underscoring the project's influence on urban planning and environmental policy at a municipal level.

Spatial data analysis using VIIRS data from 2012 to 2019 provided critical insights into the density and frequency of active fires and burned areas. This data was shared with the Ministry of Housing, City, and Territory to inform the development of guidelines and strategies aimed at reducing wildfire risks in rural fire-prone areas. The PEER team's action framework for disseminating knowledge on integrated fire management also played a crucial role in shaping national policies on deforestation and sustainable forest management.

Through comprehensive training programs, the PEER project enhanced the understanding of wildfire dynamics among legislative technical units in the Congress of Colombia and institutional stakeholders. They conducted workshops and provided practical training on fire patterns, wildfire management concepts, and policy analysis, thereby strengthening local and regional capacities for fire management.

Looking ahead, beyond the completion of the PEER project, Dr. Armentera's team continues their impactful work. They have initiated an ongoing initiative funded by Colombia's royalties program, focusing on the "Management of fire-resilient multifunctional landscapes under climate change scenarios" in the Orinoquia region. This initiative aims not only to fortify local capacities but also to shape national action plans and policies, using specialized participatory tools tailored to the region's unique environmental conditions. By empowering local communities, engaging with students and emerging researchers, and advocating for sustainable practices, the team strives to generate significant environmental impacts locally within Colombia and globally.

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COLOMBIA - PROJECT 7-275: IMPLEMENTATION OF ESSENTIAL BIODIVERSITY VARIABLES FOR BIODIVERSITY ASSESSMENT AND MONITORING AT THE SUBNATIONAL LEVEL IN COLOMBIA

PI: Maria Londoño, Instituto De Investigacion En Recursos Biologicos Alexander Von Humboldt
U.S. Partner: Victor Gutierrez-Velez, Temple University (Funded by the National Aeronautics and Space Administration)
Dates: December 2018 – September 2022

PROJECT OVERVIEW

Colombia is a hotspot of biological diversity that supports environmental goods and services. The signing of the 2016 peace agreement has brought out new environmental challenges: areas that used to be isolated are currently facing pressure from the expansion of deforestation and agriculture. Biodiversity and environmental services in these areas are expected to decline, but these trends are poorly assessed and understood.

The overall goal of this PEER project was to advance the implementation of the essential biodiversity variables (EBVs) framework in Colombia. Dr. Londoño and her colleagues sought to evaluate the effectiveness of EBVs at the ecosystem levels and validate which different EBVs provide meaningful information relevant to the local ecosystem patterns. This project aimed to include the needs and priorities of sub-national scales in the USAID project "Riqueza Natural," integrating this project's results with the tools, datasets, training and workshop events related to the decision support system (DSS) implemented as part of the USAID project. The team sought to implement the EBV framework with a bottom-up perspective through a participatory process that validates and recognized EBV by Colombian experts and decision-making stakeholders.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER project team began by identifying variables among the EBVs that were necessary and of high priority for decision-making at the subnational level in tropical dry forest ecosystems. The researchers used a participatory process that empowered local communities and associations to identify and monitor key natural resources for the sustainability of their livelihoods. Over the course of the project, the researchers built a monitoring cycle with three local communities that allowed them to track the impact of their conservation and productive activities on a desired future where biodiversity is conserved and restored. The results of this collaboration were published in "Monitoreo Comunitario de la Biodiversidad en Montes de Maria," which presents a roadmap for implementing the proposed community monitoring scheme and strengthening local capacities to contribute to decision-making for management and use of biodiversity.

The researchers also focused on understanding the environmental dynamic of the studied regions through remote sensing. This work helped describe the impact of seasonal dynamics in northern Colombia on EBVs related to ecosystem function. It also produced land cover maps that provided a methodology that efficiently produces land cover change analysis in megadiverse countries and workflows for estimating ecosystem structure change and its implication in species habitat retention.

One of the main products of this project is BioTablero, an open platform for accessing these biodiversity indicators. Most of the information available was derived from this project, particularly the information available at department or administrative unit levels through the geographic query module. In terms of potential development impacts, after the launch of BioTabero the team received a request for this information to help construct a baseline for a project also financed by USAID. The team expects that the information will support decision making for the different actors of the country's environmental sector (environmental authorities, research institutes, universities, and NGOs) and private companies in charge of developing environmental management actions. The team anticipates that by 2025 BioTablero will be recognized and used as the technical and scientific tool for informed decision making on biodiversity management and sustainable development at the national level. Although this PEER project has ended, the PI and her team will continue their research thanks to more than US $500,000 in additional grants obtained from several international and Colombian sponsors.

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COLOMBIA - PROJECT 5-331: DEGRADATION OF TROPICAL FORESTS IN COLOMBIA: IMPACTS OF FIRE

PI: Dolors Armenteras, Universidad Nacional De Colombia
U.S. Partner: Jennifer K. Balch, University of Colorado, Boulder (Funded by the National Aeronautics and Space Agency)
Dates: December 2016 – November 2019

PROJECT OVERVIEW

Tropical forests host the highest levels of biodiversity and maintain some of the greatest carbon stocks of all terrestrial ecosystems, having an essential role in global carbon cycling. Colombia is no exception and hosts a diversity of tropical forests that are not only rich in both carbon and species but also highly threatened. Colombia has made advances in quantifying carbon stocks and measuring emissions from deforestation but has yet to address the drivers and consequences of forest degradation.

Recent studies have identified fire as a major driver of tropical forest degradation. Fires affect landscape structure, patterns, and processes and have shaped species composition and biological diversity. However, fires have also been used more recently as a tool in management practices for land clearance, crop or pasture maintenance, and slash-and burn agriculture in tropical forest systems. Though a natural mechanism in many ecosystems, human actions have altered regimes and the extent and frequency of fires have increased in many regions of the world, particularly in tropical forests.

This PEER project aimed to advance understanding of the interactions of fire frequency and intensity on the resulting biomass depletion and carbon stocks in different types of forests, assess how fuel load and fuel moisture change along forest types and develop a model to quantify the response of different types of forests to changing fire regimes. This work sought to develop the ability to include estimates of carbon emissions from forest degradation caused by fire into end-user decision-support systems and provide a basis of knowledge that will help reduce threats to agriculture systems.

FINAL SUMMARY OF PROJECT ACTIVITIES

During field campaigns, the PI and her team sampled plots of burned interior forest, burned forest edge areas, and non-burned forest, resampling sites across different time periods. Their study plots included locations inside El Tuparro National Park and Iguaque Flora and Fauna Sanctuary. They studied the composition and structure of forests affected by fire, determined the fuel load of these forests, and analyzed the changes in soil carbon, moisture, and nutrients. The team built an integrated database and dataset maps of their results and developed a fire policy for publication and policy briefs for the Colombian House of Representatives and Senate and the Bogota Local Council. They also presented at the Brazilian Symposium of Remote Sensing and Max Planck Symposium/Colombia Frontiers of Science. The PEER team participated in a fire management workshop in Vichada with private sector stakeholders and organized a workshop in Boyaca with government representatives to discuss their results, fire ecology case studies, and gather potential future actions.

Based on their review of the national and international political context and the gaps they identified in the management of forest fires, the team also worked to contributing to formulation of a draft National Law that addresses the causes and management of forest fires to aid in territorial planning and Colombia's overall development. A key point is to encourage academia in Colombia to become a leading actor for the country to enter a transition phase, from a paradigm based on the suppression of fire to the adoption of policies based on compression and integral fire management.

In the light of the raging fires in the Amazon, Dr. Dolors Armenteras and her work on forest fires have received increasing media attention. On August 23, 2019, Dolors gave a live-streamed interview to the national newspaper El Tiempo on the impacts of deforestation, national regulations, and actions to be taken to reduce the risks of forest fires. On September 2, 2019, El Tiempo published an article on preparation of a draft bill on integral management of fires, featuring Dolors.

The PI and her team continued their work on fire ecology and translating results in the policy in Colombia with support from an award under PEER Cycle 8.

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SELECTED NEWS COVERAGE

RCN Radio article: https://www.rcnradio.com/estilo-de-vida/medio-ambiente/la-amazonia-brasilena-esta-cerca-del-punto-de-no-retorno

News media in Brazil: https://www.razonpublica.com/index.php/internacional-temas-32/12229-por-que-arde-la-amazonia.html

COLOMBIA - PROJECT 4-70: SATELLITE-BASED ESTIMATIONS OF RIVER DISCHARGE INTO THE CARTAGENA BAY, CARIBBEAN COLOMBIA: CAPACITY BUILDING TO MITIGATE SOURCES OF UPSTREAM RUNOFF AND ASSOCIATED RISKS OF POLLUTION

PI: Juan D. Restrepo, Universidad EAFIT

U.S. Partner: Robert Brakenridge, Dartmouth Flood Observatory (DFO), CSDMS, INSTAAR, University of Colorado (Funded by the National Aeronautics and Space Agency)

Dates: October 2015 – April 2020

PROJECT OVERVIEW

The city of Cartagena and its bay, a UNESCO World Heritage Site, have a limited capacity for water resource management, as evident in the degradation of coastal water quality. During the last six decades, coastal fisheries and ecosystems (sea grasses and coral reefs, for example) have almost disappeared, and Cartagena Bay is considered one of the Caribbean's "hot spots" for pollution due to human-induced stressors impacting water quality and ecosystems services. Flooding has also been devastating. During the wet season, in strong La Niña years, flooding has caused many fatalities and infrastructural and agricultural damages of over $7.8 billion. Mitigation of such disasters lacks data-supported scientific approaches for evaluating river response to extreme climate events. Ground-based data on river discharge and flood magnitudes are often not readily available for decision makers of many developing nations, including Colombia, preventing data-supported scientific approaches for evaluating river response to extreme climate events.

The ambiguity of the problem means that mitigation strategies are lacking. This PEER project team aimed to generate a clearer and more precise foundation of knowledge on continental runoff fluxes and related marine pollution problems to inform the development of adaptive strategies at both the community and political level. This effort was a collaboration between the Dartmouth Flood Observatory at the University of Colorado and EAFIT University-Colombia. The researchers' main goals included estimating river discharge from the Dique Canal-Magdalena River system into Cartagena Bay by applying satellite-derived measurements; identifying climate variability and human impacts for the Magdalena River basin, making satellite-based data available as GIS files to be incorporated into decision-support systems; and developing capacity for satellite-based river freshwater estimation.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Restrepo and his colleagues used a satellite-based technique to measure river discharge at selected sites for the main northern Andean River, the Magdalena, back calculating daily river discharges over a period of two decades, thus making it possible to determine return intervals of significant flood events. Their findings show that satellite-based river discharges capture the inter-annual variability of stream flow measured at ground-based gauging stations, the natural seasonality of water discharge along the lower Magdalena floodplains, and the peak discharges that were observed during La Niña events in 2008-2009 and 2010-2011.

The La Niña events are likely more accurate compared to ground-based gauging stations, as ground-based stations tend to overflow during large flood events and as such are hampered in accurately monitoring peak discharges. The PEER team also found that these derived discharges can form the base to study river-floodplain connectivity, providing environmental decision makers with a technique to better monitor river and ecosystem processes.

The PEER team also convened a workshop, in which the PI and three other scientists developed a syllabus for a course on Rivers of the Americans in the Anthropocene, presenting it to graduate programs of the researchers' four universities. The team also developed a new graduate course at EAFIT, inspired by the PEER project and its findings, called "Watershed Management for Environmental Protection."

The PI and U.S. partner published their findings, presented their work at an AGU Oceans meeting in early 2020, and published a special report in the journal El Eafitense. The satellite daily water discharge data have been incorporated in the dynamic model of runoff dispersion into the bay, and the team shared their findings and technique for obtaining satellite-derived water discharge in near real time with the technical team at the Magdalena River Environmental Authority. The data will be incorporated in the GPS navigation system along the river, especially for assessing discharge variability in some river reaches.

PUBLICATIONS

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Juan D. Restrepo and Heber A. Escobar. 2018. Sediment load trends in the Magdalena River basin (1980–2010): Anthropogenic and climate-induced causes. Geomorphology 302: 76-91. https://doi.org/10.1016/j.geomorph.2016.12.013

Rogger Escobar C., Juan D. Restrepo, G.R. Brakenridge, and A.J. Kettner, A.J. 2017. Satellite-Based Estimation of Water Discharge and Runoff in the Magdalena River, Northern Andes of Colombia. In: Lakshmi, V. (eds) Remote Sensing of Hydrological Extremes. Springer Remote Sensing/Photogrammetry. Springer, Cham. https://doi.org/10.1007/978-3-319-43744-6_1

J.D. Restrepo, A.J. Kettner, and J.P.M. Syvitski. 2015. Recent deforestation causes rapid increase in river sediment load in the Colombian Andes. Anthropocene 10: 13-28. https://doi.org/10.1016/j.ancene.2015.09.001

COLOMBIA - PROJECT 2-487: INTEGRATED HUMANITARIAN LOGISTICS SYSTEM FOR DEVELOPING COUNTRIES

Pi: Victor Cantillo, Universidad Del Norte
U.S. Partner: José Holguin Veras, Rensselaer Polytechnic Institute (Funded by the National Science Foundation)
Dates: August 2017 - November 2018

PROJECT OVERVIEW

This project aimed to contribute to the development of an integrated humanitarian logistics system for post-disaster relief response in developing countries. As part of the work, the research team collaborated to propose humanitarian logistics models that explicitly incorporated a key aspect that had not been considered before: deprivation costs (i.e., the cost associated with lack of access to life-sustaining items). This was important in order to develop appropriate models capable of representing human suffering. The research was expected to produce algorithms and heuristics to solve and validate the proposed formulations and propose an effective emergency management system for post-disaster relief operations. This led to analytical formulations that properly considered the consequences of logistics decisions once populations had been impacted by disasters and, ultimately, to more effective and coordinated strategies to deliver critical supplies in developing countries. This research was complemented with a plan to enhance project impacts by attracting students to careers in engineering at graduate level, integrating research and education, and reaching out to practitioners with training sessions in disaster response operations.

The importance and relevance of the proposed work were evidenced by direct observations and field work conducted during recent humanitarian logistics efforts after super-storm Sandy, Hurricane Katrina, and the Joplin tornado, as well as the earthquake response in Haiti and the Dominican Republic and the response to the Japan earthquake and tsunami. Research conducted highlighted the challenges of disaster relief systems in both developed and developing countries. These findings were complemented with additional field work conducted by the team at ongoing disaster relief operations in Colombia. This proposal included a close relationship with disaster relief operations agencies such as the local Emergency Disaster Response Office, which worked with the research team and social scientists in data collection regarding the last major disasters in Colombia. This work and coordination provided an excellent and unique opportunity, as the number of disasters in the country had shown a notable increase in the last few years, especially due to climate changes. It was expected that the analysis of the datasets and case studies and a review of best practices would allow the team to adapt them to the needs of developing countries and be able to propose a disaster management system that minimized human suffering. Furthermore, this system could be used to provide training to relevant agencies to make their response as effective and efficient as possible. In that sense, practitioners had first-hand exposure to the problem and possible ways to resolve it.

FINAL SUMMARY OF PROJECT ACTIVITIES

[Note: Dr. Cantillo received a PEER Evidence to Action supplement in August 2017 to support a one-year outreach and capacity building effort as a follow on to his PEER Cycle 2 project, which was completed in October 2016. During the final stages of that project, the PI and his team worked on designing a model emergency management system, based on an analysis of current practices in developing countries but extending that to propose a model for the internal organization of the relevant government agencies consistent with the humanitarian logistics models the team had developed. Now, the researchers aim to apply the system they developed and propose specific policy recommendations regarding natural disaster preparedness and response. In particular, they will focus on the communities affected by floods in the Colombian Caribbean Region during the rainy season in 2010 and 2011. The first main objective is to train people in charge of disaster preparedness, mitigation, and response on policies that will ensure humanitarian assistance in areas with high levels of disaster risk, based on the results of the original PEER-supported research. The second aim is to develop a collaborative work plan with municipal and provincial authorities in the target communities in order to introduce the recommended policies in their strategic planning and investment process in preparation for potential disasters.]

Now that this PEER Evidence to Action supplement has ended as of November 30, 2018, Prof. Cantillo reports that it was valuable in allowing him and his team to build and maintain several important relationships with government agencies and other groups interested in disaster and risk management. Working in collaboration with these stakeholders, he and his team had the opportunity to identify specific problems facing the disaster relief system. Through site visits and interviews they collected specific information on the experiences of local residents in areas affected by the 2010-2011 floods. This information was used to design a work plan, lectures, and workshops for practitioners and relevant officials in the areas of risk and disaster management. The training program lasted three sessions (June 22, June 29, and July 6, 2018) for a total of 24 contact hours. The 96 participants had the opportunity to listen to presentations, ask questions, share experiences, give different points of view, and socialize drawbacks faced within disaster events. The last session was intended to provide maximum potential for interaction among the participants, who were invited to take part in developing plans based on real life case scenarios based on actual disaster events that had happened in Colombia, including floods, landslides, and the resulting emergency needs for shelter, food, and other necessities by those affected. This gave the participants a chance to apply all the concepts, tools, and techniques acquired in the course of the training program. More information is available at https://www.uninorte.edu.co/web/educacion-continuada/gestion-delriesgo-de-desastres.

Following up on the training sessions, the PI reports that he and his team have produced several research papers and met with local and national disaster and risk planning authorities to recommend ways of optimizing the allocation of financial resources and eliminating some inefficient procedures that the PEER team identified. Basic information derived from this project was used in the formulation of the disaster risk management plan in Barranquilla and the Atlantic Department. Prof. Cantillo also notes that his results have inspired other researchers in the academic community, as the papers he and his team have authored with PEER support are receiving a growing number of citation from others working on the topic of deprivation costs and their estimation. Thanks to two new international research grants obtained, Prof. Cantillo and his group will continue collaborating with their U.S. partner Prof. José Holguin Veras and other counterparts, and they also plan to see additional funding from the Colombian science agency Colciencias. The project web page continues to be available at https://www.uninorte.edu.co/web/departamento-de-ingenieria-civil-y-ambiental/usaid.

PUBLICATIONS

Cantillo, V., Macea, L. F., & Jaller, M. (2019). Assessing vulnerability of transportation networks for disaster response operations. Networks and Spatial Economics, 19, 243–273. https://doi.org/10.1007/s11067-017-9382-x

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Macea, L. F., Cantillo, V., & Arellana, J. (2018). Influence of attitudes and perceptions on deprivation cost functions. Transportation Research Part E: Logistics and Transportation Review, 112, 125-141. https://doi.org/10.1016/j.tre.2018.02.007

Delgado-Lindeman, M., Arellana, J., & Cantillo, V. (2019). Willingness to pay functions for emergency ambulance services. Journal of Choice Modelling, 30, 28-37. https://doi.org/10.1016/j.jocm.2018.12.001

Cotes, N., & Cantillo, V. (2019). Including deprivation costs in facility location models for humanitarian relief logistics. Socio-Economic Planning Sciences, 65, 89-100. https://doi.org/10.1016/j.seps.2018.03.002

COLOMBIA - PROJECT 2-065: ECOSYSTEM RESPONSE TO CLIMATE CHANGE IN THE MOUNTAIN WETLANDS

PI: Juan Castaño, Universidad Tecnológica De Pereira
U.S. Partner: Jay Martin, The Ohio State University (Funded by the National Science Foundation)
Dates: September 2013 – April 2019

PROJECT OVERVIEW

Since 2008, Colombia has experienced three extreme climate events that have resulted in droughts and flooding during which more than 400 human lives were lost. During these events, 15 percent of the country was inundated and more than $6 billion in economic losses were sustained. While such national and international impacts of climate change are frequently noted and predicted by large-scale models, the local communities that suffer greatly from these disasters and are ultimately responsible for human welfare lack tools to predict and respond to changes in climate. To better prepare local communities to predict climate impacts and develop responses, this project developed an early alert system to forecast changes in the ecosystem services of water regulation and biodiversity in the Quebrada Dalí watershed. This upstream watershed, located in the central Andes of Colombia, affected agricultural and urban downstream areas that had already realized climate impacts and could greatly benefit from tools to predict further impacts and plan proper responses to climate changes.

The long-term goal was to develop a sustainable local ecosystem study site to monitor and model short- and long-term effects of climate change on the ecosystem services provided by Quebrada Dalí watershed. The early warning system that was built was based on permanent monitoring and adaptive modeling of the effect of climate change on the ecosystem services of water regulation in a watershed in the central Andes and its influence on water supply systems. A critical need for such a system at a local level was evidenced by the fact that many of the prediction models used to determine the effects of climate change on environmental services and society are based on global scale climate data, but they omit biophysical and social influences that determine local responses. As one of the most vulnerable countries to impacts of climate change, Colombia is an excellent location to examine human adaptation to impacts such as severe floods and drought.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the final months of the project in early 2019, the PI Dr. Castaño and his colleagues organized two workshops. The first was with the faculty council of the Environmental Sciences School at his university. As planned, the council decided to commit funds to support the continued operation of the study site for academic purposes now that PEER funding has ended. A video showing the council's visit to the site is available at https://www.youtube.com/watch?v=VNdw9IgXP6M. Another workshop was conducted with the Frisby Foundation, an NGO founded by a prominent Colombian businessman based in Pereira who owns a farm near the study site. His property also features wetlands that he is interested in restoring. This NGO promotes children's education through several activities, and the PI has discussed possible ways they could use the study site in their programmatic efforts with local kids.

The PI reports that he and his colleagues and students achieved significant results on all project objectives. The first was to create a baseline study of the ecosystems services of water regulation and biodiversity at the Quebrada Dali watershed. They installed a weather station, rain gauges, water level meters, and time-lapse and trap cameras around the site, and using this equipment they have created a five-year data set showing how the structure and composition of aquatic macroinvertebrates, amphibians, mammals, and wetlands vegetation evolved along with the natural succession process in the study site. The data will also be useful in promoting conservation of endangered species. The second objective focused on modeling rainfall and runoff, and the data collected should be useful in helping predict future climate impacts such as flash floods and landslides. The third objective was to build local institutional capacity to enhance long-term sustainability at the study site. Thanks to a PEER Evidence to Action supplement, the PI and his team set up three public nature trails with explanatory signs telling visitors about the natural features they were seeing. They also upgraded a building at the site so it can be used by researchers, students, and scout groups for academic work and information environmental education. The PEER team also strengthened linkages with other local universities, government agencies, a public utility company, schools, and of course the U.S. partner, and they plan to continue building on those relationships even now that the PEER grant has ended. The team has published two papers and made 16 technical presentations, with two other papers under revision as of June 2019.

Through his PEER project, the PI and his colleagues improved several graduate and undergraduate courses, including the Fundamentals Seminar I for the Master's program in ecotechnology, the Hydroclimatology and Environmental Chemistry courses for the BS in environmental administration, and the Sustainable Development course for the BS in industrial engineering. The improvements included incorporation of PEER research study data into lessons and use of the study site for hands-on field training and research by the students themselves as part of their coursework. A total of 434 students (60% of them female) took the improved courses between 2014 and 2019.

In addition, the PEER team also developed virtual educational modules to train Scout leaders in the following topics: conservation, climate change, solid waste management, and risk management. More than 500 people (schoolchildren, scout groups, university students, etc.) have been trained somehow in the study site. He and his team have also worked hard share their data and spread the word about their workshops and other activities through many channels, including webpages, blogs, and videos. Besides the links at the top of this page, here are a few more videos produced as part of this project:

1. Video edited to be used in the local Zoo
2. Promotional video of the study site
3. Campaign to prevent illegal wildlife trafficking
4. Video about mammals at the study site
5. Training course for scout leaders with modules on Conservation, Climate Change, Solid Wastes, and Risk Management. Modules may be accessed by visiting https://univirtual.utp.edu.co/sitio/ and entering the following log-in and password: Usuario: 7807, Contraseña: eureka.

As of June 2019, Dr. Castaño reported receiving a total of $718,833 in new grant funds to support his continued research efforts, provided by three different sponsors: his university, the Risaralda local government, and the local water company Aguas y Aguas de Pereira. The latter organization, which is the team's main local partner, is doing a project to convert the study site into a formal nature reserve so it can continue to serve the general public as well as local university and school students. A five-year memorandum of understanding has been signed with the university in this regard, and Aguas y Aguas has incorporated information about the site into a video they produced about the educational activities they support: (https://youtu.be/4H_S9QpyFTI). With respect to awards and public recognition, Dr. Castaño and his research team received public recognition during the celebration of the 25th anniversary of their university, among other reasons for their work and results at the study site. In addition, the PI became a member of the Otun river watershed council, which is made of representatives of governmental institutions, private sector, NGOs and universities. He also continues his membership in the American Ecological Engineering Society.

COLOMBIA - PROJECT 1-31: IMPACTS OF CLIMATE CHANGE ON TROPICAL WETLANDS: TRACKING THE EVOLUTION OF TWO ANDEAN LAKES AND A FLOODPLAIN CIENAGA IN COLUMBIA

PI: Julio Eduardo Cañón, Universidad De Antioquia
U.S. Partner: Francina Dominguez, University of Arizona (Funded by the National Science Foundation)
Dates: May 2012 - July 2015

PROJECT OVERVIEW

Communities in tropical regions along the Andean Cordillera in South America face an uncertain future, as mountain lakes and snow peaks exhibit receding trends and strong fluctuations associated with climatic drivers (i.e., climate change and El Niño) and local human activities. Such fluctuations are apparent in Colombia, where these changes will have direct impact on strategic ecosystems such as the Orinoco and Amazon basins and the highly populated Cauca and Magdalena River basins. Therefore, understanding how these water systems evolve in the near future is of critical importance for the communities that depend on them for their survival.

This project aimed to develop long-term monitoring of the evolution of three natural water bodies: Colombia´s two main Andean lakes (Tota and Cocha) and the floodplain wetland of Ayapel. These natural reservoirs not only represent the accumulated effect of hydrological processes in their respective basins but also serve as examples of environments from which several rural and urban communities derive their water resources and develop their economic activities.

This project gathered data about the areas of interest by contacting local, national, and international agencies for technical reports, census information, hydrologic databases, and remote sensing imagery. The information gathered, as well as gauges installed at the lakes and visits to record geographical, geophysical, and socio-economic data, was used to build models that describe the evolution of these bodies of water. Young researchers at the Master's and doctoral levels in Colombia used the project as the foundation for developing their dissertation research.

FINAL SUMMARY OF PROJECT ACTIVITIES:

The team's findings showed significant relationships between variables such as temperature, precipitation and levels in the wetlands and temperatures of the Atlantic and Pacific oceans. Researchers ran models to determine the moisture sources on the Colombian Andean region where the three lakes are located and highlighted the importance of moisture fluxes from the Atlantic, the Amazon, the Orinoco.

The researchers developed mathematical models to simulate the availability and quality of water of these wetlands under different climate change scenarios (i.e., higher temperatures with lower/higher precipitations) and human interventions (i.e., farming, fishing, tourism, industry, and water supply systems) for a time horizon of 50 years.

Each wetland under study told a different story. La Cocha (Nariño), the second largest mountain lake in the country, has relatively more protected environmental conditions within the international

Ramsar wetland convention, serving as a reference case for interpreting changes that can be expected due to climate variability. The Tota Lake (Boyacá), the largest mountain lake in Colombia, both water quality and levels were projected to be significantly impacted as a result of withdrawals. In Ayapel Cienaga (Cordoba), water levels faced an unusual challenge due to heavy alterations suffered by the failure of a dam on the Cauca River in 2010. Overall, the study concluded that the three wetlands could survive in the conditions raised by the critical scenarios of higher temperatures and lower rainfall beyond 2050, but they would be dependent on water resources management and on decisions taken by local communities related to agricultural and other livelihood activities.

The project contributed to the professional and research development of one undergraduate, three Master's students, and a doctoral student, and several student team members received grants for their work and future research in this area. The team participated in 11 local workshops to disseminate the results of the research and gain insight about specific aspects of each site to understand next steps. The PI and his colleagues also presented their results through academic talks on the national level and two Fall Meetings of the American Geophysical Union.

Two graduate courses were designed and offered by the PI at Universidad de Antioquia as a result of the PEER project: Statistical Methods in Time Series Analysis and Ecohydrology. In addition, three telemetric hydrological stations were built and installed by the project in each of the wetlands. The long-term aim is to keep the information about these three lakes updated and eventually incorporate other wetlands to the database.

PUBLICATIONS

Lantua, S. G. A., Hooghiemstra, H., Vuille, M., Behling, H., Carson, J. F., Gosling, W. D., Hoyos, I., Ledru, M. P., Montoya, E., Mayle, F., Maldonado, A., Rull, V., Tonello, M. S., Whitney, B. S., & González-Arango, C. (2015). Climate variability and human impact on the environment in South America during the last 2000 years: Synthesis and perspectives. Climate of the Past Discussions, 11, 3475-3565. https://doi.org/10.5194/cpd-11-3475-2015

Plata Fajardo, A. M., Cañón, J., & Lafortezza, R. (2015). The value of rural landscape in Aquitania (Colombia): Application of spatial hedonic models in real estate analysis. Cuadernos de Desarrollo Rural, 12(76), 155-179. http://dx.doi.org/10.11144/Javeriana.cdr12-76.vrla

Salazar, J. F., Hoyos, I., Villegas, J. C., & Poveda, G. (2014). Amazon deforestation effects on mean and extreme river flows: Insights from ecohydrological scaling. Paper presented at the AGU Fall Meeting, December 2014, San Francisco, California. http://dx.doi.org/10.13140/2.1.1170.8488

DOMINICAN REPUBLIC

DOMINICAN REPUBLIC - PROJECT 9-410: RESILIENCY ANALYSIS FOR THE DEVELOPMENT OF MICROGRID ARCHITECTURE AGAINST CLIMATE-DRIVEN EVENTS IN THE DOMINICAN REPUBLIC'S ELECTRIC SYSTEMS

PI: Ramón Emilio De Jesús Grullón, Pontifica Universidad Catolica Madre Y Maestra
U.S. Partner: Hashem Nehrir, Montana State University (Funded by the National Science Foundation)

Dates: April 2021 - August 2023

PROJECT OVERVIEW

Recent severe power outages caused by increasingly frequent climate-driven events have highlighted the urgent need to improve grid resilience worldwide. Traditionally, the power industry focused on methods that aimed to restore loads after a fault by altering the topological structure of the distribution network, effectively isolating the fault and restoring as much load as possible after the general blackout. However, when the distribution system was severely damaged, traditional approaches could not guarantee that energy would be supplied to much-needed critical loads. This is where microgrids (MGs) emerged as a tool due to their potential to recover quickly and effectively, providing an alternative approach.

Active MG integration into the grid required a robust modeling process and hardware testing, and this PEER project tackled both. Researchers used the latest real-time power hardware-in-the-loop (HIL) simulation platforms to model device integration and created a PHIL testbed, the first developed in the Dominican Republic. The testbed served not only as an educational tool to promote training and learning in this key technology area but also as a benchmark for government agencies, communities, and industry looking to integrate renewable energy sources and resilience into their decision-making process and policies. It also performed as a test platform for device-agnostic energy storage and electric vehicle integration into the energy grid.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team developed a working group with a regional utility company EDENORTE. Working with the company's research team, Researchers developed a documentation on how to obtain, clean, and transform the utilities' existing GIS data to be fed into the QGIS2OPENDSS Plugin, developed to automatically generate distribution network models for OpenDSS. This plugin was developed by researchers at the EPER Lab in the University of Costa Rica (UCR) to exponentially reduce modeling time to simulation time when assessing the evolution of distributed generation and power systems.

When they completed this work, the researchers shared a technical presentation of results, tools, and possibilities for more in-depth analysis to EDENORTE. They also undertook a series of trainings on the real-time simulator for the microgrid laboratory and new testbed, which was installed in mid-2022.

Throughout the project period, team members organized a variety of events, including a seminar on Smart Cities, a capacity building workshop on modeling and simulation of electrical distribution networks, and webinars on microgrids and the future of energy in the Dominican Republic. They also organized a symposium on the latest in microgrid research. Project members kept stakeholders and others updated through publishing a blog on their research efforts, and launched a GitHub repository with the Geographic Information System (GIS) and Distribution Network data, along with the OpenDSS network models created the project, serving as a platform to develop future work and research.

With the creation of the microgrid laboratory on campus, many electrical engineering courses now have access to new testing tools for practical and conceptual lessons.

As part of his PhD research, PEER project team member Rafael Batista conducted research on the use of biological-inspired optimization techniques in networked microgrids for resiliency, exploring Swarm Intelligence (SI) and the particle swarm optimization algorithm (PSO). The project team received several grants to continue their work, including a $345,000 grant from National Fund for Scientific and Technological Innovation and Development. In addition, early in the project period, PI Ramón Emilio De Jesús-Grullón served as the main external researcher and editor for the Dominican Republic's "Indicative Plan for Critical Energy Infrastructure."

Outreach with the USAID Mission in Santo Domingo has also been ongoing. The team presented the progress of the project to Mission staff and agreed to connect with related projects in the country, such as the Energy Sector Reform (ESR) project, Green Recovery Investment Platform (GRIP), the Fulbright program. The team hope this will help them establish further connections with more professionals, as well as discover further financing and capacity development opportunities.

PUBLICATIONS

Ramón De Jesús-Grullón, Rafael Batista, Abraham Espinal Serrata, Juan Pichardo, Nestor Guerrero, and Justin Bueno. Modeling and simulation of distribution networks with high renewable penetration in open-source software: Qgis and Opendss. Available at SSRN: https://ssrn.com/abstract=4523911 or http://dx.doi.org/10.2139/ssrn.4523911

The Microgrid Research blog is now hosted on the official PUCMM´s server which will give the MG Research team a bigger audience to share their insights.

DOMINICAN REPUBLIC - PROJECT 9-210: CREATING KNOWLEDGE ON COCOA POLLINATORS IN AGROFORESTRY SYSTEMS OF THE DOMINICAN REPUBLIC FOR IMPROVING PLANTATION MANAGEMENT PRACTICES

PI: Colmar Serra, Pontifica Universidad Catolica Madre Y Maestra
U.S. Partner: Justin Runyon, United States Forest Service (Funded by the United States Department of Agriculture/ Forest Service)
Dates: April 2021 – March 2024

PROJECT OVERVIEW

The Dominican Republic (DR) is the world's primary exporter of organic cocoa with more than 153,000 ha cultivated and 85,000 tons exported in 2018. This commodity plays a strong role in the economy and supports more than 36,000 producers and their families. The vast majority of Dominican cocoa plantations are cultivated under agroforestry schemes. Cocoa-based agroforestry systems (Cocoa AFS) are cropping systems based on a perennial crop, the cocoa tree (Theobroma cacao L.), where farmers intercrop several other annual and perennial crops. In the DR, farmers associate more than 45 plant species with cocoa in heterogeneous patterns, thus creating a variety of habitats for cocoa pollinating insects. These cocoa AFS are known for their biodiversity conservation value and are often found near protected forest patches, where they buffer the transition between forest and agricultural land. However, it has been shown that plant species found in cocoa AFS strongly differ from those found in nearby forest fragments. In general, little is known about cocoa pollination ecology and services, although they appear to be key elements to understand yield functions. Moreover, on-farm habitat management and surrounding landscapes can affect the abundance and efficacy of cocoa pollinators, but this is poorly understood, and more research is needed in order to exploit habitat management and improve cocoa pollination.

The main objective of this PEER project was to understand how both the composition and the efficiency of cocoa pollinators' communities are affected at plot level by farmers' practices and surrounding land uses. The researchers analyzed and evaluated several landscapes and practices, including identifying landscape gradients surrounding cocoa plantations in each region, sampling composition, ecological functions and structure of cultivated plants at plot level, and identification of insect communities. The PEER team sought to develop capacity among local technicians, researchers, and cocoa farmers and their families.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers took several exploratory trips to identify forest patches adjacent to cocoa farms in three zones: Medina/Loma Verde and Los Bracitos, as well as the provinces of San Cristóbal and Duarte. Within these selected patches, they took a floristic inventory, recording the abundance and diversity of plant species present within 100-sqm plots. They estimated vegetation cover and analyzed biological types and biogeographic status of each species, as well as calculated biodiversity indices.

The PEER team also surveyed 90 Dominican cocoa producers, 30 in each of the three zones, on agricultural practices including agroforestry, plant protection, economic performance, access to credits, commercialization, and other aspects of cocoa production. Students from the Autonomous

University of Santo Domingo were trained on techniques for video monitoring of cocoa pollinators, and they helped support PEER team members on field visits. The researchers collected soil and insect samples at nine cocoa plantations and three forest patches in San Cristóbal Province. Work on a variety of related objects is continuing even after the project ended in April 2024, and the PEER team expects to present their findings at a joint meeting of the Caribbean Food Crop Society and Dominican Society of Agricultural and Forestry Researchers in July 2024.

The PEER team has developed collaborations the Loma Quita Espuela scientific reserve and the FUPAROCA foundation, as well as the Cacao Forest project, which provided guidance and logistics in the field for the identification of forest patches and cocoa producers in San Cristobal and Duarte provinces. The project has been presented and included in Cacao Forest's national strategy for rehabilitation and renovation for Dominican cocoa plantations.

DOMINICAN REPUBLIC - PROJECT 7-434: TECHNOLOGY AND CITIZEN SCIENCE FOR CREATING A SOLID AND PARTICIPATORY BIODIVERSITY INFORMATION SYSTEM IN HISPANIOLA

PI: Yolanda Leon, Instituto Tecnológico De Santo Domingo
U.S. Partner: John Lloyd, Vermont Center for Ecostudies (Funded by the United States Department of Agriculture/ Forest Service)
Dates: November 2018 - April 2021

PROJECT OVERVIEW

Despite being part of a global biodiversity hotspot, the Dominican Republic lacks information about its biodiversity at a suitable spatial scale for ecological research, species distribution, and habitat modeling, to influence land-use decisions. As a result, critical habitats are destroyed every day, pushing many species closer to extinction. Few experts and resources existed in-country for acquiring and/or digitizing the data required for such databases. Recently, two online citizen science platforms (inaturalist.org, ebird.org) amassed vast amounts of geolocated species-level observations for Hispaniola. Also, worldwide herbaria and museum collections were increasingly shared through common data standard platforms, such as the Global Biodiversity Information Facility (GBIF), which already included over 500,000 records for Hispaniola, many geolocated. This project created a step-by-step protocol for combining these rich datasets into a Hispaniolan species checklist and occurrence database, with a special focus on the Jaragua-Bahoruco-Enriquillo (JBE) UNESCO Biosphere Reserve of the Dominican Republic. Unfortunately, some faunal groups of Hispaniola are underrepresented in available datasets, as they are difficult to observe in the wild. One such group are the amphibians, currently considered the most endangered assemblage on Earth, with 98% endemic species. The JBE Reserve is one of the richest in amphibian species for the island, providing refuge to at least 12 endemic frogs and toads.

The goal of this project was to enrich amphibian data occurrence datasets through acoustic monitoring, which proved to be an efficient way to find and study amphibians. All the data generated by the project provided a valuable tool for decision makers, land use planners, scientists, conservationists, tourism, educators, communities, students, and the general public, as well as helped enforce species’ and area-based protection laws. For researchers, these data allowed for hypothesis testing of many questions in the areas of biogeography, evolution, and ecology, as well as provided a key historic public resource for natural habitat restoration for immediate use or for generations to come. In the process, the project team promoted and built capacity for biodiversity data management and citizen science, as well as created a greater engagement of the public with nature and the environment that could well be key to its survival.

FINAL SUMMARY OF PROJECT ACTIVITIES

According to the project PI Dr. Leon, this PEER project helped develop citizen science around biodiversity in the Dominican Republic. Its impacts in this regard ranged from basic name recognition of the term, to creating a community around local biodiversity knowledge and appreciation. It also helped provide a means to channel anyone´s interest in nature in a productive way by contributing to science while learning about species that are locally relevant for various community groups and individuals. On-going requests beyond project end to help train in citizen science attest to this success.

Two iNaturalist projects created by the project already gather over 3000 for project Reserva de Biosfera Jaragua-Bahoruco-Enriquillo (https://www.inaturalist.org/projects/reserva-de-biosfera-jaragua-bahoruco-enriquillo) and over 50,000 for Atlas Viviente RD (https://www.inaturalist.org/projects/atlas-viviente-rd).

By promoting biodiversity knowledge, its data collection and sharing in the field through the use of smartphones, the project helped create a new public awareness on the local manifestations of biodiversity and the severity and irreversibility of its loss, bringing home the impacts of the global biodiversity crisis. Project staff was able to supply site-specific biodiversity information tailored to different areas, for instance to inform the defense of Cotubanamá National Park against hotel development. Such information proved valuable for local and public empowerment in the defense of natural sites.

The project helped build biodiversity literacy through more formal classroom education opportunities. This was done by developing undergraduate and graduate class modules and practical exercises on biodiversity as well as an informal class for the general public to learn more about Hispaniolan biodiversity in a more structured way. This will ensure learning on these topics well beyond project end.

The PI states that the project helped build national capacity in the complex skill of database creation and management, combining for the first time expertise on taxonomy and data science. As a result, the project team successfully compiled the first biodiversity taxa checklists for Hispaniola (amphibians, reptiles and vascular plants), an Endangered Species checklist for the Dominican Republic and the National Red List of Threatened Species of the Dominican Republic, as well as a woody plant (plantas leñosas) occurrence dataset for the Jaragua Bahoruco-Enriquillo Biosphere Reserve of the Dominican Republic. However, the work on biodiversity information showed the team how they were just barely scratching the surface on this topic. Even the relatively simple first step of creating taxa checklists ran into a number of unforeseen complications, given how little most taxa have been studied in Hispaniola. In particular, the finding of two new reptile species by one of the undergrad students in the team during a few field trips to Sierra de Bahoruco speaks to this and the need for more research on Hispaniolan biodiversity.

The project helped build connections with various stakeholders and sectors of society centered around biodiversity. This included national and international non-governmental organizations, including educational, interest, community groups and research organizations as well as national and local level government institutions and private companies. These connections have already proven useful in extending project activities and benefits beyond project end. In sum, according to the PI, this PEER project provided a solid foundation for future citizen science and biodiversity knowledge growth and empowerment.

PUBLICATIONS

Geary, M., Brailsford, C.J., Hough, L.I. et al. Street-level green spaces support a key urban population of the threatened Hispaniolan parakeet Psittacara chloropterus. Urban Ecosyst 24, 1371–1378 (2021). https://doi.org/10.1007/s11252-021-01119-1

DOMINICAN REPUBLIC - PROJECT 5-400: DEVELOPMENT AND USE OF THE I-TREE TOOL TO EXPLORE THE POTENTIAL FOR URBAN GREEN INFRASTRUCTURE AS AN ADAPTION STRATEGY TO CLIMATE CHANGE RESILIENCE IN THE CITY OF SANTO DOMINGO

PI: Solhanlle Bonilla Duarte, Instituto Tecnológia De Santo Domingo (Intec)
U.S. Partner: Gerald Bauer, Us Forest Service, International Institute of Tropical Forestry (Funded by the United States Department of Agriculture/Forest Service)
Dates: January 2017 - November 2020

PROJECT OVERVIEW

This study used an Ecosystem Services approach to generate information for land use planning within the context of climate change adaptation. This approach employed science-based indicators that classified ecosystems and their functions and potential services to evaluate the influence of social, economic, and environmental service flows on human well-being, with the ultimate goal of guiding land-use planning. Reducing the impacts of urbanization and climate change has been a primary target of ecosystem services research, but research activity of this type in the tropics had been limited. The i-Tree is a public domain model provided by the USDA Forest Service and was used to aid planners and managers in the valuation and management of urban forests by quantifying the ecosystem services they provide. Although the i-Tree tool has been widely used in many U.S. cities and internationally, its use in the Caribbean had been very limited as well. The proposed project assisted in gathering scientific information that could be readily used to set ecosystem function and services management goals and evaluate climate change scenarios that were appropriate for a tropical ecosystem context, thus expanding the i-Tree model. Additionally, this project established an innovative collaborative platform that integrated multiple scientific disciplines with outreach and education towards greater understanding of urban infrastructure and sustainability.

As many small island nations, the Dominican Republic is vulnerable to climate-related impacts, including sea level rise, flooding, heat, prolonged droughts, and disruptions in water supply. State and local agencies in the DR addressed these potential impacts and worked towards developing adaptation strategies in collaboration with U.S. based agencies, including USAID and the USDA Forest Service. Urban areas, such as Santo Domingo, were of particular concern because of the greater number of people living in particularly poor, marginalized communities located in high-risk areas. The extensive and aging infrastructure throughout the city and the lack of forest vegetation created added risks such as urban flooding and water quality issues that would exacerbate climate-related impacts and biodiversity impoverishment. The Instituto Tecnológico de Santo Domingo (INTEC), in partnership with the Municipality of Santo Domingo, USAID, Universidad de Puerto Rico, and USDA Forest Service, took steps to develop adaptation strategies, such as the use of green infrastructure at the watershed level to minimize flood risks throughout the city. The i-Tree tool, which is a widely used application in cities worldwide, was used to assess and manage community forests and their faunal communities, and link urban forest management to environmental quality and community livability in the Santo Domingo area.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Bonilla and her team embarked on a collaboration with i-Tree Forest Service scientists to conduct an extensive assessment of urban green infrastructure in Santo Domingo. This initiative is pivotal in understanding and enhancing the city's green spaces, biodiversity, and the ecosystem services they provide. Utilizing i-Tree tools, the project aimed not only to quantify the extent and health of green areas, but also to evaluate their contributions to environmental quality and resilience in the face of climate challenge.

Central to their approach was the empowerment of local stakeholders through targeted workshops and training sessions. These efforts were designed to equip municipal managers, decision-makers, and community leaders with the knowledge and tools necessary to effectively manage and sustain urban green spaces. By building local capacity, the project not only fostered a deeper appreciation for the role of urban forests but also strengthened collaborative networks across academia, civil society, and government sectors.

The project's impact extends beyond academic circles. It altered perceptions of urban forests, highlighting their critical role as providers of essential environmental services and as integral components of climate adaptation strategies. Through the establishment of air quality monitoring networks and in-depth biodiversity assessments, the project contributed significantly to advancing scientific understanding and public awareness of urban ecosystems' complexities and values.

Moreover, the project made substantial strides in education and outreach, having trained a diverse cohort of over 200 individuals both nationally and internationally in the use of i-Tree tools. This capacity-building effort includes engaging students and municipal staff in hands-on research activities, thereby fostering a new generation of urban forestry practitioners equipped to address contemporary urban planning challenges.

One of the project's standout achievements lies in its comprehensive inventory of green spaces and species diversity throughout Santo Domingo. By establishing more than 206 measurement plots and conducting detailed surveys in residential areas, the project has generated invaluable data that not only informs local policymaking but also contributes to broader scientific discourse on urban biodiversity conservation and management.

The significance of the project is further underscored by its contributions to Santo Domingo's recognition as a bird-friendly city, a testament to the project's holistic approach to urban ecosystem management. By integrating scientific research with practical outcomes, such as policy recommendations and community engagement initiatives, the project exemplifies a model for sustainable urban development rooted in rigorous scientific inquiry and collaborative partnerships.

Looking ahead, the project holds tremendous potential for scaling its methodologies and tools to benefit other urban areas facing similar challenges worldwide. By sharing its findings and best practices through national and international forums, the project not only enhances global knowledge but also catalyzes future research endeavors and policy innovations aimed at promoting resilient and livable cities.

DOMINICAN REPUBLIC - PROJECT 2-270: TEMPERATURE PROFILE OF THE OCEAN SEABED, FROM THE CITY OF PUERTO PLATA, DOMINICAN REPUBLIC, AND PRELIMINARY DESIGN FOR A COMMERCIAL EXPLOITATION OF COLD WATER TO SUPPLY FOR A CENTRAL AIR CONDITIONING SYSTEM

PI: Eduardo David Sagredo Robles, Universidad Tecnológica Santiago
U.S. Partner: Naphtali David Rishe, Florida International University (Funded by the National Science Foundation)
Dates: August 2013 to July 2016

PROJECT OVERVIEW

Electricity shortages represent one of the major problems facing the Dominican Republic. For more than 50 years, the country has experienced daily electric power blackouts lasting some four to five hours. The cost of electricity in the Dominican Republic is more than 2.5 times the average cost worldwide, which causes financial hardships not only for the general public but also for operators of the large hotels that contribute substantially to the country's economy. Air conditioning uses approximately 60% of the electricity consumed in tourist areas. Given the high cost of electricity and frequent power outages, implementation of a reliable, renewable, and nonpolluting energy source that can supply air conditioning to these hotels would represent the difference between economic survival versus bankruptcy, with its associated severe impacts on local employment.

This PEER project studied a potential site in the city of Puerto Plata for a Sea Water Air Conditioning System (SWAC), which uses pumped seawater to provide cooling through district energy, cooling multiple nearby buildings in a single system.

FINAL SUMMARY OF PROJECT ACTIVITIES:

The PI and his team placed remote sensors at regular intervals along the seabed to gather data to create a seabed temperature profile extending eight kilometers north of Puerto Plata to a depth of 1,000 meters. They also collected sonar seabed floor data along the projected axis for the layout of an extraction pipe. These data collected helped the PI properly design a pipe along the seafloor to the surface at Puerto Plata to provide a cold-water supply for air conditioning. Researchers studied the environmental impacts of the potential system, as well as optimization of the energy needed to pump the seawater.

The PI met with many stakeholders during the course of the project, including the Consorcio Energético Punta Cana Macao (CEPM) and a large hotel complex in Puerto Plata, both of which could be potential clients for the district cooling system, as well as the Office of the Ministry of Economic Planning of the Dominican Republic. The team prepared detailed scientific and engineering reports and drawings of the potential project, as well as undertook an economic analysis of the project. Researchers also held a final workshop on July 22, 2016, to present results and technological and economical needs for the project to stakeholders and potential clients. Alberto Veloz, the ex-Vice-Minister of Energy, of the Ministry of Energy and Mines was the keynote speaker.

The PI also applied for a follow-on grant to the Clean Energy Finance Facility for the Caribbean and Central America (CEFF-CCA), a program under USAID auspices, in order to conduct a more extensive feasibility study. He and his colleagues hope that once the potential economic benefits and return on investment can be more fully documented, it will be possible to create a private corporation to implement their technology in Puerto Plata.

ECUADOR

ECUADOR - PROJECT 1-384: REDD BASED FOREST EXPANSION, FOOD CONSUMPTION, AND REDUCED EMISSIONS AGRICULTURAL POLICIES (REAP) IN THE ECUADORIAN AMAZON

PI: Carlos Mena, Universidad San Francisco De Quito

U.S. Partner: Thomas Rudel, Rutgers University (Funded by the National Science Foundation)

Dates: May 2012 - November 2015

PROJECT OVERVIEW

In tropical forest frontiers, agricultural policies that encourage cultivation increase greenhouse gas emissions. Forest policies that encourage an expansion in forest cover reduce greenhouse gas emissions but can create risks for food security. Can these contrasting goals be reconciled? This project aimed to inform the current debate by proving links between payments for ecosystems services (i.e., Reducing emissions from deforestation and forest degradation or "REDD+") and the production of foodstuffs using emergent silvopastoral landscapes (pastureland with increasing forestation) in the Ecuadorian Amazon. The emergence of these new forested landscapes is viewed by these researchers as both an opportunity for REDD+ due the characteristics of these landscapes as a carbon sink and as a natural experiment to explore the relationship between the expansions of forested landscapes and the production of food.

The project sought to identify the extent and drivers of silvopastoral landscapes, identifying how food consumption and production patterns are affected by the emergence of silvopastoral landscapes, and develop an emissions profile of peri-urban and urban farmers with an eye towards providing them an equitable distribution from the benefits of REDD+.

The researchers focused on two main areas of the Ecuadorian Amazon: Coca and Macas. They share key characteristics, including high population growth, high urban expansion, and the emergence of silvopastoral landscapes, but differ in several respects. Coca is the center of oil exploration and extraction in Ecuador, which is a driver of agricultural expansion or land abandonment. Macas, on the other hand, is undergoing agricultural change due to international out migration from agricultural areas. The PEER team used remote sensing, household surveys, and complex systems modeling to study impacts and sought to generate recommendations for reduced-emissions agricultural policies for Ecuador and the Amazon in general.

FINAL SUMMARY OF PROJECT ACTIVITIES

The research team estimated the total amount of carbon released into the atmosphere due to deforestation in the Ecuadorian Amazon by the year 2038, using a model to find the probability of land use change between time periods, validating using existing vegetation maps. The regions where most land use change was likely to occur were identified and then aggregated to a final prediction map. These areas were overlaid on a pre-existing baseline carbon map (MAE & FAO, 2014) to estimate the amount of carbon that would be released into the atmosphere by the year 2038. The team ran a simulation of deforestation rates in the Amazon region under two different scenarios. The first assumed existing protected areas are left intact and free from any deforestation while the second will examine the changes that could occur if protected areas are subject to deforestation. This will estimate the amount of carbon emissions that can be controlled in protected areas when REDD+ guidelines and regulations are implemented in contrast to the current deforestation trend.

The PEER project team has managed to work with and through an extensive network of actors and organizations partners in the Ecuadorian Amazon, including during a two-day workshop in Puyo, Pastaza Province, on June 25-26, 2015. The workshop introduced Geographic Information Systems tools to generate a discussion on the main needs of the communities and what applications of the technology could be used in terms of the management of their territories and resources. Researchers also held several meetings with the Ministry of Environment and the Ecuadorian Institute of Agricultural Research (INIAP) to explain the products of the project and coordinate activities, developing policy briefs to be given to the Ministry and INIAP. They also worked actively with Frente de Defensa de la Amazonía and the Red Angel Shingre, two local social organizations that support the project.

PUBLICATIONS

Lerner, A., Rudel, T., Schneider, L., McGroddy, M., Burbano, D., & Mena, C. F. (2015). The spontaneous emergence of silvopastoral landscapes in the Ecuadorian Amazon: Patterns and processes. Journal of Regional Environmental Change, 15, 1421–1431. https://doi.org/10.1007/s10113-014-0699-4

Mena, C. F., Guevara, A., & Sampedro, C. (2014). Exploring linkages between land use, conflicts, and oil extraction in the Ecuadorian Amazon. Paper presented at the Annual Meeting of the Association of American Geographers, Tampa, Florida, April 8-12, 2014.

Mena, C. F., Guevara, A., & Sampedro, C. (2013). Linking people, oil and silvopastoral landscapes: The case of the Orellana province in the Ecuadorian Amazon. Paper presented at "Pastures, Climate Change, and Sustainable Intensification in the Tropics: An International Workshop," International Center for Tropical Agriculture, Cali, Colombia, May 28-29, 2013.

ECUADOR - PROJECT 1-108: LONG-TERM SUSTAINABILITY OF WATER RESOURCES AND BIODIVERSITY UNDER SCENARIOS OF CLIMATE CHANGE IN THE NAPO WATERSHED, ECUADOR

PIs: Juan Manuel Guayasamin, Universidad Tecnológica Indoamérica, and Andrea Encalada, Universidad San Francisco De Quito

U.S. Partner: Leroy Poff, Colorado State University (Funded by the National Science Foundation)

Dates: June 2012 - May 2016

PROJECT OVERVIEW

Some of the most critical challenges faced worldwide are related to the conservation of freshwater ecosystems and their biodiversity, especially under the prospect of rapid climate change. Although most water sources are intertwined with human life, most rivers are within watersheds that have suffered uncontrolled and unplanned anthropogenic disturbances, including pollution, in-stream constructions, invasive species, and extractive uses. Climate change has the potential to magnify the risks that are already present by altering patterns of temperature, precipitation, and runoff, thereby disrupting biological communities and ecosystem processes.

This project gathered physiological, genetic, and environmental data generated by the National Science Foundation-funded EVOTRAC project in Ecuador, which predicted the vulnerability of organisms to rapid climate change, and combined it with new information to produce a set of recommendations intended to improve the conservation and management practices of aquatic ecosystems in the Napo basin. This effort represented an important first contribution to the long-term sustainability of water resources and biodiversity in this region. More specifically, in the Napo basin, this project had several major objectives. It determined and mapped ecological integrity of streams along an altitudinal gradient, using environmental (water quality and quantity) and biological data generated by the EVOTRAC project. Land use and land cover maps of the Napo watershed were also developed to help understand the main anthropogenic threats along an altitudinal gradient. This new information was then applied to identify and determine priority areas within the basin for management and conservation and to develop a conservation portfolio for freshwater ecosystems that included representation of biodiversity, ecosystems, and ecological processes and their vulnerability to climate change. The research findings and conservation portfolio were communicated to local communities, governments, NGOs, and the academic community by means of publications in scientific journals, on the Web, and as practical guides and workshops aimed at local communities and a general audience. The ultimate aim was the promotion of new management practices in the Napo basin to advance freshwater ecosystem sustainability.

FINAL SUMMARY OF PROJECT ACTIVITIES

Final Summary of Project Activities

By the time the project ended as of May 31, 2016, Dr. Encalada and Dr. Guayasamin had reported significant progress on all of their project objectives. An outline of their results and impacts is presented below, categorized by goal:

To determine and map ecological integrity of streams along an altitudinal gradient, using environmental (water quality and quantity) and biological data generated by the EVOTRAC

- The team finished sampling 144 streams in the Río Napo watershed, taking both biological (aquatic invertebrates and amphibians) and physicochemical samples ((chemistry, width, depth, flow). They also characterized the general surroundings of each surveyed stream in terms of landscape use (for example, human populations, agriculture, cattle farming, forest, mining activity, oil extraction, etc.).
- All amphibian samples were identified to the species or morphospecies level. The team is preparing papers describing two new species that they expect to submit by the end of July 2016.
- Invertebrate samples have been identified to family level, with specimens from the order *Ephemeroptera* (mayflies) being identified to the morphospecies level. Dr. Encalada is working on an article describing the diversity pattern of mayflies that she plans to submit by August 2016.
- Analyses of chemical variables show contamination in several streams, and USFQ researcher Dr. Valeria Ochoa is leading efforts to draft an article summarizing these results. They expect to have a manuscript ready by July 2016.
- The team has finished a guide for aquatic invertebrates that will facilitate species identification and give information on stream bioindicators. The guide is part of a book on the rivers of the Andes and Amazon basin that will be published in 2016.
- The main product related to this goal is a manuscript with a diversity map of the Napo watershed based on the ecological modeling of vertebrate and invertebrate diversity. The article was just accepted for publication in the journal Neotropical Biodiversity (http://www.tandfonline.com/loi/tneo20) and should appear in the August 2016 issue. This paper represents the first time that freshwater species have been used to highlight diversity patterns and conservation priorities in Ecuador. The manuscript is entitled "Freshwater vertebrate and invertebrate diversity patterns in an Andean-Amazon basin: implications for conservation efforts (authors: J. Lessmann, J. M. Guayasamin, Eduardo Toral-Contreras, José Schreckinger, Kayce L. Anderson, I. Jácome-Negrete, and A. Encalada).

To develop land use and land cover maps of the Napo watershed to understand the main anthropogenic threats along an altitudinal gradient

- GIS specialist Janeth Lessman and USFQ undergraduate student María José Troya have finished obtaining and systematizing data on anthropogenic activities that impact the biodiversity and water resources of the Napo basin. The information includes human settlements, main roads, oil activity, mining concessions, hydroelectric plants, thermoelectric plants, agricultural land use, water consumption and fisheries. The main results related to this goal are summarized in recently completed manuscript that builds upon maps with land use and land cover of the Río Napo watershed. The results show the impacts of oil activity and roads on ecological integrity, which was assessed using in situ information (macroinvertebrate community composition, riparian integrity, fluvial habitat quality, pH and conductivity). The two variables (oil activity and roads) can be used to create a model that predicts integrity throughout the watershed, including areas where no detailed information is available. These results are promising to establish priority conservation in large areas, such as the Napo watershed and the Amazon basin. A manuscript entitled "Validating GIS threat maps as a tool for assessing river ecological integrity: a case study in the Napo basin, Ecuador" (authors: Janeth Lessmann, María José Troya, Esteban Suárez, Andrea Encalada, and Juan M. Guayasamin) is being submitted in June 2016.

- Three other manuscripts are in various stages of preparation, describing (1) spatial prediction of stream physicochemical parameters for the Napo River basin, (2) hydrocarbons and oil contamination in the Napo Basin, and (3) the Napo river classification system.

To use this new information to identify and determine priority areas within the basin for management and conservation.

- The team expects to submit a manuscript in October 2016 that integrates their findings in terms of freshwater diversity, human threats, and conservation priorities. Contributors to this study include Dr. Encalada, Dr. Guayasamin, and Ms. Lessmann.

To develop a conservation portfolio for freshwater ecosystems that includes representation of biodiversity, ecosystems and ecological processes, and their vulnerability to climate change, and communicate the research findings and conservation portfolio to local communities, governments, NGOs, and the academic community.

- The researchers developed a "Conservation Portfolio" that was discussed in a workshop about Amazonian Freshwater Ecosystems organized by the Wildlife Conservation Society in January 2016. They plan to show the improved portfolio again to government authorities and national and international NGOs during the meeting "Conferencia Internacional de Aguas Amazonicas," which will be held in Lima July 15-16, 2016. The team expects that this document, together with their manuscript on Napo Conservation Priorities, could help guide conservation decisions and priorities in the Andean-Amazon regions.
- The PIs and their group have finished writing their book "Los Ríos Andino-Amazónicos del Ecuador: Manual de biomonitoreo para evaluación de su integridad ecológica" and it is expected to be published in July 2016. The draft version of the book was used during the Workshop "Evaluación de la calidad del agua y la integridad ecológica de riachuelos de la Cuenca del Napo," which drew 60 participants from various Andean-Amazon communities. The workshop was held at Tena, the capital city of Napo Province, in October 2015, and the discussions and feedback from the event were used to make revisions in the book.

Both Dr. Encalada and Dr. Guayasamin were honored in 2016 by the Secretary of Higher Education, Science, Technology, and Innovation of Ecuador as recipients of the Matilde Hidalgo Award, with Dr. Encalada being named a Consecrated Researcher and Dr. Guayasamin a Rising Researcher. Also this year, Dr. Encalada was invited to become a member of the Academy of Sciences of Ecuador. Although their PEER award has now ended, the team has built excellent relationships with community groups in some of the main towns and cities of the Napo watershed, and they have worked closely with members of the Oyacachi community (Andes) and with Amazonian communities. This interaction with local communities also includes the discussion, revision, and implementations of a guide for evaluating water quality, which will be published during 2016. The researchers also had initial contacts with government officials to discuss the importance of ecological flows in Andean-Amazonian streams and watershed during the 2016 workshop. They expect that communication will become more frequent as the results of their projects are further disseminated.

EL SALVADOR

EL SALVADOR - PROJECT 5-58: DATA SCIENCES TRAINING AND RESEARCH TO ADDRESS CRIME AND INSECURITY IN EL SALVADOR

PI: Oscar Picardo, Universidad Francisco Gavidia

U.S. Partner: Carlos Castillo-Chavez, Arizona State University (Funded by the National Science Foundation)

Dates: January 2017 - November 2018

PROJECT OVERVIEW

The 2015 UNESCO Science Report (Towards 2030) showed that El Salvador ranked poorly in Latin America in science, technology, and innovation (STI) capacity. Improving Salvadoran STI capacity was challenging, as approximately 32% of the population lived below the national poverty line in 2014, the country was plagued by gang violence, and among countries not at war, El Salvador had the world's highest estimated murder rate in 2015 (6,600 homicides out of a population of 6.3 million). Given this backdrop, the project sought to increase STI capacity in El Salvador by addressing crime and insecurity in the country. To do so, the project team launched a data sciences training and research program at the Universidad Francisco Gavidia (UFG) for 30 Salvadoran participants. Program participants included ten UFG students, ten participants from Salvadoran judicial institutions or law schools, and ten STEM teachers selected from two public secondary schools in San Salvador. After an intensive two-month training phase, the participants divided into a Judicial Group and a Teachers Group and began a ten-month research phase. The program structure was modeled after the successful NSF research experience for undergraduates (REU) program, the Mathematical and Theoretical Biology Institute (MTBI), which the U.S. partner on this project had operated for 20 years.

Inspired by the success of Dr. Rodrigo Guerrero Velasco in applying data sciences and epidemiology to combat crime in Cali, Colombia, the Judicial Group created a crime data sciences laboratory at UFG to collect and analyze crime and violence data in El Salvador. Their research objective was to improve the tools to guide crime and violence prevention strategies in El Salvador. Education is a critical short- and long-term remedy to mitigate crime and violence, but the low average quality of teachers constrained efforts to improve educational efforts. To address this constraint, the Teachers Group worked to improve the professional development of Salvadoran STEM teachers. Specifically, the group helped teachers create hands-on STEM activities with an emphasis on data collection and analysis to supplement STEM curricula in public secondary schools. They also formed teacher Lesson Study groups at two public secondary schools.

This PEER project addressed USAID's goals of mitigating crime and insecurity in El Salvador. By training the Judicial Group participants and creating a crime data sciences lab, the project provided valuable data sciences resources that increased the competence of the judicial sector. By training public school teachers in San Salvador and promoting the development of new STEM curricula that were not focused on rote learning, the project improved STEM education for at-risk youths, which helped mitigate the lure of gangs and provided the foundation for learning valuable technical skills. The focus on training teachers created a multiplier effect, as these teachers could train their colleagues, and this network reached more students than other types of programs. The training of UFG students also strengthened their marketable job skills and provided a pipeline of valuable government and private sector employees. In addition, the crime data sciences lab was the first project for the new UFG Center for Mathematical Modeling in San Salvador to study crime, violence, and insecurity and their impacts on Salvadoran society.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project ended in November 2018. According to the PI Dr. Picardo, almost all of the indicators established in the baseline of the project have been a success, supporting the hypothesis that improving science reduces violence and improves school indicators. After receiving STEM equipment, throughout the duration of the project, beneficiary schools held science contests to motivate their students to think in unconventional ways and to create interest in STEM technologies, in efforts to create a safe space for kids to be off the streets. Dr. Picardo reports that mechanisms were developed as part of group projects to help set boundaries between schoolmates, also contributing to their social and leadership skills, and that measurable results have been a big motivating factor for the participating schools to maintain STEM methodologies, and the students are happy to engage in science in such a unique way. During the execution of this project, beneficiary schools developed their own initiatives to hold workshops and science fairs, with motivating impact on the students. Other initiatives included creation of classroom discussion groups where students openly discussed their individual skills to apply in team projects. As a result, according to Dr. Picardo, this generated positive impact in young participants' perception of science, creating additional motivation to stay off the dangerous streets.The PEER team focused on young people, who can advocate for change in methodology in schools, with teachers playing a fundamental role in the application of new techniques that help with the development of STEM within their classrooms. According to Dr. Picardo, the PEER project motivated both teachers and students to adopt STEM methodologies and, importantly, gain practical hands-on science learning within their classrooms, which contributes to improvement of the learning environment.

Now that the PEER project has ended, the project team will stay in touch with the participating schools in hopes that they will develop at least one STEM project in the course of the school year. Individual follow-up visits will be made to monitor progress, to make sure the donated equipment is being used appropriately, and to monitor the development of the STEM project indicators in comparison to the indicators recorded during the previous years.

EL SALVADOR - PROJECT 1-354: DEMONSTRATING THE INTEGRATION OF GROUND-BASED MONITORING AND SATELLITE REMOTE SENSING FOR FORECASTING LANDSLIDES AND FLOODING HAZARDS IN VOLCANIC TERRAINS

PI: José Fredy Cruz, Universidad De El Salvador
U.S. Partner: John S. Gierke, Michigan Technological University (Funded by the National Science Foundation)
Dates: June 2012 - September 2014

PROJECT OVERVIEW

This project coupled long-term, ground-based monitoring of watershed hydrology with remote sensing data in developing computer models of watershed hydrology and risk maps for development institutions. These institutions were able to use these tools to forecast and plan for rain-induced flood and landslide hazards in steep, partially developed (agricultural), populated volcanic slopes. Spatially comprehensive monitoring with near real-time access to precipitation amounts was used to better understand the hydrology of large watersheds in steep terrain and the impacts of land use to allow for effective forecasting and communication of hazards posed by excessive rains.

This collaborative effort took advantage of the different skills and strengths of each participating institution, including remote sensing, data processing, computer modeling, local knowledge of hazard risks and landscape, and hydrological monitoring to create and develop tools to use near real-time precipitation information with previously collected data. The principal investigator and his group at the Universidad de El Salvador (UES) worked with Michigan Tech researchers and students currently serving in the US Peace Corps to establish precipitation and stream/river flow monitoring. Topical workshops in remote sensing and image processing and computer modeling were delivered by the Michigan Tech group to faculty and students at UES, who shared their understanding of how disaster plans and responses evolved before, during, and after a crisis. UES also hosted workshops and a four-month-long diploma program based on the work conducted in this project. The data from this collaborative project was archived and made public using Web pages and a Web-based database system that was developed and hosted by the Michigan Tech group through their National Science Foundation-supported work. This project also leveraged ongoing work by a Salvadoran nongovernmental organization (NGO), CEPRODE, for establishing weather monitoring and an international NGO, Caritas, involved with developing hazard mitigation plans.

FINAL SUMMARY OF COMPLETED PROJECT ACTIVITIES

Although this project was completed as of September 30, 2014, Prof. Fredy Cruz and his team have continued recording water levels in wells where they installed their sensors. This has been especially important in 2015, as many crops have been lost due to the unusually heavy rains. Despite the rains, water shortages remain a problem in San Vicente, so data collected from the well sensors is vital in helping to shape decisions regarding conservation and protection of water sources. As part of their project, the researchers produced complete maps of the modeling of lahars and identified communities that are most vulnerable in areas surrounding the Chichontepec volcano. These maps were prepared through the collaboration between researchers from Michigan Technological University and Prof. Cruz during his visit to MTU and were subsequently reviewed and validated by technicians from El Salvador's Disaster Protection Center (CEPRODE) and Civil Protection agency. A meeting was held involving researchers from the University of El Salvador, MTU, CEPRODE technicians, staff from Civil Protection and other local authorities (including the local mayor and governor) to analyze the lahar modeling map and discuss emergency preparedness for communities identified as being in the path of potential landslides. As a result, the parties agreed to gather information on possible temporary shelter sites for communities that are facing this threat. Further dissemination of the project results is planned to reach out to other relevant institutions in the country's Paracentral Region, including civil protection authorities, the municipal mayor's Technical Center for Disaster Protection, Caritas, the Ministries of Education and Health, and the Municipal Civil Protection Commission of San Vicente.

Another outcome of the project was implementation of a diploma course in Disaster Risk Management, the first such course for technical staff from different institutions, municipalities, and communities of the Paracentral area. This diploma course was developed with the support of the National Endowment for Development (FUNDE) and CEPRODE, in collaboration with Civil Protection. As a follow-up, the PEER team prepared a proposal for another diploma course, "Risk Management and Disaster Municipal Development." This course was only for technical staff of the mayors of the Paracentral region for the Project for Strengthening Local Governments (PFGL) of the Sub Secretariat of Territorial Development, attached to the Technical Secretariat of the Presidency. The course was presented nationally, in the western, eastern, and central regions of El Salvador in 2014, and a similar course focused on local problems in the Paracentral area will begin on July 11, 2015.

On the capacity-building side, Prof. Cruz and his colleagues have used equipment purchased through the project to develop a basic course of geographic information systems for the management of natural resources, which will be offered to agricultural engineering students. Other professors of the Multidisciplinary Paracentral Faculty were motivated by the project to submit a proposal to CSUCA (the Central American University High Council) and are currently developing another research degree program in Disaster Risk Management. The PEER-supported collaborative relationship between UES-FMP and MTU has also opened up additional opportunities with other national and international institutions. This in turn has allowed the Graduate Unit to make a greater contribution to capacity building in San Vicente and other municipalities, both on disaster risk management and on territorial economic development. UES has signed a letter of understanding with the Foundation for Local Development and Municipal and Institutional Strengthening of Central America and the Caribbean, supporting the organization of a diploma course in local economic development management aimed at municipal technicians, fishing cooperatives, grain and vegetable producers, tourism boards, and other umbrella organizations.

Another letter of understanding was signed with the Ministry of Finance through the Strengthening Local Governments (PFGL) program to develop two graduate programs, one on Risk Management and Municipal Development and another on Economic Development and Sustainable Land Management. Overall, the team's activities and their integration of different actors in the region can help improve access to research data, reduce research costs, and facilitate involvement and better disaster preparedness for the most vulnerable communities.

HAITI

HAITI - PROJECT 6-18: STUDENTS WITH DISABILITIES AND PEDAGOGICAL PRACTICES OF TEACHERS IN THE SCHOOLS IN THREE REGIONS OF HAITI

PI: Rochambeau Lainy, Groupe D'initiative Pour L'etude De La Cognition Du Langage, De L'apprentissage Et Des Troubles (Gieclat)

U.S. Partner: Nathalis Wamba, Queens College (Funded by the National Science Foundation)

Dates: April 2018 - March 2021

PROJECT OVERVIEW

The project involved the collection and analysis of data on students with disabilities and the pedagogical practices of their teachers in areas of Haiti devastated by Hurricane Matthew on October 3, 2016. The Grand Anse, Nippes, and Southern areas of Haiti suffered massive destruction of all infrastructures, including housing, health, transportation, and education; many people in these areas of Haiti had likely already been devastated by the severe earthquake in January 2010. While ongoing efforts responded to the basic needs of survivors, less than two percent of humanitarian aid efforts went to education. Of the humanitarian aid for education, very little was allocated for children with disabilities. In the post-earthquake and hurricane reality, meeting basic life needs was difficult for everyone (with or without disabilities) in the best of circumstances. The Haitian Ministry of Education had begun to address the educational needs of those with disabilities, but demographic summaries suggested that less than four percent of children with disabilities were registered in school. It was reasonable to expect (though uncertain) that the number was even smaller at that time, and that children with disabilities were receiving very little education. Given this large area of need, Dr. Lainy and his colleagues focused their project on expanding known data about youth with disabilities in Haiti. The objectives of the project were to (1) estimate the number of students with disabilities in three departments of Haiti, (2) survey the needs of students with disabilities in these departments, (3) determine services received by these students, and (4) describe the educational context for these students, including resources and practices of teachers and schools.

Since the devastating earthquakes in 2010, Haiti had received $4.2 billion from the U.S. Government to help transition from disaster relief to a long-term development plan. This project supported these goals by building an information infrastructure about the status and needs of those with disabilities in Haiti, many of whom were disabled directly by the disaster events. Specific expected results and outcomes of the project included:

- Providing donors and stakeholders (e.g., USAID/Haiti, the Ministry of National Education, NGOs, etc.) with credible and reliable data to guide their actions to increase access to educational activities for youth with disabilities in Haiti.
- A description of the causes, symptoms, and impacts of mental and/or motor disabilities among school students in Grand Anse, Nippes, and Southern areas of Haiti.
- A description of the limitations of the pedagogy used and the weaknesses of the available infrastructures.
- Increased awareness among teachers, principals, parents, and local authorities regarding the impacts of disabilities.

- A set of resources and a way forward to assist students with disabilities.
- A summary description and analysis of the psychological impacts of disabilities on students.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project was a comprehensive effort to address the challenges of inclusive education in Haiti, with a particular focus on the Grand Sud region. The primary goal was to conduct qualitative research, supplemented by quantitative methods as needed, to understand and improve educational practices for students with disabilities. The research initiative identified 13 communes and two localities, Léon and Fonds-Cochon, as key research sites. Additionally, schools in five communes of the South and four communes of Nippes were included in the study. This broad geographical scope ensured a diverse representation of educational contexts, both urban and rural, across the targeted regions.

One of the significant findings was the glaring absence of inclusive education within university curricula, particularly at institutions like UPGA (Université Publique du Grand'Anse). This gap underscored the need for systemic changes in how teachers and educational leaders were prepared to support students with disabilities effectively.

In terms of methodology, the project sampled 60 schools in the Grand'Anse region, 12 in the South, and 10 in Nippes. This extensive sampling allowed researchers to document various learning difficulties among students and assess the capacity of teachers and school administrators to address these challenges adequately. The research highlighted deficiencies in school governance related to handling disabilities, prompting a critical evaluation of existing educational policies and practices.

A pivotal aspect of the project was its impact on stakeholders within the educational community. Teachers and administrators demonstrated a growing interest in inclusive education principles, moving away from outdated and narrow conceptions of disability. Through discussions, interviews, and collaborative efforts with researchers, these stakeholders began to embrace a more inclusive approach to teaching and school management.

The dissemination of findings was another key outcome, with significant media coverage and scholarly publications. Notably, the project resulted in ten articles published in Haitian and Guadeloupean media outlets and eleven scientific articles in a Canadian publication focusing on disabilities in Haitian schools. This dissemination helped raise awareness and fostered broader discussions on educational equity and inclusion.

Furthermore, the project's success led to additional funding and support for expanding its initiatives. This included initiatives such as further teacher training and the establishment of a Master's program in Inclusive Education at UPGA. These developments were crucial in institutionalizing inclusive education practices and building capacity among future educators and educational leaders in Haiti.

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HAITI - PROJECT 4-245: EXPLORING SUSTAINABLE SOLUTIONS AIMED AT REDRESSING ENVIRONMENTAL DISASTERS IN HAITI

PI: Rene Jean-Jumeau, Universite Quisqueya
U.S. Partner: Jerry Bauer, International Institute of Tropical Forestry (Funded by the United States Department of Agriculture/ Forest Service)
Dates: October 2015 - July 2023

PROJECT OVERVIEW

Since the industrial revolution, an unprecedented amount of greenhouse gases has overloaded the earth's atmosphere, threatening large-scale disruptions in climate. When it comes to climate change, extreme weather, and health, the connections are very clear in Haiti. According to Germanwatch, for the past 20 years, Haiti has been the third most negatively impacted country in the world by global climate change. In the summer of 2008, four successive tropical storms made landfall on Haiti, leaving the country's fourth largest city, Gonaives, inundated for months. The poorest country in the Western Hemisphere, Haiti is also prone to a variety of other natural disasters that can severely cripple such a small economy. The particular susceptibility of the landscape makes matters worse: Haiti has less than 2% of its original forest cover still standing, increasing the chances of flooding and landslides.

The PEER project aimed at developing sustainable solutions to address some of the environmental problems, including the effects of global climate change in Haiti. Specifically, the objectives of this study were to (1) use GIS and remote sensing tools to evaluate the magnitude of deforestation and reforestation in Haiti; (2) train Haitian students in environmental sciences at the University of Puerto Rico; and (3) develop research projects and master's theses in areas leading to sustainable development in Haiti, such as reforestation and renewable energy using marine algae-based biofuels. The principal investigator and his team partnered with the University of Puerto Rico and the USDA International Institute for Tropical Forestry, which provided mentoring and guidance, as well as access to GIS/remote sensing facilities and laboratories. This study provided an excellent opportunity not only to train the next generation of environmental scientists in Haiti but also to continue efforts to rebuild the university system of Haiti, which was severely damaged during the earthquake of January 2010.

International organizations have concluded that unless a viable and less expensive substitute fuel is found to replace charcoal in supplying Haitian households, there will never be any slowing of deforestation in the country. In order to address this vicious cycle, the project team developed a framework for sustainable actions to address some of the environmental ills lying at the root of the problem. First, by monitoring and evaluating deforestation and reforestation in Haiti, the team expected to better gauge remediation efforts. Second, by focusing their efforts on marine algae for use in bioenergy, they promoted clean alternatives to charcoal use while exploring sustainable and renewable options. Third, this initiative contributed to the training of Haiti's next generation of green workers for a sustainable economy, which would provide income-earning jobs to the rural poor. These objectives were accomplished through active engagement with the community and by providing the necessary tools to key development actors to help them approach their pressing issues in an environmentally sustainable manner.

FINAL SUMMARY OF PROJECT ACTIVITIES

A number of outreach activities were carried out at the onset of the project. A presentation, workshop, and lecture around the project were conducted during the Caribbean Studies Association Annual Forum in June 2016. On November 10, 2018, the PEER team presented a panel at the annual meeting of the Haitian Studies Association (HSA) held at Université Quisqueya in Port-au-Prince. The panel was entitled "USAID PEER Project: Climate Change Adaptation and Mitigation in Haiti" and was chaired by René Jean-Jumeau. Professors Gervais and Jean-Jumeau made presentations at the event.

The project team pursued research on methanization (i.e. decomposition) of sargassum algae in a saline environment. Professor Gary Gervais, assisted by Haitian graduate student Jordany Fortuné, conducted experiments to analyze the digestibility of fresh and dried sargassum compared to a control system. Professor Cliford Louimé submitted four scientific manuscripts for review and publication based on this research. Additionally, an update of the assessment of the level of vegetation cover in Haiti was successfully achieved. Updated statistics on vegetation cover in Haiti were determined by a GIS technician, Mr. Constantin Joseph. The work, validated by Prof. Noël of UniQ, succeeded in characterizing and estimating wooded areas in the country, identifying and estimating forest areas, and quantifying the rate of vegetation cover of all types.

Another training element of the project was the researchers' contributions to a new course in environmental sciences examining energy solutions to environmental problems. The research partners collaborated with Professor Viviane Julien of UniQ's School of Agriculture and Environmental Sciences on the content of the course. Dr. Gervais also worked on the descriptions of two new courses: a biomass energy course and an environmental entrepreneurship course for undergraduate students. Laboratory spaces for the study and resolution of environmental disasters were reinforced. Support was given to UniQ's Polyvalent Laboratory – which serves a great deal of students in various scientific fields – for collaboration with the professors involved in the PEER program, both local and international.

The program supported and supervised the fieldwork in the Parc Macaya of Haitian student Hervé Chevalier for his Master's thesis at UPR. He analyzed the effectiveness of one of the reforestation programs in the Parc Macaya and was able to fully complete his fieldwork and produce his thesis document. Two scholarships for graduate studies at UPR were also awarded to two UniQ graduates, Naldy Hans Steev Celestin and Billy Dessalines, who are currently pursuing their graduate degrees at UPR.

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MEXICO

MEXICO - PROJECT 3-129: POVERTY AND CLIMATE CHANGE IN MEXICO: THE IMPLICATIONS OF MITIGATION POLICY, CLIMATE IMPACTS, AND DEVELOPMENT PATHWAYS FOR HOUSEHOLD WELFARE

PI: Landy Sanchez, El Colegio De Mexico
U.S. Partner: Brian O'Neill, National Center for Atmospheric Research (Funded by the National Science Foundation)
Dates: September 2014 to November 2018

PROJECT OVERVIEW

Climate change will impact the Mexican population's wellbeing over the next decades. There were few worldwide studies that considered the impact of mitigation policy on poverty, and no estimation of corresponding scenarios for Mexico, since integrated analysis of climate impacts and mitigation policy was very novel. In order to design sound development policies, it was imperative to understand the linkages between poverty risks and climate change, as well as to quantify how mitigation targets would diminish or increase such risks in the short and long run. This research study examined the combined implications of climate impact and mitigation policy for poor households, through their effects on agriculture and energy, addressing limitations of current research. The research team aimed to: (1) enhance the representation of Mexico's development trends for climate change scenarios, with an updated and detailed survey analysis of demographics, income, and consumption of Mexican households over time for iPETS; (2) develop climate and socioeconomic scenarios for Mexico, in a global context; (3) examine the joint consequences of climate impacts and mitigation policy on households: variations in the number of poor households, as food prices responded to impacts on crop productivity and land availability; energy prices impacted poverty headcounts under climate policy; and whether demographic and income transformations might offset food and energy prices effects, under different adaptation and mitigation policies that might alleviate negative consequences on poverty; and (4) fostered capacity building for climate and socioeconomic scenario research among researchers and policy makers in Mexico.

The research team, in collaboration with the U.S. partner, trained, strengthened, and better informed researchers, graduate students, and policy makers on the use of climate and socioeconomic scenarios, fostering their capacity to evaluate the welfare implications of climate policy. In order to achieve this, the project included different venues for presenting the fundamentals of scenario design using integrated assessment models (IAMs). The project paid special attention to climate-change implications for households, arising from socioeconomic pathways and demographic heterogeneity. Since the impacts were likely to be uneven, identifying differential effects across household groups served as an important input for development of better policies in Mexico, given its large demographic and social inequality. The research project contributed to USAID's goal of decreasing vulnerability to poverty. Although Mexico had estimates about mitigation costs for the country, there was no study that evaluated how global climate policy would impact its population, and to what extent future social and economic transformations could balance such effects. This project, with its integrated approach, helped inform Mexican policy makers on mitigation and adaptation policies, and how they could be designed without harming poor household groups.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project ended in November 2018 with three main goals accomplished, including: (1) a better understanding of the heterogeneity of household impacts and responses to food and energy constraints; (2) developed national scenarios of climate change impacts; and (3) contribution to building capacity on the study of social implications of climate change. Through research, publications of multiple papers (6 peer-reviewed journal articles, 2 peer-reviewed book chapters) and 21 technical presentations, the project explored how household sociodemographic characteristics shape their response to increments of food and energy prices. Analysis of scenarios allowed the project team to evaluate the impact of climate change in agricultural productivity and its derived effect on consumption and income. Results show negative impacts on population wellbeing for Mexico, more substantial than in most other regions of the world. The detrimental effect on consumption and income, according to the PI, is similar across socioeconomic scenarios, but population groups fare differently, with urban household being the most affected. In the mid-term future (2030-2050), mitigation adds to the negative impacts of climate due to increased energy prices. Urban households experience the largest total losses in food and energy consumption because of their higher intake levels and because of the structure of their consumption: they are mostly food net buyers and still rely heavily on fossil fuels. The results of the research, according to the PI, support the need for developing a social policy to protect households from the effects of climate change and the need to understand the population subgroups that will benefit the most from it.

The project strengthened the study and understanding of the social dimension of climate change. First, it fostered the abilities of the Mexican research team, and it contributes to improving the curricula of graduate courses in urban and population studies. Second, it helped to develop research networks among Mexican academics on issues of household environmental behavior and climate change distributive impacts.

In terms of most recent outreach, the team organized a workshop for local state officials in Puebla, Mexico, in November 2018 to provide training on how to take into account climate change risks on local government plans. Representatives of 18 municipalities attended. Participants' towns vary in their socioeconomic characteristics and their vulnerability to climate change facing varying challenges and priorities. As a result, the team has agreed to continue working with these municipalities in addressing specific issues (energy, waste, food security, water) in future workshops.

As a direct result of the PEER project, a group of Mexican researchers began to collaborate in studying the social dimensions of climate change, particularly those linked to food security and poverty, and Prof. Sanchez was appointed Chair of the Environment Research Network of the Latin American Association of Population Studies (2018-2020). Now that the project has ended, the team still needs to publish the climate change scenarios results as the manuscripts are being finalized for submission. The PI will keep working on the distributional impacts of climate change by considering a) changes on household structures; b) assessing the effect of higher public transfers and lower inequality between rural and urban settings. For that matter, the PI will employ macro-micro simulation methods, where scenarios results will be combined with household survey data. Datasets and documentation are available at https://climapob.colmex.mx/

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MEXICO - PROJECT PP-10: NSF-PIRE COLLABORATION: SUSTAINABILITY EVALUATION OF JATROPHA OIL PRODUCTION IN YUCATAN, MEXICO

PI: Julio Sacramento-Rivero, Universidad Autonoma De Yucatán
U.S. Partner: Kathy Halvorsen Et Al., Michigan Technological University (Funded by the National Science Foundation)
Dates: December 2012 - March 2017

PROJECT OVERVIEW

Dr. Julio Sacramento-Rivero and his colleagues worked with Dr. Kathy Halvorsen and her group at Michigan Tech to address such questions as “How did bioenergy development affect social systems?” and “What sustainability indicators and metrics best assessed biofuel sustainability across highly variable Pan American socio-ecological systems?” This work was performed in the context of the jatropha oil industry that was under development in the state of Yucatan, Mexico. This case study was unique in that it presented both universal and idiosyncratic aspects of sustainability that were evaluated. Although commercial-oil production was not expected to begin in Yucatan until 2014 or 2015, several communities had already been affected by the planting and cultivation stages, and it was uncertain how the currently planned commercialization model would impact sustainability in the region.

Thus, this project aimed to evaluate the sustainability of the production and commercialization process of jatropha oil, and the socioeconomic impacts of this activity on the local communities in Yucatan and the broader national system. Also, although the current commercialization model was primarily concerned with biodiesel sales, it had been strongly suggested that the economic viability of such systems could greatly benefit from the integral use of the jatropha plant. In that sense, a biorefinery system was designed and included in the sustainability assessment as an alternative, expanded system. For this stage, fundamental engineering experiments were performed on the local feedstock at the Faculty of Chemical Engineering at UADY and at MTU, which generated characterization data of the local feedstock that was required for evaluation of both biofuel-oriented and biorefinery-oriented systems. Funds from the PEER Science grant to UADY supported the purchase of new lab equipment, materials, and software; domestic and international travel for fieldwork and training; and PhD student stipend support.

FINAL SUMMARY OF PROJECT ACTIVITIES

In this now-completed project, Dr. Sacramento and his colleagues evaluated the environmental, socioeconomic, cultural, and political impacts of jatropha plantations in the Yucatan from a multi-stakeholder’s perspective, including the views of government agencies, private companies, and Maya small farmers. The research team was multidisciplinary, with leaders in the areas of engineering, anthropology, and economics from the Universidad Autonoma de Yucatan (UADY), with support from U.S. partners in these areas from Michigan Technological University. By analyzing the institutional context in which jatropha plantations were promoted and implemented in the Yucatan, they concluded that public programs were making many assumptions unsupported by scientific facts, similar to the situation in other countries. Jatropha is still a wild plant, with no technological package for optimizing seed yield, no selected elite varieties that can ensure good productivity, and associated with myths of being a plant that can endure marginal soils without need of irrigation, pesticides, or fertilizers. Many projects worldwide were initiated under these premises, following business projections assuming annual productivities between 5 and 10 tons of seed per hectare; this led to inevitable failure when after 4 years annual yields could not reach 1 ton/ha in most cases. Implementation of jatropha projects in Yucatan was different than in other regions of Mexico and the world, in the sense that the investment in land and infrastructure came from private companies, which in turn had access to some limited seed capital from public funds. Global Clean Energy Holdings (GCEH), the company in which this team centered their case study, created many jobs in the local community of Sucopo, and while it lasted, provided better salaries and benefits than those required by law, offering much better job conditions than what the peasants were used to from experiences working for other companies in the region. Unfortunately, they also created expectations of long-term jobs and therefore, when the jatropha business collapsed after only 4 years, they were left unemployed and disappointed.

By analyzing the economic costs and benefits of jatropha plantations in Yucatan, Dr. Sacramento and his group identified that the local peasants increased their annual household income by about U.S. $1,080 during the time they had the jobs. This amount was significant to them, allowing them to purchase goods such as TVs and motorcycles and improving the local economies in the process. From the investors' point of view, the project was an economic failure due to the low productivities that made it impossible to move to the biodiesel production stage. By analyzing the compatibility between traditional milpa production (long fallow swidden system) and the production of jatropha for biodiesel, the researchers observed two main issues. First, workers in the jatropha plantations did find themselves with additional time to dedicate to their own private milpas or parcelas. This reflected in the economic analysis as increased household income relative to those that did not work in the jatropha plantations. Second, although the plantations were established on private land categorized as "abandoned cattle ranches," local community members declared that they removed vegetation older than 20 years in clearing the sites. Some of this land was culturally considered by the local Maya people as part of their natural heritage, and therefore they traditionally obtained some environmental services from that area, including, for example, by gathering wood, wild fruits, and in some cases medicinal plants or by hunting animals. When the jatropha companies cleaned more than 5,000 ha of this secondary forest, many species lost their habitat and food sources, becoming pests to the neighboring farmers, whose milpa harvests were subsequently devastated.

By evaluating the environmental burden of the (hypothetical) biodiesel production system from a Life Cycle Assessment (LCA) perspective, it became clear that the production of biodiesel from jatropha can be energetically self-sufficient. Even though the GHG emission savings are considerable (57% or higher), using pesticides, fungicides, and insecticides on the plantations causes important impacts, especially on the eutrophication potential. These red flags should be further investigated in the local context (i.e., karstic soil, underground river flows, and cenotes) using an environmental impact assessment, in order to evaluate with greater accuracy the impacts that these new activities would have on the local environment. Furthermore, agronomic studies should be directed at minimizing the use of these substances without significantly decreasing seed yields.

By comparing the overall sustainability assessment of the biodiesel-oriented and the biorefinery-oriented systems, the main result of this project was the finding that the process can be economically feasible even at low seed productivity if a pyrolysis process is implemented to produce a high value-added biochar. In order to achieve this, a viable market should be identified in the region. Greenhouse gas emissions and other environmental impact indicators also benefit in a biorefinery-oriented system. These results have already had an impact in the academic community, as the methodology used for the sustainability assessment can be generalized for assessing many different systems for bioenergy production (for example, lignocellulosic bioethanol and solid biofuels). This methodology will be proposed in subsequent projects to governmental stakeholders to promote its use as part of national standard sustainability assessment methodologies.

During the 4 years that the project was in operation, the results of these evaluations have been presented in various fora where academics, researchers, and students have learned about the sustainability issues of biofuels. This has been done through conference presentations, project meetings, and a formal online course offered for graduate students in both Mexico and the United States. As a result of these interactions, the PI has been included in two important Mexican national networks of biofuel research: the Red Tematica en Bioenergia and three clusters of the Centro Mexicano de Innovación en Bioenergía (CEMIEBio). The latter provided access to funds to polish the methodologies proposed in the PEER project and apply them to other biofuel pathways relevant to Mexico. Although his PEER grant ended as of March 31, 2017, Dr. Sacramento expects to continue collaborating with his U.S. partners.

NICARAGUA

NICARAGUA - PROJECT 2-459: MARINE BIODIVERSITY INITIATIVE FOR CENTRAL AMERICA: INTERNATIONAL PARTNERSHIP FOR RESEARCH AND TRAINING ON MARINE BIODIVERSITY AND GENOMICS

PI: Jorge Alberto Huete-Pérez, Universidad Centroamericana

U.S. Partner: Martin Polz, Massachusetts Institute of Technology (Funded by the National Science Foundation)

Dates: August 2013 to April 2015

PROJECT OVERVIEW

This PEER project sought to assemble an international network of scientists to train local researchers and assist them in the study of neglected Mesoamerican coastal marine biodiversity and the impact of climate change (e.g., via ocean acidification), specifically in Honduras, El Salvador, and Nicaragua. Using a cross-disciplinary approach integrating taxonomy, molecular biology, and genomic techniques with biodiversity conservation, the network identified gaps in knowledge to determine a new course of research on marine biodiversity in Mesoamerica and developed collaborative programs on the sustainable use of marine resources and anthropogenic influences on ocean biodiversity.

The PEER project sought to advance scientific and technical knowledge for informing development-related policies, improve the capacity of local institutions, enhance the technical infrastructure of local, and impact the broader community in the region through partnerships between researchers, community leaders, authorities, educators and students. The project built upon a foundation of collaboration between the PI's team and counterparts in the European Union to work with communities in the Gulf of Fonseca to increase their awareness of the value of their marine resources. The project aimed to set the stage for eventual commercial activities based on local stewardship of coastal resources and on diversification of the coastal economy.

FINAL SUMMARY OF PROJECT ACTIVITIES:

The project began with training workshops on marine ecology and genomics techniques in October 2013 and March 2014, the latter including a week-long field trip to Juan Venado Island Nature Reserve. As the centerpiece of the project, Dr. Huete-Pérez and his team organized the VII International Conference on Central American Marine Biodiversity and Genomics in Managua May 8-10, 2014. The principal goal of this conference was to promote the development and use of biotechnology innovation in Nicaragua and surrounding countries and to create an international network for local marine biology exploration and research. Tandem goals of great importance included strengthening ties between the academic, governmental, non-governmental and private industry sectors; and providing training to local researchers in Nicaragua and the Central American region. Participants discussed key threats to the region's marine ecosystems, priority topics for further study, and various constraints hindering the adoption and implementation of appropriate environmental management policies. To promote new collaborative linkages, there were also networking sessions for the international participants, including Nobel Laureate Sir Richard Roberts, to interact with local researchers and students.

As a follow-up to the conference, the PEER project team held a training workshop in August 2014 on methods and bioprospecting for research on marine microorganisms at the PI's home institution. The week-long workshop, taught by Dr. Tracy Mincer of the Woods Hole Oceanographic Institution, included lectures, a field visit to Pochomil, a sandy beach on the Pacific coast of Nicaragua, and hands-on lab work. Attendees included delegates from various Nicaraguan institutions, including the Molecular Biology Center (CBM-UCA), the Bluefields Indian and Caribbean University (BICU), the University of the Autonomous Regions of the Caribbean Coast of Nicaragua (URACCAN), and UCA itself. As a result of the workshop, the team proposed the organization of a new research seminar series focused on marine conservation and bioprospecting, providing an informal setting to discuss current projects, data interpretation, and future proposals.

The Marine Biodiversity Initiative Project continued with another set of workshops in February and March 2015 to provide specific training for young researchers from CBM-UCA focused on two main topics, the microbial quality of medicinal plant materials and biodiversity and sustainable use of fish in the coastal zone of Central America. After the project was completed, Dr. Huete-Pérez reported that he and his colleagues were seeking support from other sponsors for new research projects focused on marine conservation and bioprospecting.

PERU

PERU - PROJECT 9-229: MULTI-SCALE, INTERDISCIPLINARY INTEGRATED ANALYSIS OF SOCIETAL AND ECOSYSTEM VALUES OF PERUVIAN AMAZON PEATLANDS

PI: Sandra Ríos Cáceres, Instituto Del Bien Común, With Co-Pi Aoife Bennett
U.S. Partner: Hinsby Cadillo-Quiroz, Arizona State University (Funded by the National Science Foundation); Victor Gutiérrez-Vélez, Temple University
Dates: April 2022 – May 2024

PROJECT OVERVIEW

While the peatlands of Southeast Asia have long been recognized as threatened major stores of carbon, the tropical peatlands of Amazonia have only recently begun to be identified. Their distribution, depth, carbon content, and socioeconomic dynamics are not well known. Furthermore, existing knowledge is largely based on remote-sensing data with little field validation, and almost no engagement with local peoples.

This PEER project carried out research in the two focus areas of Loreto and Ucayali in the Peruvian Amazon. Indigenous and smallholder communities live inside and close to known peatlands, and they will play a central role in managing and conserving them going forward. However, outside of a few sites in Loreto, previously there had been no rigorous assessment of how local people value and use these peatlands, and no explicit research into opportunities for collaborative conservation beyond the sustainable use of the over-harvested aguaje palm tree. This project team aimed to co-create new knowledge on the distribution of peatlands, their carbon storage, and how local people understand, use, and steward these ecosystems.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers created high-resolution remote sensing maps of various kinds, some of which were ground validated using a local field team and subsequently checked in workshops with indigenous communities; others were randomly validated (remote). These maps show some newly discovered areas of peatland and will be returned to the communities for their knowledge and political use.

In terms of statistical precision for maps, the overall accuracy in identifying ecosystems with the potential for peatland presence was 97%. However, there is a paucity of high-resolution images on the west side of the river, which has led to a certain degree of uncertainty, particularly in the case of the Pisqui river. The results obtained indicate that the peatlands within the study area contain an average of approximately 568 trees per hectare. A total of 201 species belonging to 45 families were collected. The researchers also found the carbon storage potential of peatlands were significantly influenced by species composition (wood density) and stem density (e.g. trees per hectare). Sampling of 125 distinct soil samples showed a remarkable diversity in the total soil carbon content.

The team also co-developed a dynamic territorial-political peatland map of local populations and their socioeconomic activities with indigenous community. This mapping process involved the drawing of landscapes by the communities, as well as working on large maps with the legal polygons brought to the communities, which were overlaid with plastic sheets for each topic of interest. The resultant map ended up highlighting the threats and opportunities to the peatlands in a new geopolitical context.

The researchers spent the entire two years of the project co-creating the socio-ecological nexus, mainly in the form of a novel methodology. However, in working with the indigenous people they changed the “nexus” to “research at the interface of Indigenous and Western science” because this group of inter-cultural (indigenous and non-indigenous) researchers believe indigenous research methodologies and methods are as rigorous and progressive as Western ones. Not approaching indigenous research in this way creates barriers to the generation of high-quality robust, resilient, ethical, and reciprocal research that could otherwise be useful to people and nature. The team interweaved indigenous methods, Western social and natural science methods and both participatory remote sensing mapping and applied the methodology in indigenous communities to derive qualitative and quantitative results on themes of Violence, Nature, Migration, Ethnicity, and Deforestation. Other topics included the future the community wants and opportunities for restoration and regeneration of degraded areas.

The PEER team was able to bring one of the co-creators from the Shipibo-Conibo tribe to Oxford University to promote their process to students, academics, and other interested parties, and the team received a grant of $14,000 from Oxford’s Leverhulme Centre for Nature Recovery for their work. The PEER team and indigenous researchers are preparing two papers for academic journals on their findings and published an interactive map about processes of the ecological mapping (taking staples, traversing difficult terrains and consulting with communities to get the best soil samples in the area).

PERU - PROJECT 9-124: IMPROVING SUSTAINABILITY AND RESILIENCE OF PERUVIAN AMAZON SYSTEMS THROUGH SILVOPASTORALISM

PI: Carlos Gomez, Universidad Nacional Agraria La Molina
U.S. Partner: Heathcliffe Riday, U.S. Dairy Forage Research Center, U.S. Department of Agriculture – Agricultural Research Service
Dates: April 2021 - March 2024

PROJECT OVERVIEW

Peru recently included the establishment of silvopastoral systems (SPS) with improved pastures in its national determined contributions (NDCs). Their goal is to reduce direct and indirect greenhouse gas (GHG) emissions by livestock production and to increase sustainability and resilience of pastoral systems. Livestock is among the main drivers of deforestation in the Peruvian Amazon. Silvopastoral systems with improved pastures can avoid pasture degradation and recover degraded pastures in the region. They can also lead to increased pasture quality and yield, which reduces the land area needed for livestock production. Thus, well managed SPS not only reduce deforestation but also increase livestock production efficiency.

Sustainability and resilience of SPS compared with other pasture-based systems have been studied by a few authors in Peru, but previously none has looked at various sustainability measures and resilience within a single study. This PEER project sought to evaluate sustainability and resilience of SPS in Peru in a holistic assessment, comparing SPS with conventional pasture-based systems (CPS) through life cycle, economic, socioeconomic, and resilience assessments, as well as amount of carbon storage.

The U.S. Dairy Forage Research Center played a crucial role in this work. The U.S. partner and other scientists from the Center shared expertise in the agroecosystem carbon storage potential of agricultural lands and provided training in additional measurement techniques and data analysis, including Landsat and MODIS satellite data to estimate productivity and ecosystem respiration of pastoral systems. Neither of these techniques had been used previously in Peruvian livestock research. Data generated in this project is being made available to regional databases on carbon storage to inform soil carbon models. The team worked also with the Peruvian Institute of Agricultural Innovation, which has a long-term relationship with farmers, to ensure they are directly involved and that the research is put into practice.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers made a preliminary visit to Cuñumbuque, the main milk-producing district in the San Martín Region, to explore potential livestock associations to collaborate on the project. After identifying appropriate dairy producers, the team interviewed 20 producers and took soil samples during the rainy season. The inclusion of additional Master's students in the project team further expanded the project's scope and deepened research in key areas, such as estimating carbon stocks in the soil. The data from the interviews and sampling were systematized and analyzed for the various assessments.

The researchers found that silvopastoral systems for cattle production in the tropical region of Peru are more resilient than conventional pastoral ones due to their higher water efficiency, better economic feasibility (higher profit per animal per year), and lower greenhouse gas emissions intensity (CO_2-eq/kg milk). SPS also had a larger potential to store carbon and improve physical and chemical soil traits. In both systems, the highest carbon stocks were reported at 0-15 cm depth with values of 31.4 t/ha and 34.4 t/ha, respectively, being higher in silvopastoral systems (SPS) despite the absence of statistically significant differences due to high variability coefficients in these field evaluations.

Team members presented their findings at the International Symposium on Herbivores and the International Congress on Silvopastoral Systems and were awarded a $200,000 grant from FONTAGRO to continue their work. The PEER team also produced a policy brief and shared it with institutions such as INIA and PROMEG Tropical so they can incorporate improvements into their policies or intervention programs in the Amazon region.

PUBLICATIONS

R. Salazar, J. Alegre, D. Pizarro, A.J. Duff, C. García, and C. Gómez. 2024. Soil carbon stock potential in pastoral and silvopastoral systems in the Peruvian Amazon. Agroforestry Systems. https://doi.org/10.1007/s10457-024-00969-w

PERU - PROJECT 8-161: A WOOD SPECIES IDENTIFICATION TOOL TO AID IN COMPLIANCE AND ENFORCEMENT OF PERUVIAN TIMBER REGULATIONS

PI: José Ugarte Oliva, Instituto Tecnológico De La Producción - Citemadera
U.S. Partner: Michael Wiemann, U.S. Forest Service, Forest Products Laboratory
Dates: January 2020 - December 2021

PROJECT OVERVIEW

llegal harvesting of trees ranks third in international crimes, causing up to 70 percent of deforestation and costing billions of dollars in lost revenue annually (WWF, 2019), severely impacting Peru. Many of the traded woods are high-value species considered endangered by the Peruvian government (Resolución Ministerial Nº 0505 – 2016 – MINAGRI, 2016). In the case of Cedrela odorata and Swietenia macrophylla, they were also included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Law enforcement agencies were mandated to develop strategies to curb this activity, but the ability to identify species accurately was limited to a few specialists worldwide. This situation was amplified in Peru due to the large number of commercial species, necessitating regulators to be familiar with diverse anatomical characteristics and numerous species that look similar. Species identification was reported to be the limiting factor in enforcing compliance with national and international laws regarding the legal harvesting of timber. Training in wood identification and the development of tools to aid in wood species identification were needed by an expanding international community within public and private organizations. Therefore, the aim of this PEER project was to empower Peruvians in the enforcement of Peruvian environmental laws by implementing a field-deployable wood identification machine vision technology, XyloTron. The Wood Technological Innovation Center (CITEmadera), a government entity linked to the Technological Institute of Production (ITP) and a partner in the Peruvian timber sector, was responsible for executing this project. The U.S. and external partners consulted on the acquisition and curation of the botanical samples, production of XyloTrons in Peru, and model building for the new species in the machine learning classifier. They also provided assistance during field deployment.

The implementation of the XyloTron identification system for the 15 most important Peruvian tropical timbers had many positive impacts on the forestry sector of Peru. The country went through a difficult period due to conflicts between trade and forest resources conservation, and monitoring and enforcement operations for illegal timber were reinforced. Enforcement tasks were concentrated primarily at 40 active control points and the exportation ports, where the timber was inspected, with species identification being a key element. However, wood identification required much knowledge and expertise, and neither Peru nor the rest of the world had enough of the necessary specialists to meet these needs. This PEER project implemented the XyloTron system as the key to improving the capability of wood identification at control points and ensuring legal harvest and trade. As part of the project objectives, CITEmadera also transferred this technology to Peruvian government institutions responsible for the control of illegal timber so that they could test its effectiveness and integrate it into their workflow. In addition, the equipment of the XyloTron system was made available for further investigations of Peruvian wood species, and the PEER team provided the necessary training. All of these actions helped Peru better manage its legacy of precious wood and contributed to the global effort to combat illegal timber harvest.

FINAL SUMMARY OF PROJECT ACTIVITIES

Working in close cooperation with the National Forestry and Wildlife Service of Peru (SERFOR) and forestry companies in the regions of Huánuco, Ucayali, and Loreto, PEER team members completed a carefully planned field sampling program, collecting 274 wood slices and associated botanical samples from 103 trees. The collection activities involved allied research centers such as CITEforestal-Maynas and CITEforestal-Pucallpa, which supported the development of the project and with whom relevant information on research with commercial forest species is usually exchanged, so the large number of samples collected can be used as a reference for identification in these centers for other future research projects. The botanical identification of the tree samples collected yielded a total of 35 species, many more than the initially planned 15-20 species. All the botanical samples were deposited in Scientific Depository Institutions of Biological Material authorized by SERFOR, who carried out the identification up to the species level. This identification not only served the purposes of the project but also to discuss the identification of species by the forestry companies where the collections were made. Many samples were obtained from this process, some were stored to be added to the database later and others were shared with other research centers, universities, and various research projects, to contribute to scientific research studies and for the implementation of wood samples that help with the identification of forest species in other regions. The identifications support by the project using both botanical and digital imaging methods will serve to verify and correct the identification made by the forestry companies since there is a notable difference between the records of these companies and the identification obtained through the project, adding in many cases up to three species of the same genus that were registered under the same scientific name by the companies.

From the raw wood samples collected in the field, the research team specially sized and smoothed almost 6,700 samples and then imaged them using the Xylotron system, which includes a laptop and a Xyloscope device, which has a camera and a special lens. All the prepared samples were coded to order the process allow for tracing each sample by origin and location of the trees from which they were collected. The images were then added to the Xylotron database for further analysis. In addition to using Xyloscopes donated to the project by the U.S. Forest Service, the team also built their own device using parts and instructions provided by the system's developer, Dr. John Hermanson. The methodology used to replicate this device was recorded for inclusion in an illustrative manual that can be used and shared for future replications. The new models created for species identification made it possible to perform internal validation (laboratory tests) of the Xylotron system, which was done with the wood samples used for the project, on their prepared and unprepared surfaces. In this way, it was possible to cover the different forms in which wood is found in the field. The laboratory tests were important because they allowed the team, working in remote collaboration with Dr. Hermanson, to quickly verify the effectiveness of the Xylotron system for species identification, and with these results, they were able to suggest some improvements or updates for some species in the system, before carrying out identification tests in the field. These tests were carried out at the Pucusana (South), Corcona (East), and Ancon (North) checkpoints, important and nearby locations where there is a continuous traffic of various forest resources, including timber of different species, which is often seized or confiscated because it does not have the corresponding documentation or is of illegal origin. This timber is stored in warehouses, and it is precisely there where the field tests were carried out. The PEER team trained the personnel in charge of species identification at each checkpoint, from the explanation of the Xylotron system to the demonstration and operation with the participation of the staff members who will be responsible for applying this system in the future.

After the training workshops and field tests carried out at the ATFFS-Lima checkpoints, those involved expressed interest in using the Xylotron system as a tool to enhance their activities related to wood cargo inspection, evaluation, and identification. In this regard, SERFOR has accepted the donation of three Xylotron kits (laptop + Xyloscope) from USFS. This approach to new technology in the identification of species will allow the checkpoints to have support when corroborating the information of the Transport Guides (GTF) and verify the legality of the wood. A fourth donated Xylotron kit will remain at CITEmadera to continue facilitating wood sample imaging and technology transfer to control entities and to support the construction of the reference database of Peruvian species in the Xylotron System.

The project fit well with the aims of PEER Cycle 8, which was intended to support projects taking the “last mile” to practical implementation. Following are several key outputs and impacts:

1. Donation of four Xylotron devices to Peruvian agencies (three to SERFOR and one to CITEmadera) as noted above
2. Enhanced collaboration with Peruvian forestry companies, providing with guidance on species identification and linkages with regional herbaria that can reinforce their forest management knowledge and practices
3. Improvement in the operation of the Xylotron system for species important in Peru
4. Creation of four detailed protocols and six technical reports on various aspects of wood sampling, sample processing, imaging, and application of the Xylotron system for wood identification

Although the project has been completed, the researchers plan to continue and expand their collaborations: with USFS, SERFOR, German Society for International Cooperation in Peru (GIZ), World Wildlife Fund-Peru, and Continental University, the United Nations Office on Drugs and Crime in Peru, and La Molina National Agrarian University of Peru.

PERU - PROJECT 8-235: IMPACTS OF ALLUVIAL MINING IN THE MADRE DE DIOS BASIN: PHYSICAL EFFECTS AND MITIGATION PLANNING

PI: Mónica Moreno Brush, Universidad De Ingeniería Y Tecnología
U.S. Partner: Eddy Langendoen, United States Department of Agriculture/ Agricultural Research Service
Dates: January 2020 - June 2022

PROJECT OVERVIEW

Despite many efforts in the Madre de Dios Basin to estimate the impacts of alluvial gold mining with regard to mercury concentration, deforestation, and socioeconomic implications (e.g., human trafficking, tax evasion), very few investigations were conducted to understand the effects of extensive alluvial mining operations on the rates of sediment supply and morphodynamics of the rivers in southeastern Peru and on the spatiotemporal distribution of mercury concentrations. This was a time-sensitive project because mining activities were advancing rapidly, producing drastic physical alterations to river systems, and the Peruvian National Government lacked adequate impact assessment methodologies of alluvial mining concessions, many of which were already operating. Currently, basic analyses with satellite imagery featured these assessments, rather than analyses with multi-temporal and historical data to elaborate predictive models to determine principal sources and sinks of mercury across the watershed and gold deposits that indicated potential areas to be targeted for mining. The location and topography of the Madre de Dios headwaters, where alluvial gold mining occurred, created a high potential for escalating this environmental and public health problem, putting large portions of the basin at risk. There was a critical need to provide both a baseline of river morphodynamics and linkages between aquatic ecosystems and landscapes to develop not only decision-relevant indicators for environmental quality but also methods for identifying trends to determine environmental quality in the future.

This PEER-supported project involved an integrated assessment of a coupled natural-human system in southeastern Peru where there was an urgent need to develop science-based sustainable practices and conservation of natural resources. By combining state-of-the-art techniques in field measurement, remote sensing, and mathematical modeling of riverine processes, this project explored the interactions between flow, sediment transport, and channel change in rivers in association with the distribution of mercury along the food chain. The outcomes provided useful insights for land managers and decision makers on river morphodynamics and function, a crucial gap in the understanding of rivers, which was currently a critical national priority for Peru. Local authorities and partners working in the region were encouraged to share their knowledge about sediments in rivers in the area, as well as gaps that could be fulfilled with this research. They were also encouraged to incorporate best practices and environmental standards in their management efforts and to include river morphodynamics as a component of natural resource management. Developing a more sustainable approach for the use and monitoring of the environment promoted and supported responsible economic activity in the Amazon region through viable economic alternatives to illegal exploitation of natural resources and the development of alternative processes for extracting gold with the least possible negative impact on the surrounding ecosystems.

FINAL SUMMARY OF PROJECT ACTIVITIES

Despite launching in January 2020, only two months before the start of the COVID-19 pandemic, this PEER team managed to overcome the many challenges they faced to accomplish their multi-faceted research and dissemination objectives. Following is a compilation of their activities and achievements on the various work packages involved:

1. River morphology

a. Hydrogeomorphology: The team's analysis of the riverbed dynamic of the Madre de Dios River confirmed the impact of mining-derived riverbed aggradation (accumulation of gravel and boulders on the river bottom) on the natural physical dynamic of the river. The Madre de Dios River naturally transports sand and gravel, but riverbed aggradation due to mining activities increases the size of the riverbed material, reducing the capacity of the river to transport or move it. Continuous physical monitoring of the river water and sediments is necessary to have a comprehensive characterization of the river's dynamic and hydrogeomorphic processes and will help to design adequate mitigation actions against human activities such as mining and infrastructure projects.

b. Remote sensing: The effect of alluvial gold mining activities on the morphological change of the Madre de Dios River was investigated through the analysis of satellite images of a river section of about 330 km covering the period 1984-2020. The evaluation of six morphological parameters showed that mining activities conducted along the river have changed the river's morphology (morphometry) and fluvial processes (morphodynamics). During the study period, the Madre de Dios River naturally experienced significant morphological changes in its fluvial dynamics, but these changes are concentrated upstream from mining activities. The identification of anthropogenic morphological changes in river sections where intense mining is or has been conducted suggests that mining intensifies or modifies the natural morphological changes of the river. This is the first study to report a quantitative analysis of the morphometric and morphodynamic changes in the Madre de Dios River.

2. Numerical Modeling

The researchers applied the hydrological model Soil and Water Assessment Tool (SWAT) to evaluate the hydrological response of the Madre de Dios River basin to land use and land cover changes. The analysis of three different scenarios of deforestation by gold mining demonstrated the susceptibility of the sub-basins of the Colorado and Puquiri rivers to changes in land use and land cover. The implementation of more hydroclimatological monitoring stations in the Madre de Dios River basin would enable a more efficient hydrological modeling for better decision-making in the management and management of alluvial mining impacts.

3. Hydrobiology

One objective of this study was to do a fast biological inventory of the Madre de Dios River and its three tributaries—Chilive, Colorado, and Inambari—as well as verify the state of conservation of the aquatic communities in relation to the presence of gold mining activities. Research findings suggest that periphyton could be an environmental quality indicator in rivers affected by gold mining. A gradual decrease in fish richness (in terms of number of species) was observed along the Madre de Dios River as it enters the mining area, suggesting a possible impact due to this activity. In the sampling locations with mining activities, the aquatic communities of ichthyofauna and macroinvertebrates had a different diversity distribution than in places without mining. Overall, the research findings suggest that macroinvertebrates, periphyton, and ichthyofauna are possible good indicators for evaluating the impact of alluvial mining in rivers and streams and could be used as a methodology for monitoring the impact of mining in the study area and other areas affected by alluvial gold mining.

4. Mercury Pollution

a. Mercury transport in rivers: An update on mercury distribution in sediments from the Madre de Dios River and its mining-affected tributaries Inambari and Colorado was made. Additionally, the team studied the influence of hydrodynamic and sediment transport on riverine mercury transport. In bottom sediments, mercury was found enriched in the fine fractions (clay and lime), confirming the need to consider grain-size distribution when investigating mercury in sediments. Furthermore, as in other Amazonian rivers, mercury in the study rivers was mainly found to be transported adsorbed to suspended sediments, and the mercury load in rivers strongly depends on river hydrodynamics and sediment transport, but also on the location of mining activities, which increase natural erosion by dredging. Among the two studied mining-affected tributaries, the Inambari River was found to contribute about 5 times more water, 7 times more suspended sediment, and 10 times more bottom sediment to the Madre de Dios River than the Colorado River. Thus, the Inambari River is the main contributor of sediment and mercury to the Madre de Dios River. This is the first study to investigate mercury transport and load in rivers affected by gold mining activities by combining mercury, hydrodynamic, and sediment load data.

b. Mercury in fish: A rapid risk assessment of the impact of gold mining activities on the ecotoxicological risk of the wildlife (fish and birds) of the Madre de Dios River showed that carnivore fish have the highest mercury levels, confirming that mercury biomagnifies along the local food web. The consumption of carnivore fish might represent a higher risk of exposure for human and wildlife populations given that most detected contractions surpassed the toxicological reference values reported in the literature. Higher mercury levels in carnivore fish from areas with mining compared to areas without mining suggest that mining activities increase mercury levels in fish. Therefore, the consumption of fish, especially carnivore fish, from mining-impacted areas may pose a health risk to Amazonian piscivore birds. The implementation of a standardized protocol for monitoring mercury in fish would serve to analyze concentrations and potential risks for consumers throughout time.

This PEER project was especially notable for its emphasis on outreach and dissemination of the research findings, and the team included dedicated communications specialists to ensure this aspect was well covered. The research findings and technical recommendations of the project were communicated and disseminated in a total of 18 webinar talks, 2 workshops, and 11 scientific conference contributions. Communications deliverables such as a technical report, media material (press notes, promotional videos, and social media posts), and a project website were also produced. Six research briefs to communicate the research findings of each work package have also been produced for publication. In her final report on the project, PI Dr. Monica Moreno Brush notes that the activities and communication products efficiently brought the scientific and technological knowledge produced by the project to policymakers. The technical webinars were a space to communicate the research findings of the project beyond academic circles and to promote them in policymaking. They were also a space to interact with researchers from Peru and abroad working on the topics of watershed management and gold mining in the Amazon region. The discussion panels in the webinars and workshops brought scientists and policymakers together to discuss common issues in the Madre de Dios region and were a space that enabled the project to persuade government agencies and decision-makers to adopt research-supported recommendations on how to effectively assess and monitor the morphological changes and mercury pollution in Amazonian rivers affected by gold mining activities.

The outreach activities on the project elicited very favorable feedback from the stakeholders who participated. The director of the Water Administrative Authority of Madre de and Dios highlighted the importance that his organization starts considering the hydraulic and physical data of the rivers when interpreting their results, and how important it is to use technology such as drones and riverbed profilers when monitoring rivers. In the same way, the Sub-Manager of Territorial Conditioning of the Madre de Dios Regional Government acknowledged the relevancy of the information provided during the workshop and that it could be an important contribution to the regional development plan. The Service of Protected Areas for the State (SERNANP) expressed its interest in including the methodology and recommendations of the project for assessing and monitoring streams and rivers in the next Management Plan of the Tambopata National Reserve. The conversations are to resume after the project publishes its research results.

The data and results generated by the Remote Sensing work group have been published in the open access data portal Dancing Rivers developed by CITA-UTEC. Link to the map data: https://www.dancingrivers.com/mapdata#.

Although the PEER project has ended, the Water Research and Technology Center (CITA) from the University of Technology and Engineering (UTEC) will remain active in the search for additional funding to continue working on the environmental impacts of small-scale artisanal mining and finding solutions for their mitigation. Their plan includes writing proposals for funding in Peru and abroad in collaboration with their local and international partners. They also plan on publishing research papers that include their more relevant and original findings.

PERU - PROJECT 7-355: NUMBA WACHOKKERI: EMPOWERING INDIGENOUS PEOPLES TO PROTECT THEIR FORESTS WITH CUTTING-EDGE TECHNOLOGY

PI: Sidney Novoa, Asociación Para La Conservación De La Cuenca Amazónica (Acca), And Carlos Saito Villanueva, Pontificia Universidad Catolica Del Peru (Pucp)
U.S. Partner: Eben Broadbent, University of Florida (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: November 2018 - February 2022

PROJECT OVERVIEW

The Peruvian Amazon has a diverse landscape with rich biodiversity and cultural heritage. Within the Madre de Dios region of the Amazon lies the Amarakaeri Communal Reserve (ACR), which protects more than 690,000 hectares of tropical forest and the native indigenous communities inhabiting it and connects other important conservation areas, including Manu National Park, Madre de Dios Indigenous Territorial Reserve, Tambopata National Reserve, and Bahuaja-Sonene National Park. The Peruvian National Park Service (SERNANP) co-manages the reserve with an elected indigenous-based organization known as the Executor of the Administrative Contract of the Amarakaeri Communal Reserve (ECA-Amarakaeri). Unfortunately, in recent years the ACR has suffered severe forest loss from illegal activities, especially gold mining and logging. While Madre de Dios is the biodiversity capital of the country, it also has the second highest deforestation rates in Peru.

Control and monitoring actions in these remote areas have high logistical costs and pose a serious risk to the safety of park employees and the indigenous community because of possible confrontation with offenders. This PEER project sought to increase the use of remote sensing technology, including drones and satellite imagery, to increase the effectiveness of monitoring efforts in the ACR and transfer technical knowledge to the indigenous communities so they can incorporate it to their control and monitoring actions.

FINAL SUMMARY OF PROJECT ACTIVITIES

After discussion with U.S. partner Dr. Eben Broadbent, the PEER team decided to purchase Nimbus VTOL V3 drones, including reception antennas with a greater range, a GPS tracker to locate the equipment in the event of an accident, and high-performance tablets for flight planning. Their first tests with the drones were carried out in local aerodromes near Lima, then the central jungle of Junin to perform flights with conditions similar to those in the ACR. Additional test flights were made in the buffer zones of the ACR, including one in the Quincemil sector, as part of the special patrol activity of the SERNANP and the ECA Amarakaeri in October 2019. The area is known to have illegal mining in the main water sources, and access is extremely difficult. During this flight, researchers found a mining camp, and park rangers and volunteers went to remove it. After an interruption due to the COVID pandemic, the PEER team underwent a training workshop and continued flights in the Sabaluyoc buffer sector, confirming a remarkable expansion of coca crops throughout the ACR buffer zone.

The PEER team, with the support of the ECA Amarakaeri and NGOs, launched a virtual course entitled “Technological tools for remote monitoring of protected natural areas.” Fourteen specialists took this course, including three female participants, and eleven continued on to take specialized training on the Nimbus VTOL drone at the facilities of the Manu Biological Station of Conservacion Amazónica.

The VTOLs, a high-performance computer, and related equipment purchased under the PEER project have been donated to the ECA-Amarakaeri for their ongoing use. Walter Quertehuari, president of the ECA-Amarakaeri, as well as Asvín Flores and Edwin Dunga, chief and specialist of the ACR, jointly updated their Surveillance and Control Strategy to include the use of technological resources, such as drones, mobile applications, and early alerts, as valid resources that complement surveillance and control actions. This document promotes the implementation, use, and training of technological resources for surveillance and monitoring activities. Building on the foundation established by the PEER project, both the ECA-Amarakaeri team and the SERNANP specialists planned overflights in the Setapo sector with the VTOL drone. The data were later processed in the monitoring room implemented in the offices of the ECA-Amarakaeri.

Both the PI Sidney Novoa and co-PI Carlos Saito presented their project and its results at a variety of international conferences, including the 3rd Congress of Protected Natural Areas of Latin America and the Caribbean and the 13th Annual International Conference on Education and New Learning Technologies, EDULearn.

The project team produced a video highlighting the achievements of the PEER project, with the special focus on the VTOL drone training that was carried out following the onset of the pandemic. The team received additional funding, including a grant funded by the U.S. Embassy in Peru intended to support technology to protect the Amazon and combat corruption to help expose illegal logging and corruption in the Amazon. The team also received another grant to develop a project to help protect isolated indigenous Mashco Piro people in the aftermath of COVID and address ongoing deforestation issues in the Peruvian Amazon.

PUBLICATION

Saito, C., & Novoa, S. (2021). Numba Wachokkeri: Empowering indigenous peoples to protect their forest with cutting-technology. In Edulink Proceedings (pp. 7619-7627). https://doi.org/10.21125/edulearn.2021.1549

PERU - PROJECT 6-330: PREVENTING LEAD EXPOSURE OF PERUVIAN CHILDREN FROM MINING AND BATTERY RECYCLING WITH A NEW FIELD TEST KIT

PI: Johny Cesar Ponce-Canchihuamán, Universidad Peruana Cayetano Heredia & The Center For Research In Environmental Health (Creeh Perú)
U.S. Partner: Alexander Van Geen, Lamont-Doherty Earth Observatory Of Columbia University (Funded By The National Science Foundation)
Dates: March 2018 - September 2023

PROJECT OVERVIEW

Exposure to lead (Pb) in contaminated soil is a significant health threat for children throughout Peru, a country with a long history of mining. However, Peru does not have the resources to carry out expensive laboratory or field tests to identify hot spots of lead contamination. For this project, the PI Dr. Johny Ponce Canchihuamán and his team collaborated with U.S. partner Dr. Alexander van Geen to use a new field test kit for Pb in soil developed at Columbia University. They sampled soils in communities representing four different potential contamination types, enabling the researchers to identify areas of high lead risk in communities that are impacted by different lead-contaminating industries, including battery recycling (Lima), ore mining (Cerro de Pasco), smelting (La Oroya), and ore shipping (Callao)

This kit is intended for public use, so the team worked with local high schools to deploy the kits as a hands-on project component in a science course to assess its feasibility for a national-scale deployment, ensure data reliability, and improve local education. The researchers trained schoolteachers and selected high school students to use the field kit, and the teachers incorporated deployment of the field kit into their courses, teaching students about lead, its origin, and its health impacts. Special care was taken to provide the students with lab and field safety instructions and personal protective equipment.

The PEER team sought to validate the field kit as an affordable way to find and prioritize areas for cleanup in Peru and to empower local communities to identify lead contaminated areas and safe areas, which they otherwise would not have had the means to test. Its deployment through high school science classes offers a sustainable way to scale up these kits while improving science education and getting students excited about doing research.

FINAL SUMMARY OF PROJECT ACTIVITIES

After education sessions on lead contamination and the hazards towards young children, as well as on soil sampling, students were asked to take five soil or house dust samples in their community where young children play. Using the SurveyCTO app, students recorded the GPS location and photo of each sample site on a provided smartphone. Teachers supervised the soil analysis to determine the lead level. The kit uses a glycine solution at pH 1.5 for extraction and the addition of sodium rhodizonate to produce a purple color, categorized as low, medium, or high in intensity. As part of this educational module, students created maps of soil lead and presented them to their community, along with information about lead, its risks, and how to minimize the exposure of infants.

The researchers did additional XRF analysis on the samples. Out of a total of 3,674 samples, high-school students or CREEH staff recorded a visual reading of low or medium for 3,495 (95%) of the extracts. For 3,054 (87%) of the extracts with low or medium readings, XRF analysis indicated a concentration no higher than 200 ppm extractable Pb. Within the remaining 179 (5% of the total) samples for which a high visual reading was recorded, the dilution-corrected extractable Pb concentration measured by XRF was >200 ppm for 74 (41%) extracts. Low and medium kit readings therefore reliably classify soil as posing limited risk, whereas high kit readings overestimate the risk of Pb exposure by about a factor of two. The highest risk sites were the Cerro de Pasco mine and the semi-industrial Ate neighborhood of Lima, where the highest percentage of high intensity kit readings were recorded.

The researchers and teachers saw a surge in student interest in science, evident in their initiative to collect soil samples, ascertain lead levels, and devise innovative remediation plans for their communities. The project was featured in a national science fair by the third-year secondary school students of teacher Fernando Belaunde Terry and was presented at the 2019 Fall Meeting of the American Geophysical Union.

As for outreach and broader impacts, the "Lead Free Kids - Peru" project has garnered substantial interest from influential institutions, fostering a collaborative effort toward implementing impactful actions based on the project's findings. Representatives from the ministries of the environment, health, and education have shown keen interest in leveraging the project's results. The project's potential for scaling up has caught the attention of the CTeI Special Popularization Program at CONCYTEC, the Peruvian National Council for Science, Technology, and Innovation. They aim to expand the project's implementation with the support of corporate social responsibility support.

PUBLICATION

J. Ponce Canchihuamán, E. Palacios, P. Ponce, J. Languasco, W. Mormontoy, F. Landes, and A. van Geen. 2019. Soil testing for lead by high-school students in several Peruvian towns. Abstract #GH13A-1052, presented at the American Geophysical Union, Fall Meeting 2019.

PERU - PROJECT 5-259: AGUA-ANDES: ECOLOGICAL INFRASTRUCTURE STRATEGIES FOR ENHANCING WATER SUSTAINABILITY IN THE SEMI-ARID ANDES

PI: Bram Willems, Centro De Competencias Del Agua - Cca

U.S. Partner: Andrea Gerlak, University of Arizona (Funded by the National Science Foundation)

Dates: January 2017 - January 2020

PROJECT OVERVIEW

This project focused on Ecological Infrastructure as an adaptation strategy for ensuring water sustainability in South America's Semi-Andes region. Dr. Willems and his team sought to advance our understanding of ecohydrologic processes that took place in headwaters ecosystems, effects of changes in climate and anthropogenic drivers, and how these were reflected in the water supply along the basin. Andean puna wetlands were far less studied than tropical glaciers, but they played an even more crucial role in the hydrology of the majority of Peru's Andean basins and hence in the provision of water to urban and productive centers of the country. As glaciers had almost disappeared in the team's study site, this project produced relevant information for climate change adaptation plans by generating new knowledge about post-glacier hydrological processes in the Andes.

In addition, the researchers studied the eco-hydrological properties of human-made water-regulating ecosystems and their scalability for ecological interventions in urban and rural areas.

On the social science side, the team aimed to better understand how actors made decisions around Ecological Infrastructure. Specifically, they wanted to know how decision-makers received information and learned about ecological infrastructure design and implementation, as well as what obstacles they faced in understanding and advancing ecological infrastructure. This entailed understanding trade-offs decision-makers faced with regard to strategic planning, public investments, and institutional capability.

Overall, the objective of this project was to establish an integrated, participatory approach to the design and implementation of Ecological Infrastructure Strategies that could be utilized in Peru's Andean urban centers and communities. This research addressed a key challenge in understanding how society underwent changes in the use and distribution of environmental resources, and it contributed to our understanding of decision-making around water sustainability more broadly.

The project aligned with USAID's new Adaptation Flagship Program for Peru, in which green infrastructure investments in watersheds were a key adaptation strategy. The project site (the headwaters of the Cachi basin and the 180,000-inhabitant city of Huamanga in Ayacucho) was selected to align with USAID's focal regions within Peru. To promote interdisciplinary research and develop effective ways of mobilizing science to address societal needs, Dr. Willems and his team planned several specific activities.

They developed robust scenarios pertaining to the water supply in the region under different global change pathways. These scenarios were implemented together with the Regional Government of Ayacucho, local governments, and the local water authority, institutions responsible for elaborating the policy, strategy, local planning, and regulation of water resources.

The researchers also developed Ecological Infrastructure Strategies by integrating natural and man-made water-regulating ecosystems with landscape planning, urban planning, and water and wastewater management, giving due and balanced consideration to social, economic, and environmental factors and involving local authorities and community organizations. These Ecological Infrastructure Strategies facilitated the incorporation of ecological infrastructure within water planning investments. Throughout the project, they worked closely with the University of Ayacucho (UNSCH) on the implementation of the Regional Research Institute for Water – Food – Energy Security (ir-NEXUS), which was envisioned as a think-tank that supported policy formulation and public investment processes with relevance to the local and the Andean region sustainable development.

Finally, they supported the implementation of postgraduate programs at UNSCH to actively involve graduate students in the natural and social sciences.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team has gained substantial understanding of the eco-hydrological behavior of Andean puna wetlands and their role in the water provision along the basins. The PEER team's studies have shed light on the feedback interrelations between anthropogenic processes and the wellbeing of Andean ecosystems and water resources. At the city level, the team have advanced the understanding surrounding the complexity of urbanization processes and designed interventions based on functional ecological infrastructure interventions for both solving water related problems (e.g. landslides, water shortage) and improving the wellbeing of the neighborhoods. The knowledge built is crucial for the design of preservation and adaptation strategies towards global change, both at the basin and city level.

Technical achievements include: validation of remote sensing techniques for identification of Andean wetlands, characterization of soil cover, and the construction of ecosystem pressure maps. Furthermore, water treatment technologies for drinking water and wastewater treatment have been developed and validated in real conditions. On the basis of these experiences, the team is now capable of designing and implementing solutions for rural drinking water and sanitation.

The project produced 3 journal articles, 3 proceedings, 1 book chapter, 4 MSc theses, 3 undergraduate theses, 6 international theses (1 UWE, 5 KUL), 2 broad audience publications, and leveraged $843,550 in funding.

Capacity Building:

- In collaboration with the Urban-Andes projects, the PEER project contributed substantially to the organization of two International Design Workshops, in which more than 70 professionals coming from Ayacucho, Peru and abroad (Belgium, US, South Africa, Australia, Slovakia and Brasil) actively participated. Each workshop event consisted of a 10-day intensive training session in landscape and urban design techniques, during which designs of ecological infrastructure strategies were developed.

- A total of 16 scholarships were granted to outstanding local students, who developed their research work within the framework of the PEER project and complementary projects (Newton and Urban-Andes). The PEER project sponsored participation of the Ayacucho team in several capacity building sessions in Lima and abroad. For instance, in 2018 and 2019, the Ayacucho team has had the opportunity to attend the master classes organized within the IV Panamerican Wetland Congress and the Expo Agua Perú 2019, respectively, both in Lima. Following completion of the PEER project, the team continues research on water treatment technologies at the partner university, UNSCH. Currently, 2 students, under the lead of Prof. Cipriano Mendoza, are working on the development of new pilots as part of their thesis research, beyond PEER.

Examples of data/research used or research used to inform a policy or program:

- PEER team's research experience in Andean headwaters areas served for the design of the guidelines for the assessment of Andean ecosystems within the framework of the Payment for Ecosystem Services Law (MERESE Law). These guidelines were developed under request of the Ministry of Environment and will become the official document of the Ministry of Environment, that will guide the implementation of MERESE along the country.

- The results of the project's research activities in the highlands of the Chicllarazu sub-basin were presented in a technical report to the peasant community of Chuschi, following the template that is used for the formulation of green public investment projects. Thus, the report itself constitutes a first step in the process towards implementing ecosystem restoration and/or preservation interventions in the headwaters of the Cachi basin, a process that also involves the participation of SUNASS, SEDA Ayacucho, and the Regional Government of Ayacucho.
- The team continues collaborating with SUNASS in providing them with data on water flow in two of their monitoring sites in the Cachi basin. Through the project, the team have acquired water level sensors, which have been installed at the SUNASS monitoring spots.

Project Impact Highlights:

- Constructed a strong collaboration network composed of the Ministry of Environment, the Regional Government of Ayacucho, the Municipality of Huamanga, the water utility SEDA Ayacucho, SUNASS, the peasant communities of Chuschi and Pilpichaka, international NGO's (CONDESAN, Forest Trends), private companies (e.g. Buenaventura Mining Company).
- Worked closely with the peasant communities of Pilpichac (Huancavelica) and Chuschi (Ayacucho), providing these the technical and scientific assistance for the design of public investment projects within the framework of the Payment for Ecosystem Services Law (MERESE Law), oriented to preserve water resources and grassland in the headwater areas.
- Commissioned by the Ministry of Environment, we have developed the guidelines for the assessment of Andean ecosystems within the framework of the MERESE Law.
- Within the Agua-Andes congress of September 2017, together with the national council for science and technology of Peru (CONCYTEC), the team organized a workshop for the presentation of the National Research Plan for Water Resources. During the workshop, the team of CONCYTEC have had the opportunity to receive feedback from stakeholders, decision makers and researchers, and hence include the local agenda into this major policy tool. It is worth mentioning the plan, once approved, will trigger several funding mechanisms for developing research relevant to water resources management. So, our PEER has provided a platform for further enriching a key policy tool of the Government of Peru.
- The CCA has been invited by the Ministry of Environment to serve on two Commissions: (1) the Technical Commission on Andean Ecosystems and (2) the Technical Commission on Andean Peatlands. Both commissions are further integrated by representatives from the Ministry of Environment, the Ministry of Agriculture, SUNASS, universities and international NGO's, among others.
- In collaboration SUNASS Ayacucho and the Centro Loyola, the PEER team has designed and installed a water filtering systems in two schools of Ayacucho; namely, Javier Heraud of Carmen Alto (211 students) and Abraham Valdelomar (1206 students), benefiting more than 1400 students. Additionally, the CCA team members designed a proposal for a Water Interpretation Center on request of the peasant community of Cuchoquezera. The objective of this center is to raise awareness

on resilient waterrelated practices. Aslo, a pilot wetland system for treating wastewater to be recycled for irrigation of green areas in Ayacucho city has been developed with the Municipality of Huamanga, CEDAP and SUNASS. Team members also collaborated with ARPOA to conduct workshops on urban and organic agriculture.

• The PEER project largely contributed to the organization of the Agua-Andes International Congress (2017) and the I Sustainable Cities and Communities Expo (2019) in Ayacucho. Both events counted on a total of more than 20 international speakers and an attendance above 600 participants. During these events, the advances and results of the PEER project have been presented by the team members. Furthermore, the PEER project also collaborated with the organization of the IV IV Panamerican Wetland Congress in Lima (2018).

• As part of the PEER project, the project team have started a research area on water treatment technologies in the UNSCH, their partner university. Currently, 2 students, under the lead of Prof. Cipriano Mendoza, are working on the development of new pilots as part of their thesis research, beyond PEER..

• One of the ongoing impacts of the PEER project continues to be Expo Agua Peru, an initiative promoted by the CCA and the country's main water expo, where the latest technological innovations and integral solutions for the integrated management of water resources are presented. Due to COVID pandemic, With 5 editions organized since 2015, Expo Agua Peru has been consolidated as the main gateway to the emerging water market in Peru. For 2020 and 2021, the US is the host country. According to Dr. Willems, the PEER project has allowed CCA to start a collaboration with the Commercial Service of the US Embassy in Lima back in 2017, and participation of the US as host country is the result of this process (see U.S. Embassy video). The event brings together leading companies in their fields, international experts, decision makers and governmental bodies, and a broad segment of end-users coming from the water sector and related sectors (agriculture, mining and industry); who share their experiences and solutions to the problems and challenges that face Peru and the Andean region.

• Rossi Taboada and Martín Leyva who initially got involved as students during the first Willems' PEER project back in 2013, became key team members of the CCA, first leading work packages, then taking charge of the full management of projects to, finally, writing proposals and securing new funding for CCA, with Dr. WIllems role as an advisor.

PUBLICATIONS

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PERU - PROJECT 4-116: TROPICAL MONTANE FORESTS AND CLIMATE CHANGE IN THE PERUVIAN ANDES: MICRO-ENVIRONMENTAL, BIOTIC, AND HUMAN IMPACTS AT THE TREE LINE

PI: Norma Salinas, Pontificia Universidad Catolica Del Peru
U.S. Partner: Miles Silman, Wake Forest University (Funded by the National Science Foundation)
Dates: October 2015 - July 2022

PROJECT OVERVIEW

Cloud forest environments respond strongly even to small changes in temperature, and a large fraction of species within these environments are vulnerable to extinction due to climate change. Species distributions can be strongly influenced by many factors, including potential ecological barriers and forces driving altitudinal migrations of tree species. The PI and her team contend there are several important human actions that can have a significant impact on species migration along the treeline, and a better understanding of the factors involved will improve the ability to predict if, where, and how species will migrate. This project aimed to contribute to current knowledge of the complex dynamics of treeline ecotones by reevaluating the question of tree species migration into highland grasslands in light of microenvironmental and microbiotic information. The researchers on this PEER project propose that it is possible to control and manage the factors, both environmental and human. A better understanding of how species distribution and survival are likely to be affected can provide better guidance to conservation strategies and their integration into socially effective programs in the face of climate change.

The project was conducted in areas located at the border of the Cuzco and Madre de Dios regions in southeastern Peru, within and surrounding the Manu National Park. Planned project activities were designed to help strengthen environmental governance through a mitigation-oriented management program of the treeline in the park in collaboration with park personnel and local communities. The project team worked with NGOs currently involved in forest management initiatives in the area to help local communities develop forestry-based alternative revenue sources along the treeline, with the goal of reducing the pressure of livestock grazing within park boundaries.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER researchers worked with a German NGO, the Frankfurt Zoological Society (FZS), to study three areas purchased by FZS from which they had effectively removed cattle. This allowed the team to monitor regeneration in the areas where livestock and fire had been eliminated as primary impacts, evaluating above- and below-ground biomass gain and soil organic carbon. They compared this against areas with cattle impact to evaluate differences in the establishment and dynamics of the tree line. The researchers prepared a paper on above-ground carbon densities in grassland measured across the landscape by field sampling in areas with and without grazing,

They also worked with local residents from Pillco Grande to set up nurseries for the propagation of native trees for the project experiment, which also increased the engagement of women in the community in the project. The team conducted field outings during the project period, monitoring the changes in the plots, as well as installing more sophisticated climate data loggers and flux towers to gather additional data.

Both PIs served as instructors at the DAAD Summer School on climate change and organized a workshop for Peruvian students on biophysical and biometric methods for the determination of primary productivity in ecosystems. The meeting also served to discuss potential collaborations with The Pennsylvania State University on future projects.

The results of this project helped provide improved information on ecosystem services in the target area, including carbon sequestration, biodiversity, and ecosystem products that are valuable for the local population as sources of sustainable income (edible commodities,
wood for art crafts, plant dyes for textiles, etc.). Dr. Salinas and her colleagues also were awarded a total of $526,000 across several additional grants, including from the German International Climate Initiative, to continue their work. The PI was also invited to participate on the Steering Committee of ANDEX, a scientific project of World Climate Research Programme that aims to improve understanding, modeling, and prediction of the dynamics of the water and energy cycles over the Andes cordillera.

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PERU - PROJECT 3-127: GLACIER RETREAT AND WATER RESOURCE SUSTAINABILITY IN THE PERUVIAN ANDES: INFORMING ADAPTATION STRATEGIES THROUGH COLLABORATIVE SCIENCE

PI: Cirilo Lagos, Instituto Geofisico Del Peru
U.S. Partner: Bryan G. Mark, The Ohio State University (Funded By The National Science Foundation)
Dates: December 2014 - January 2017

PROJECT OVERVIEW

Glaciers in the Peruvian Andes have been shrinking faster than expected, with several already disappearing. NSF-sponsored research on glacier studies in the Cordillera Blanca, the most glacierized region of Peru and the global tropics, showed that glacier recession reduced water supply and had far-reaching consequences for the mountain environment and communities. Additionally, the results showed that during the dry season, hydrologic processes in the pro-glacial zone were often as important as glacier meltwater. These high-impact findings were facilitated by the development of new Andes-specific methods to measure glacier volume changes, pro-glacier hydrology, and the creation of a predictive hydrological model to estimate future river discharge. The results were compelling and underscored the urgent need to better understand the interactions between climate, glaciers, and society, effectively linking them with human activity, policy, and local community needs on a broader scale.

The research team, in collaboration with their U.S. partners, transferred and applied this new knowledge and methodology to another Peruvian watershed, the Shullcas River watershed, which was also impacted by rapid glacier recession, a growing population, and existing social conflicts due to water scarcity. Farmers seeking to maintain food security clashed with an urban population demanding adequate water availability. The project resulted in a better understanding of glacier and groundwater contributions to streamflow and projected future Shullcas River discharge up to the year 2050. This information was crucial for designing and implementing adaptation strategies by water resource policymakers, farmers, global change specialists, development practitioners in the power generation community, and scientists studying related topics such as chemical weathering and physical sedimentation. Furthermore, insights into the future hydrologic regime were key for informed decision-making regarding adaptation to glacier recession and dwindling water supplies in the Peruvian Andes due to climate change. The project's efforts included intensive research training for undergraduate students at Peruvian universities, as well as technical training for the local institution responsible for water resource management and policy.

FINAL SUMMARY OF PROJECT ACTIVITIES

Completed as of the end of January 2017, this project was designed to provide a realistic projection of water availability in the Shullcas River watershed through 2050, considering the ongoing retreat of the Huaytapallana Glacier due to global warming. To achieve this goal, Dr. Lagos and his colleagues needed to improve scientific understanding of how recent glacier changes are impacting stream flows and therefore better anticipate how ongoing climate change will affect water resources in the region. They acquired and analyzed current and historical hydrometeorological data from the region, but because such observations are generally unavailable on a continuous basis, the researchers also relied on hydrochemical and hydrological data collected along the Shullcas River and its tributaries during 2015-2016. The results provided useful information to characterize and quantify the relative source-water contributions to drainage from the Shullcas River watershed. After conducting chemical and isotopic analyses of water samples collected in different seasons throughout the watershed, they used the Hydrochemical Basin Characterization Method (HBCM) developed elsewhere in Peru to calculate the percentage contribution of Huaytapallana Glacier meltwater to the Shullcas River. In addition, the results of the team's river discharge measurements using a portable magnetic-inductive current meter and a coloration or flurometry method showed the contribution of the Shullcas River to water availability in the entire basin. Thanks to this PEER project, a distributed network of gauging stations has been put in place, comprising digitally logging sensors to record continuously the lake and stream stages, temperature, and conductivity. Overall, analysis of the data is helping to improve our quantitative understanding of the temporal changes of glacier and groundwater contributions to the Shullcas River discharge.

The Provincial Municipality of Huancayo and the company SEDAM Huancayo SRL have expressed interest in using the results of the project to initiate studies to increase the availability of water in the Shullcas River subbasin. A memorandum of understanding between IGP and MPH has been signed to use the PEER project results to initiate studies on ways of increasing the availability of water in the Shullcas watershed, and another MOU with SEDAM is under consideration to support follow-ups on hydrologic monitoring in the watershed.

The PEER program has also strengthened the collaboration between the PI and his U.S. partner Bryan Mark, as the latter provided training to the Peruvian group in the use of hydrochemical and hydrological methods for the acquisition and analysis of hydrological data. PEER support gave the colleagues the chance to work together to write articles and disseminate their work at international scientific conferences and public presentations, as well as to develop and co-teach a new upper-level university seminar curriculum in Peru. The deliverables from this research and educational collaboration have also motivated local governmental decision makers to work in an inter-institutional and multidisciplinary fashion to address the problem of water scarcity in the city of Huancayo, thus bringing the results of the study to bear in addressing urgent social problems.

Although the project has ended, Dr. Lagos and his team plan to continue with their field work, including seasonal monitoring of stream discharge, water sampling for chemical and isotopic analysis, and downloading of sensor data from instruments in streams and lakes that were installed in seven selected locations in the Shullcas River watershed in July 2015. Given their expected battery duration, these devices should continue providing useful data for 5-10 years to come. The researchers will also download data from the pressure transducers they installed to monitor groundwater levels at several wells on an hourly basis. In addition, they will continue with infiltration rate measurements, with seasonal monitoring campaigns planned for March and June 2017 with funding from IGP and Ohio State University. The results of these new studies will help to provide a better understanding of the recharge process of underground water in the mountain region. Analysis of historical climate data will also continue. The team has finished analyzing historical air temperature data recorded at the IGP Huancayo Observatory, including the calculation of monthly, annual, and decadal trends for maximum, minimum, and average air temperatures, as well as the diurnal temperature range. Dr. Lagos and his colleagues continue to work on manuscripts for submission to international scientific journals.

PERU - PROJECT 2-359: STRENGTHENING RESILIENCE OF ANDEAN RIVER-BASIN HEADWATERS FACING GLOBAL CHANGE

PI: Bram Leo Willems, Universidad Nacional Mayor De San Marcos
U.S. Partner: Christopher Scott, the University of Arizona (Funded by the National Science Foundation)
Dates: August 2013 to July 2016

PROJECT OVERVIEW

Decreasing water availability in Andean river basins, rising temperatures, increased probabilities of drought occurrence, and expanding water demand all indicate that Peru will experience a severe future water crisis. This PEER project considered Andean headwaters, particularly páramos and puna wetlands, as social-ecological systems (SESs) in which coupled natural and human processes like drought, flooding, water use and impoundment in reservoirs for irrigation, and mining act together to destabilize and threaten water availability and quality for human and ecosystem purposes.

Dr. Willems and his colleagues and students sought to produce better methodologies for Andean headwaters characterization by combining use of satellite imagery, products derived from their analysis (e.g., land use and land cover change), and field data (e.g., precipitation, runoff, and water use, including socioeconomic characteristics). These methodologies allowed the researchers on the project to identify headwaters, quantify their extent, and define indicators for assessing their dynamics. In turn, cross-correlation analysis between these indicators and external drivers, such as El Niño Southern Oscillation events and mining operations in headwaters, helped establish the characteristics that make Andean river basin headwaters vulnerable to global change. A second contribution of the project was the integrated assessment of Andean páramos and puna wetlands, which are far less studied than glaciers but play an even more crucial role in the hydrology of the majority of Peru's Andean basins and the provision of water to coastal regions. In addition to the research aspects, the project also involved the goal of expanding capacity-building activities as part of the Geophysics Masters's Program at the Universidad Nacional Mayor de San Marcos.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the course of the project, the PEER team undertook several fieldwork trips, including to the headwaters of the Cachi basin in Ayacucho. Together with students and researchers from the University of Ayacucho (UNSCH) and researchers from the French Research Institute for Development (IRD), they collected soil and vegetation samples, as well as data regarding water quantity and quality in two case-study wetlands. Among their findings was that 1 meter of sediment sample included more than 2,000 years of paleoclimatic information. Such information allowed the researchers to establish possible effects of historical El Niño events through carbon storage assessments and determine whether long drought periods and climate change processes occurred in the past.

Throughout the project, the researchers assessed and improved several methodologies for identifying headwater wetlands, and indicators for studying the dynamics and evolution have been validated. The team produced maps of wetland distribution for several regions in Peru. This kind of information was previously scarce, and it contributes to the efforts of the National Water Authority (ANA) in implementing the wetland inventory of Peru.

The PI and research team widely disseminated their findings, including organizing a seminar on methodologies and research experiences in geosciences at UNSCH. They also gave technical presentations at a variety of seminars and scientific events, including the AQUAFUTURA seminar of the National Meteorological Office (SENAMHI) and the National Congress of Environmental Engineering Students.

The research supported by this PEER project helped seven undergraduate and graduate students defend theses, and research team students participated in a training event organized by the National Drought Observatory. They also took part in training sessions in Colombia and Brazil.

Dr. Willems worked closely on the project to share his findings and recommendations with relevant Peruvian government agencies and align his team's efforts with their needs and interests. The project team members actively participated in and provided support to several governmental-led initiatives. One key activity involved implementation of the National Drought Observatory (ONS), an initiative led by ANA and including the participation of the Peruvian Meteorological Service (SENAMHI), the Ministry of Agriculture, Ministry of Economy, Ministry of Environment, the Peruvian Institute of Geophysics, and UNESCO's International Hydrological Program (UNESCO-IHP). The satellite-based monitoring system for assessing the evolution of Andean headwaters (one of the milestone deliverables of this PEER project) and the drought indicators will feed the ONS. In collaboration with their colleagues at UNPRG, the PEER team also developed the land degradation map of Piura at a scale of 1:25000 for the Ministry of Environment. This map constitutes the country's effort in combatting desertification by providing more detailed information about the state of the agricultural soils of Piura. The researchers have begun collaborating with the technical committee for the national wetland inventory, which is formed by representatives from the Ministry of Environment, the ANA and the National Wildlife and Forest Service (SERFOR). Through this collaboration, Dr. Willems and his group will share their results and methodologies for characterizing Andean wetlands and help the government agencies complete the inventory of the country. Meanwhile, the team's hydrological models of the Apacheta basin and the wetland distribution maps have also been used for providing information requested by the Regional Government of Ayacucho.

As part of the PEER project, the PI led the design process of a new Regional Research Institute for Water - Food - Energy Security (ir-NEXUS), holding meetings with governmental entities, private companies, NGOs, USAID and the U.S. State Department. A workshop with government stakeholders was organized to identify strategic research areas for this group. Dr. Willems and his colleagues continued their efforts under a PEER Cycle 5 project entitled AGUA-ANDES: Ecological Infrastructure Strategies for Enhancing Water Sustainability in the Semi-Arid Andes, which ran from January 2017 through January 2020.

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PERU - PROJECT 2-228: IMPACT OF TRANSBOUNDARY BIOMASS BURNING POLLUTION TRANSPORT OVER THE CENTRAL ANDES OF PERU

PI: Luis Suarez, Instituto Geofisico Del Peru (Formerly At Universidad Continental)
U.S. Partner: Detlev Helmig, University Of Colorado At Boulder (Funded By The National Science Foundation)
Dates: June 2013 - August 2017

PROJECT OVERVIEW

Biomass burning represents the primary source of air pollutants in tropical regions, and researchers worldwide have endeavored to ascertain its potential effects on air quality and climate. The Amazon basin stands out as one of the regions most in need of improved understanding regarding the impacts of pollutant transport on air quality, radiative forcing, and precipitation patterns. This PEER project focused on monitoring forest fires and assessing the adverse effects of resulting smoke and ash on climate change. Ing. Suárez and his research collaborators conducted fieldwork at two contrasting sites in the Andean and Amazon regions of Peru. These activities not only fostered intensive cooperation among representatives from the three major Peruvian universities involved but also provided new opportunities for collaboration with U.S. counterparts.

The project trained and supported six Peruvian undergraduate and three Master's-level students as they worked on their theses. Local laboratories were upgraded with new equipment to facilitate a long-term program for monitoring tropospheric ozone, aerosol optical depth, and ultraviolet spectral solar radiation at the Observatory at Huancayo. The researchers conducted a detailed evaluation of tropospheric ozone and aerosol pollutants and reported their findings to local policymakers, particularly concerning the impacts of deforestation in the Amazon. A planning workshop was also convened to discuss the establishment of a new Institute of Antarctic and Andean Research (INSTAAR) Peru, aimed at sustaining research and policy studies on these topics beyond the completion of the PEER project.

FINAL SUMMARY OF PROJECT ACTIVITIES

One of the major outcomes of this project, which ended in August 2017, was an increase in scientific knowledge about the atmospheric transport of pollutants related to Amazon deforestation, which this information being shared with international research networks and relevant Peruvian policy makers. Ing. Suárez and his team were able to make a detailed evaluation of temporal variations of tropospheric ozone and aerosols using ground and satellite measurements. The collected data contributed to a better understanding of the chemical, physical, and radiative properties of aerosols with respect to atmospheric transport in the Andean and Amazon basins. In that regard, the team worked at the regional level with the Forest Service and developed strategic cooperation in the use of remote sensing and in-situ verification for open fires. As a follow-on to the PEER effort, this work is currently being supported by the International Cryosphere and Climate Initiative (ICCI), with the specific focus being on the evaluation of two locations for agricultural open fires and their effects on air pollution, particularly Short Lived Climate Pollutants (SCLP). The PEER-supported researchers have so far published two peer-reviewed journal articles, with at least one more in preparation.

On the human capacity building side, the project improved the capabilities of local students and researchers through intensive training, technical support, scholarships, and travel grants. The principal investigator created a new research group on atmospheric pollution based at Alas Peruanas University, trained more than 100 Peruvian students in atmospheric research, and provided six PEER-supported scholarships for undergraduate studies and theses. He and his colleagues also organized and implemented the most recognized National School on Atmospheric Sciences in Peru, ENICA, with the support of well-recognized researchers based in Chile and Brazil. Several students involved in the PEER project went on to graduate and obtain scholarships to continue their advanced studies abroad, including Bryam Orihuela (studying meteorology at the University of Reading), Laura Paccini (studying at the University Pierre et Marie Curie of Paris), and Georgynio Rosales (studying environmental engineering at the Universidad Federal del Espiritu Santo of Brazil).

The technical infrastructure building aspects of the project were also significant, as PEER funds helped the Observatory of Huancayo of the Geophysical Institute of Peru (IGP) improve its laboratories with high-tech equipment and calibrate existing instruments. Thanks to the PEER support, the Observatory has enhanced research monitoring capabilities for tropospheric ozone and aerosols (including an ability to measure aerosol size distribution and black carbon concentration). The PI and his colleagues have been able to restart measurements of spectral UV radiation at this high-altitude site, which has one of the highest UV index values in the world. Additionally, the PEER project greatly facilitated the installation of a NASA Aeronet network instrument for evaluating physical, optical, and radiative properties of aerosols. As a result of international interest in the team's work, GCOS/WMO has sponsored the implementation of a high-precision station for measurements of solar radiation as part of the Baseline Surface Radiation Network (BSRN), and this will be used by local researchers for calibrating their instruments. Local funding has also enabled the PI to support the implementation of an Aerosol Sampling Network for Huancayo City, headed by the National University of the Center of Peru, with four low-volume aerosol samplers installed at urban and rural sites. This network is generating data for policymakers to evaluate air quality management in direct coordination with the Municipality of Huancayo. Ing. Suárez provided extensive technical assistance, and one sampler installed at the Observatory of Huancayo is expected to provide data on aerosol concentration (PM2.5) and the chemical composition of pollutants in the area. This will complement the data provided by other instruments and facilitate comparisons with National Air Quality Standards.

With the Observatory of Huancayo now established as the most complete station in all of Peru for the monitoring and study of atmospheric pollution, the Geophysical Institute of Peru has assured that the efforts begun under PEER will continue under IGP's project "Magnet," which includes a component on aerosols and solar radiation. This activity will also involve three fully funded scholarships for graduate students (two at the Master's level and one at the PhD level). Ing. Suárez also notes that cooperation will continue with ICCI, specifically focusing on his evaluation of two locations where agricultural open fires are prevalent and determination of their effects on air pollution, particularly SCLPs.

PERU - PROJECT 1-353: BUILDING PERUVIAN CAPACITY FOR MONITORING AND MODELING THE EFFECTS OF CLIMATE CHANGE ON THE COROPUNA GLACIER AND ASSOCIATED WATERSHEDS IN AREQUIPA, PERU

PI: Roberto Zegarra Balcazar and Felio Carderon La Torre, (Former PIs Karen Kraft And Julio F. Alegría), Aedes - Asociación Especializada Para El Desarrollo Sostenible
U.S. Partner: Joerg Schaefer, Columbia University (Funded by the National Science Foundation)
Dates: June 2012 - April 2015

PROJECT OVERVIEW

Peru is especially vulnerable to the effects of climate change due to the dependence of 70 percent of its population on glacier water in the dry season. However, at the time the project began, Peru lacked an integrated vision to build climate change resilience through linking investigation, local knowledge, and decision-making. In this project, AEDES partnered with the Lamont-Doherty Earth Observatory of Columbia University with the goal of building Peru's capacity for monitoring and modeling local climate change in its Pacific Basin.

The team sought to improve data collection and analysis through practical training, fostering knowledge and data exchanges between national and international scientists, and contributing to more robust modeling of climate change scenarios near Coropuna volcano complex and its associated glacier. The data collected by local researchers will contribute to local models to help decision makers better prepare themselves for changing climate conditions and provide the international research and policy community with vital information for understanding the sensitivity of tropical glaciers.

FINAL SUMMARY OF PROJECT ACTIVITIES

Researchers carried out a series of joint data collection and field-based trainings and maintained periodic monitoring of glacier mass and hydrological data. The PEER grant team installed a new automatic weather and hydrology station on Coropuna, 5800 meters above sea level, located in the glacier Cavalca, which should enhance data accuracy. They worked in cooperation with the glaciological unit of the National Water Authority, Environment Ministry (MINAM) and the National Service of Meteorology and Hydrology (SENAMHI). The project provided support for the thesis research and training of two Peruvian master's degree students and the team organized workshops on climate change adaptation, glaciers and hydrology in the southern Andes.

Please see http://www.senamhi.gob.pe/?p=1500 for SENAMHI's announcement (in Spanish) and photograph of the station and team members and http://laprensa.peru.com/actualidad/noticia-senamhi-instala-estacion-meteorologica-mas-alta-america-32070 for a sample of Peruvian press coverage of the event (also in Spanish). A brief video about the installation is available at https://www.youtube.com/watch?v=EInkAEBc4Ts&feature=youtu.be.

MIDDLE EAST

EGYPT

Egypt - Project 5-601: Capacity building of healthcare providers in Egypt to counsel pregnant women and their families regarding smoking cessation and second hand smoking avoidance

PI: Wagida Anwar, Ain Shams University's School of Medicine
U.S. Partner: Scott Sherman, New York University (funded by the National Institutes of Health)
U.S. Partner: Cheryl Oncken, University of Connecticut (funded by the National Institutes of Health)

Egypt - Project 2-239: The impact of biogenic and anthropogenic atmospheric aerosols to climate in Egypt

PI: Alaa Ibrahim, American University in Cairo
U.S. Partner: Allison Steiner, University of Michigan (funded by the National Science Foundation)

Egypt - Project 1-368: Spectral soil mapping for agricultural land development in El-Gallaba Plain, Western Desert, Egypt

PI: El Sayed Abbas Zaghloul, National Authority for Remote Sensing and Space Sciences
U.S. Partner: Magaly Koch, Boston University (funded by the National Science Foundation)

IRAQ

Iraq - Project 7-186: Developing water allocation optimization models for Iraqusing different sources of water to be allocated for different uses, Baghdad as a case study

PI: Mustafa Al-Mukhtar, University of Technology
U.S. Partner: Peter Fox, Arizona State University (funded by the National Science Foundation)

Iraq - Project 6-74: Conservation, restoration and current status of aquatic biodiversity in Southern Iraq

PI: Nadia Al-Mudaffar, Marine Science Centre
U.S. Partner: Brian Helmuth, Northeastern University, Marine Science Center (funded by the National Science Foundation)

Iraq - Project 6-72: Removal of hazardous materials from aqueous solution using nanofiber membranes

PI: Suhad Yasin, University of Duhok
U.S. Partner: Vince Beachley, Rowan University (funded by the National Science Foundation)

Iraq - Project 2-455: Soil water retention technology to improve vegetable production among highly permeable soils under water scarcity and dry climate conditions in Iraq

PI: Mahdi Ibrahim Aoda, Baghdad University
U.S. Partners: G. Phillip Robertson and Alvin J.M. Smucker, Michigan State University (funded by the National Science Foundation)

Iraq - Project 2-24: PEER Research Experiencesfor Undergraduates (REU): freshwater science and policy in the human-dominated Tigris River Basin

PI: Christy Jo Geraci, The American University of Iraq, Sulaimani
U.S. Partners: Ann Rypstra and David Berg, Miami University of Ohio(fundedby the National Science Foundation)

JORDAN

Jordan - Project 5-91: The occurrence and fate of pharmaceutical residues from their sources to water bodies and food chain

PI: Othman Almashaqbeh, Scientific Research Center / Royal Scientific Society
U.S. Partner: Shannon Bartelt-Hunt, Universityof Nebraska-Lincoln (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Jordan - Project 4-369: Assessment of preferential subsurface flow and transport in soils near the Zarqa River Basin
PI: Michel Rahbeh, University of Jordan
U.S. Partner: Raghavan Srinivasan, Texas A&M University (funded by the United States Department of Agriculture/ Agricultural Research Service)

Jordan - Project 3-47: Three Circles of Alemat: creating collaborative multicultural networks for women in the sciences
PI: Rana Dajani, Jordan Society for Scientific Research
U.S. Partner: Gillian Bowser, Colorado State University (funded by the National Science Foundation)

Jordan - Project 3-39: Enhancing water education at the university level in Jordan by incorporating an innovative multi-agent modeling and analysis tool
PI: Samer Talozi, Jordan University of Science and Technology
U.S. Partner: Steven M. Gorelick, Stanford University (funded by the National Science Foundation)

Jordan - Project 2-366: Optimizing water usage of irrigation systems using wireless sensor networks in Jordan
PI: Samer Samarah with co-PI Mohammed Ghazi Al-Zamil, Yarmouk University
U.S. Partner: Mehmet Can Vuran, University of Nebraska-Lincoln (funded by the National Science Foundation)

Jordan - Project 2-357: Evaluating climate change impacts on the arid lands and water resources in Jordan
PI: Yaser Jararweh, Jordan University of Science and Technology
U.S. Partner: George Jenerette, University of California, Riverside (funded by the National Science Foundation)

Jordan - Project 1-146: Floodwave propagation and infiltration in desert regions: the Azraq Basin, Jordan
PI: Mo'ayyad Shawaqfah, Al al-Bayt University
U.S. Partner: Mark Stone, University of New Mexico (funded by the National Science Foundation)

LEBANON

Lebanon - Project 9-331: Assessment of the resilience of Local Baladi goat in Lebanon: A viable sustainable solution to a changing climate in a transhumant system
PI: Pauline Aad, Notre Dame University
U.S. Partner: Joan Burke, USDA/ARS (funded by the United States Department of Agriculture/ Agricultural Research Service)

Lebanon - Project 7-101: Advancing anaerobic digestion in the upper Litani Basin for industrial wastewater treatment
PI: Mahmoud Wazne, Lebanese American University
U.S. Partner: Haluk Beyenal, Washington State University (funded by the National Science Foundation)

Lebanon - Project 5-56: Hazardous effect of pollutants in Deir Kanoun Dump on the Syrian refugees and the Lebanese people
PI: Jamila Borjac, Beirut Arab University
U.S. Partner: Diane Blake, Tulane University (funded by the National Institutes of Health)

Lebanon - Project 5-18: Enhancing water quality monitoring and improving water disinfection processes in Lebanon
PI: Antoine Ghauch, American University of Beirut
U.S. Partner: David Sedlak, University of California, Berkeley (funded by the National Science Foundation)

Lebanon - Project 4-270: Landslide risk index mapping for Lebanon
PI: Grace Abou-Jaoude, Lebanese American University
U.S. Partner: Joseph Wartman, University of Washington (funded by the National Science Foundation)

Lebanon - Project 3-26: Assessment of real evapotranspiration and recharge processes on two karst pilot groundwater catchments (Lebanon) using an integrated spatially distributed numerical model: applications for water resources management purposes
PI: Joanna Doummar, American University of Beirut
U.S. Partner: Jason G. Gurdak, San Francisco State University (funded by the National Science Foundation)

Lebanon - Project 2-514: Health assessment of earth dams in Lebanon: towards sustainable development
PI: Naji N. Khoury, Notre Dame University-Louaize
U.S. Partner: Michael A. Mooney, Colorado School of Mines (funded by the National Science Foundation)

Lebanon - Project 1-228: Assessment of the tropospheric HONO budget: instrumental development and field measurements
PI: Charbel Afif, Université Saint Joseph de Beyrouth
U.S. Partner: Sebastien Dusanter, University of Indiana (funded by the National Science Foundation)

Lebanon - Project 1-163: Earthquake-generated landslide hazard in Lebanon
PI: Grace Abou-Jaoude, Lebanese American University
U.S. Partner: Joseph Wartman, University of Washington (funded by the National Science Foundation)

Lebanon - Project 1-121: A collaborative approach towards integrated water resources management in the Litani River basin: Opportunities for climate change adaptation and socioeconomic growth
PI: Mutasem El Fadel, American University of Beirut
U.S. Partner: James Smith, Princeton University (funded by the National Science Foundation)

Lebanon - Project 1-91: Towards a better assessment and management of wildfire risk in the wildland-urban interface in Lebanon: gaining from the US experience
PI: George Mitri, University of Balamand
U.S. Partner: David McWethy, Montana State University (funded by the National Science Foundation)

Lebanon - Project 1-84: Investigation into persulfate/peroxymonosulfate oxidation of micro-contaminants toward water sustainability: mechanism, kinetics, and implementation
PI: Antoine Ghauch, American University of Beirut
U.S. Partner: Richard Luthy, Stanford University (funded by the National Science Foundation)

MOROCCO

Morocco - Project 8-230: Evaluation of a novel SS-LAMP assay for rapid, low-cost diagnosis of tuberculosis in Morocco
PI: Hassan Ait Benhassou, Moroccan Foundationfor Advanced Science Innovation and Research, in partnership with Université Mohammed V
U.S. Partner: Adithya Cattamanchi, University of California, San Francisco (funded by the National Institutes of Health)

Morocco - Project 7-246: Facilitating access to reproductive health services for refugee women in Morocco
PI: Ali Idri, University of Mohammed V in Rabat
U.S. Partner: Leanne M. Redman, Pennington Biomedical Research Center (funded by the National Institutes of Health)

Morocco - Project 5-648: Data science for improved education and employability in Morocco
PI: Ghita Mezzour, International University of Rabat
U.S. Partner: Kathleen Carley, Carnegie Mellon University (funded by the National Science Foundation)

Morocco - Project 5-398: Towards smart microgrids: renewable energy integration into smart buildings
PI: Mohamed Riduan Abid, Alakhawayn University
U.S. Partner: Driss Benhaddou, University of Houston (funded by the National Science Foundation)

Morocco - Project 5-198: Seamless solar PV integration in Moroccan buildings
PI: Mounir Ghogho, International University of Rabat (co-funded by National Instruments)
U.S. Partner: Paul Flikkema, Northern Arizona University (funded by the National Science Foundation)

Morocco - Project 3-106: Tools and resources to improve deaf educational access to science, technology, engineering, and mathematics
PI: Abdelhadi Soudi, Ecole Nationale de l'Industrie Minérale
U.S. Partner: Corinne Vinopol, Institute for Disabilities Researchand Training, Inc. (fundedby the National Science Foundation)

Morocco - Project 1-375: Assistive technology for improving literacy among the deaf and hard of hearing
PI: Abdelhadi Soudi, Ecole National de l'Industrie Minerale
U.S. Partner: Corinne Vinopol, Institute for Disabilities Research and Training, Inc (funded by the National Science Foundation)

TUNISIA

Tunisia - Project 8-015: Optimization of perennial grasses to improve forage production in Tunisia (OPGIFPT)
PI: Salma Sai Kachout, National Institute of Agronomy Research of Tunisia
U.S. Partner: Niall Hanan, New Mexico State University (funded by the National Aeronautics and Space Administration)

Tunisia - Project 8-094: Evaluation of new citrus rootstocks for their adaptation in different growing environments in Tunisia
PI: Hajer Snoussi Ep. Trifa, National Institute of Agronomy Research of Tunisia
U.S. Partner: Violeta Tsolova (previously Anthony Ananga), Florida A&M University (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Tunisia - Project 8-175: An integrated modeling approach for sustainable development for the Ichkeul Lake (eco-tourism and aquaculture): IMAS-Ichkeul
PI: Béchir Béjaoui, National Institute of Marine Sciences and Technologies
U.S. Partner: Hamidreza Norouzi, The City University of New York, New York City College of Technology (funded by the National Aeronautics and Space Administration)

Tunisia - Project 7-444: The use of modeling, monitoring and smart metering for sustainable groundwater management in a Tunisian coastal aquifer
PI: Adel Zghibi, University Tunis El Manar
U.S. Partner: Ali Mirchi, University of Texas at El Paso (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Tunisia - Project 7-400: Southern Tunisia climate hub (STCH)
PI: Bouajila Essifi, Institut des Regions Arides
U.S. Partner: Steve Ostoja, United States Department of Agriculture, Agricultural Research Service and the University of California, Davis

Tunisia - Project 7-349: Monitoring of antimicrobial resistance of bacteria for a better health of animals in Tunisia
PI: Lilia Messadi, Ecole Nationale de Médecine Vétérinaire de Sidi Thabet
U.S. Partner: Charlene Jackson, U.S. National Poultry Research Center (funded by the United States Department of Agriculture/ Agricultural Research Service)

Tunisia - Project 7-289: Improving sustainable groundwater management: A major challenge in the over-exploited Medjerda Basin (North Tunisia)
PI: Fatma Trabelsi, University of Jendouba
U.S. Partner: Clifford I. Voss, U.S. Geological Survey

Tunisia - Project 7-271: Impact of rooftop PV system integration on Tunisian electrical distribution network
PI: Ilhem Slama-Belkhodja, Ecole Nationale d'Ingénieurs de Tunis
U.S. Partner: Jonghyun Park, Missouri University of Science and Technology (funded by the National Science Foundation)

Tunisia - Project 7-184: Developing organic soil management technologies to enhance carbon capture, climate adaptability, and sustainability of smallholder farms in Tunisia
PI: Khaled Sassi, National Agronomic Institute of Tunisia
U.S. Partner: Anil Somenahally, Texas A&M AgriLife Research (funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)

Tunisia - Project 6-308: Evaluationof algal treatment options for olive mill wastewater to produce energy and biofertilizer
PI: Sami Sayadi, Center of Biotechnology of Sfax
U.S. Partner: Anthony Siccardi, Texas A&M University (original partner Walter Mulbry, fundedby the United States Department of Agriculture/Agricultural Research Service)

Tunisia - Project 5-518: Diagnosis of cutaneous leishmaniasis: development and evaluation of multiplex POC DNA assays
PI: Ikram Guizani, Institut Pasteur de Tunis
U.S. Partner: Steven Reed, Infectious Disease Research Institute (funded by the National Institutes of Health)

Tunisia - Project 5-195: Potential of currents along the Tunisia coasts for renewable power generation
PI: Ali Harzallah, National Institute of Marine Science and Technologies
U.S. Partner: Wassila Thiaw, National Oceanic and Atmospheric Administration

Tunisia - Project 5-128: Enhanced research capacity and fish health infrastructure to assist Tunisian aquaculture
PI: Nadia Chérif, National Institute of Sea Sciences and Technologies (INSTM)
U.S. Partner: James Winton, United States Geological Survey

Tunisia - Project 2-12: Contribution to drought identification and alert in Northern Tunisia
PI: Zoubeida Kebaili Bargaoui, Ecole Nationale d’Ingénieurs de Tunis
U.S. Partner: Kelly Caylor, Princeton University (funded by the National Science Foundation)

Tunisia – Project SG1-006: AIR2D: Algorithm for an Integrative Repurposing & Discovery of Drugs against Neglected Tropical Diseases: leishmaniases as application disease
PI: Emna Harigua, Institut Pasteur de Tunis

Tunisia – Project SG1-007: POC CL diagnosis: Handheld Fast PCR assays and Lateral flow detection for Leishmania parasites detection and identification
PI: Insaf Ben Hadj Ali Insaf, Institut Pasteur de Tunis

WEST BANK-GAZA

West Bank-Gaza - Project 2-347: Rainwater harvesting analysis using water harvesting evaluation tool (WHEAT)
PI: Issam A. Al-Khatib, Birzeit University
U.S. Partners: Defne S. Apul, University of Toledo, and Steve Burian, University of Utah (funded by the National Science Foundation)

EGYPT

EGYPT - PROJECT 5-601: CAPACITY BUILDING OF HEALTH CARE PROVIDERS IN EGYPT TO COUNSEL PREGNANT WOMEN AND THEIR FAMILIES REGARDING SMOKING CESSATION AND SECONDHAND SMOKING AVOIDANCE

PI: Wagida Anwar, Ain Shams University's School of Medicine
U.S. Partners: Scott Sherman, New York University, and Cheryl Oncken, University of Connecticut (Funded by the National Institutes of Health)
Dates: January 2017 – February 2023

PROJECT OVERVIEW

Exposure of pregnant women to secondhand smoke (SHS) is a significant public health concern, especially in developing countries with relatively high adult male smoking rates. There is an urgent need for interventions to create smoke-free home environments. This PEER project developed and disseminated an evidence-based healthcare professional training program on counseling smokers (both men and women) to stop smoking and establish smoke-free homes, specifically focusing on physicians and nurses who counsel pregnant women in the greater Cairo area.

The researchers held training sessions for healthcare professionals and undertook pre- and post-intervention surveys for a target group of pregnant mothers in households with a current smoker. The project team sought to create capacity for widespread dissemination of this work by developing and testing a train-the-trainer program and creating a network of professionals and organizations, including the Ministry of Health. The proposed intervention capitalizes on the "teachable moment" concept with health professionals providing advice in a situation where men and women alike are likely more receptive for behavioral change interventions that can affect the health of their unborn baby. Through a partnership between the Ministry of Health, the Syndicates of Physicians and of Nurses, and prominent universities, the research team hopes that the results of this project will lead to policy changes to promote its sustainability.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team conducted seven training sessions at El Demerdash Hospital in 2022. Participants included physicians, nurses, and health educators. Beforehand, team members had surveyed 1,002 pregnant women attending maternal care clinics across Cairo, Egypt. Up to three months after the training intervention, a follow-up survey with a similar sample size was conducted to compare how pregnant women were receiving secondhand smoke avoidance counseling and how smoke exposure levels differed from those found in the pre-intervention survey.

Participant characteristics of each survey were similar. Among the whole sample, 85% of participants answered all six knowledge-related questions about secondhand smoke and smoking harms correctly. Participants who lived with current smokers who smoked at home experienced an average secondhand smoke exposure for 18 hours per week, while those living in smoke-free homes (whether or not there was a smoker in the household) reported less than 8.3 hours per week on average.

Between the two surveys, an increased number of women reported being asked about secondhand smoke exposure (22.81% to 54.98%) and receiving secondhand smoke avoidance advice (28.46% to 60.32%). While pregnant women in the study seemed knowledgeable about the harms of smoking and secondhand smoke exposure, those living at homes with a current smoker reported being exposed at a level beyond a high risk for pregnant women and babies. The intervention's results demonstrated success in changing providers' behavior in counseling pregnant women, but whether this helped change the behavior of pregnant women needs further follow-up.

To expand this project, the PEER team established communication with the Egyptian Ministry of Social Affairs and the Childhood, Mothers, and Childhood Sector in the Ministry of Health and Population. These ministries provided the project with a list of NGOs working in the same sector. The research team selected and met with the NGOs from that list, which will join their project activities to discuss approaches to promoting smoking avoidance. The team’s final report was also disseminated to the Tobacco Control Program in the Ministry of Health.

The researchers presented their work and findings at several workshops and other events in Egypt, including No Tobacco Day 2023. They also organized a two-day conference on using implementation science to guide tobacco control in the Middle East and have several academic publications in process.

EGYPT - PROJECT 2-239: THE IMPACT OF BIOGENIC AND ANTHROPOGENIC ATMOSPHERIC AEROSOLS TO CLIMATE IN EGYPT

PI: Alaa Ibrahim, American University in Cairo

U.S. Partner: Allison Steiner, University of Michigan (Funded by the National Science Foundation)

Dates: August 2013 – January 2017

PROJECT OVERVIEW

Atmospheric aerosols are liquid or solid particles suspended in the atmosphere. Often observable as dust, smoke, and haze, they are ubiquitous in the air. Aerosols come from natural sources (biogenic), and manmade sources (anthropogenic), arising primarily from a variety of combustion sources. They affect the Earth's energy budget and climate by scattering and absorbing radiation. Atmospheric aerosols represent a key uncertainty in the understanding of the climate system and climate change. Despite observably high concentrations of aerosols in the metropolitan Cairo area, little is known about the composition and spatial distribution of aerosols in Egypt and their influence on the climate and climate change. This project tackled the issue of atmospheric aerosols through providing a national survey of aerosol sources in Egypt, assessing their impact on climate, climate change, and public health.

The project built human capacity through hiring and training junior researchers and the educational and outreach component enhanced the formal and informal educational curricula covering climate and climate change and their broad impacts through programs that target teachers, school students, and the general public.

FINAL SUMMARY OF PROJECT ACTIVITIES

With PEER funds in the final stage, Dr. Ibrahim and his colleagues completed a 12-year (2003-2014) survey of atmospheric aerosol data over Egypt, assessing the level of air pollutant particulate matter over Egypt and the state of air quality nationwide. They modeled the climate and environmental impact of natural and anthropogenic aerosols, as well as measured an increase in the rate of weather dust and sandstorm events over Egypt and the MENA region.

The PEER team collected monthly and seasonal averages of the single scattering albedo (SSA) and Angstrom exponent (AE) from Moderate Resolution Imaging Spectrometer (MODIS) over the entire country and three populated cities (Cairo, Alexandria and Asyut) as well as aerosol extinction, absorption, volume size distribution, spectral phase function, spectral coarse phase function and effective aerosol radius (for fine and coarse particles). They generated daily maps of SSA from MODIS over the entire country, to identify where absorptive and scattering aerosols dominate. The team found that this parameter is not produced regularly over the Nile Delta region (including Cairo and Alexandria), which is the most crucial region in terms of air pollution, and successful generation of this parameter from MODIS is better over arid areas. The researchers also began using aerosol optical depth and other methodologies to differentiate between three aerosol categories: desert dust, urban-industrial, and biomass burning.

The study has identified some demographic impacts, including relatively low aerosol levels year-round in Sadat City, a relatively new residential and industrial community at the border of the Nile Delta surrounded by 30,000 acres of green belt, and significantly higher aerosol levels in the populated and agriculturally active Nile Delta compared to the desert regions beyond the Delta. The PEER project team also developed a local air quality monitoring platform for local observation and verification of results obtained from remote sensing and climate modeling.

This PEER team produced an educational activity book on environmental science and air quality for elementary, middle, and high school students, as well as two outreach videos in English and Arabic. The PI gave a presentation on the results to the United Nations Summer Academy on Sustainable Development in 2016 and the team developed new collaborative ties with the OpenAQ project that collects, standardizes, visualizes, and shares air quality data across the world and are discussing possible ways to share results through this platform. Team member Dr. Ashraf Zakey was chosen to represent Egypt in the World Meteorological Organization annual meeting.

Team members organized and participated in three educational workshops on remote sensing, climate modeling and environmental education. PEER team members also were invited by the U.S. Embassy in Cairo and USAID Cairo office to present their project to NASA astronaut Dr. Mary Ellen Weber.

PUBLICATIONS

Nashaat Gad, Mohammed Shokr, and Alaa I. Ibrahim. 2017. Microphysical characteristics of atmospheric particulate matter from NASA's MODIS, MISR, and AERONET observations. IOP Conference Series: Journal of Physics: Conf. Series 869: 012081. https://doi.org/10.1088/1742-6596/869/1/012081

M. Shokr, M. El-Tahan, A. Ibrahim, A. Steiner, and N. Gad. 2017. Long-term, high-resolution survey of atmospheric aerosols over Egypt with NASA's MODIS data. Remote Sensing *9*(10): 1027. https://doi.org/10.3390/rs9101027

Alaa I. Ibrahim, Ashraf Zakey, Allison L. Steiner, Mohammed E. Shokr, M. El-Raey, Yasmin Ahmed, Ali Al-Hadidi, and Ashraf Zakey. 2014. The Impact of Biogenic and Anthropogenic Atmospheric Aerosol on Climate in Egypt. Presentation at the American Geophysical Union Fall Meeting, San Francisco, California, December 15-19, 2014. http://doi.org/10.13140/2.1.2418.0480

Alaa I. Ibrahim, Richard Tutwiler, Ashraf Zakey, Mohammed E. Shokr, Yasmin Ahmed, Dina Jereidini, and Mohammad Eid. 2014. Student and Community Engagement in Earth, Space, and Environmental Sciences Through Experiential Learning and Citizen Science as Part of Research Broader Impact. Presentation at the American Geophysical Union Fall Meeting, San Francisco, California, December 15-19, 2014. https://doi.org/10.13140/2.1.4515.2000

EGYPT - PROJECT 1-368: SPECTRAL SOIL MAPPING FOR AGRICULTURAL LAND DEVELOPMENT IN EL-GALLABA PLAIN, WESTERN DESERT, EGYPT

PI: El Sayed Abbas Zaghloul, National Authority for Remote Sensing and Space Sciences
U.S. Partner: Magaly Koch, Boston University (Funded by the National Science Foundation)
Dates: July 2012 – December 2013

PROJECT OVERVIEW

Ensuring food security and sustainable growth are among the top priorities of the Egyptian government. Major programs have been undertaken in the last decades to relieve population pressure along the narrow Nile Valley, increase Egypt's arable land, and generate new employment opportunities, especially for young people. One significant step toward accomplishing these goals is the selection of suitable sites for urban and agricultural development. Remote sensing technology has made timely and spatially explicit information gathering possible with a wide variety of sensors operating in the optical and microwave region of the solar spectrum. Despite the increasing level of sophistication of these sensors, field information is a required component of any remote sensing study to ensure proper calibration and validation of data.

This project worked with an existing U.S.-Egyptian project involving field surveys (including ground penetrating radar and soil and water sampling for lab analysis) in the El-Gallaba Plain, bounded in the east by the River Nile and in the west by the scarp face of the Sin El-Kaddab Plateau. Although soil maps exist for this region from the time when the Aswan High Dam was constructed in the 1960s, these maps do not cover the area in sufficient detail. The project addressed this problem by producing a detailed surface sediment and soil map that will provide a basis for assessing and monitoring soil types and conditions and their suitability for urban and agricultural development. The researchers conducted a spectral soil mapping campaign in conjunction with other ongoing field surveys and created a library of representative surface materials to be used in conjunction with present and future satellite sensors to spatially map the distribution of soils and surface sediments. The library will be made available to the public and used for a training workshop in spectral mapping techniques.

FINAL SUMMARY OF PROJECT ACTIVITIES

Four technical and scientific meetings were held between Egyptian research teams to determine the study area. An additional technical meeting was held between the Egyptian team and the U.S. partner to discuss the field survey groups.

The team held two workshops at the National Authority for Remote Sensing and Space Sciences in 2013. The first demonstrated the techniques and methodology used during the project, as well as soil mapping and soil classifications in the study area and water resources available for agricultural development. The second presented results from the project as well as additional technical presentations on SAR and GPR methods, and research into groundwater exploration in the KomOmbo area.

The project also supported two training courses – GPR Survey and Data Analysis and Modeling and Spectro-radiometer Survey and Data Analysis and Imaging. The Egyptian Ministry of Resources expressed interest in the project results and data in the exploration of underground water.

PUBLICATIONS

Multisensor characterization of subsurface structures in a desert plain area in Egypt with implications for groundwater exploration. Magaly Koch, Ahmed Gaber, Mohamed Helmi Gereish, El-Sayed Abbas Zaghloul, Sayed M. Arafat, and Mostafa Abubakr. Remote Sensing for Agriculture , Ecosystems and Hydrology XV, SPIE conference, Dresden, Germany, September 2013, Volume 8887.

Mapping of surface and subsurface in West Kom Ombo, The upper Nile Valley, using remote sensing techniques. El-Sayed Abbas Zaghloul and Sayed M. Arafat. National Authority for Remote Sensing and Space Sciences, Cairo, Egypt. Presented Paper, 7th International Conference on the Geology of Africa, November 2013, Assiut, Egypt.

IRAQ - PROJECT 7-186: DEVELOPING WATER ALLOCATION OPTIMIZATION MODELS FOR IRAQ USING DIFFERENT SOURCES OF WATER TO BE ALLOCATED FOR DIFFERENT USES, BAGHDAD AS A CASE STUDY

PI: Mustafa Al-Mukhtar, University of Technology
U.S. Partner: Peter Fox, Arizona State University (Funded by the National Science Foundation)
Dates: November 2018 – December 2021

PROJECT OVERVIEW

Serious water shortages in Iraq are considered an essential issue to be addressed to support the country's stability. The utilization of practical, applicable, and sustainable river basin management strategies for the Tigris and Euphrates Rivers in Iraq is important to maintain economic development, biodiversity, and social stability, while minimizing potential future water crises in connection with water quality and quantity. Therefore, sustainably allocating the existing freshwater resources and utilizing non-traditional water resources, such as reclaimed water, to different users is an urgent requirement to maintain sufficient water quantity and quality.

In this project, a water allocation optimization model was developed using a genetic algorithm (GA) to maximize the net benefit from allocating surface water, groundwater, and reclaimed water (RW) in Baghdad for five different uses, including domestic, industrial, agricultural, commercial, and recreational. The model maximized the consumption of RW to allow for the highest value uses of renewable water resources. The primary goal was to identify practical alternatives for water management to aid decision-makers by providing detailed user-friendly results. The water management model included measurements of the net economic benefits and associated optimal solutions, which will clearly demonstrate the value of water, something that is often not considered in the decision-making process in Iraq. Measures of sustainability were also presented, considering many factors, including water availability and the costs generated from using poor quality (saline) waters, along with their environmental and industrial impacts. An Iraqi PhD student at Arizona State University (ASU), originally devised this water allocation optimization model under the supervision of Dr. Peter Fox and Dr. Larry Mays at ASU. After completing his degree, Mr. Aljanabi returned to Iraq in 2019 to work with Dr. Al-Mukhtar with PEER support to further develop the model using local input and data. Dr. Fox served as the USG-supported partner on the effort, continuing to collaborate with the team in Baghdad to achieve the goals proposed.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project presented an applicable and sustainable water management strategy for Iraq's water resources systems that conserves its renewable and freshwater resources while minimizing the disposal of pollutants and other harmful contaminants to the environment. Using such optimization modeling approaches can support decision-makers and allow them to manage water allocation in Iraq with consideration of current and potential water shortages and related issues. Several water allocation scenarios were tested using Baghdad as a case study due to the size of the generated wastewater that is usually secondarily treated and discharged directly to the Tigris River and the local drainage systems. By running the developed optimization model under different water availability scenarios, it was found that as reclaimed water reuse increases, the surface water flow downstream of the studied region maintains a suitable quantity in comparison to the scenarios without the utilization of reclaimed water. In addition, the released pollutants to the environment are decreased while allowing fresher surface water that supports the downstream aquatic system.

Increasing public understanding of the approaching threats to renewable and freshwater resources increased their acceptance of reclaimed water as an essential alternative source that certainly will assist in reducing the potential impacts of water shortages and related quantity and quality issues. In this regard, meetings with stakeholders, personnel, graduate and undergraduate students, civil activists, and farmers were conducted highlighting the utilization of integrated land and water resources management techniques to minimize water consumption in irrigation and other applications. The team also highlighted how crop diversity may positively impact yield in addition to other benefits that may result if compared to traditional agricultural practices. Providing sustainable water resources during water shortages and drought seasons and other management issues were the main points of contention during the discussions due to the accumulated problems during the last four decades.

Throughout the project, the team met with numerous stakeholders in the private and public sectors, including the Iraqi Ministry of Construction and Housing & Public Municipalities (MOCHPM) and the General Directorate of Sewage. The use of reclaimed water and potential applications, as well as other programs to save the available surface water resources were explored with stakeholders to increase understanding of the situation and possible remedies.

PUBLICATIONS

Noor Sabah, Mustafa Al-Mukhtar, and Khalid Shemal. 2023. Water-food and energy nexus systems: analysis integrated policy making tool. *3C Empresa. Investigación y pensamiento crítico* 12(1): 324-344. https://doi.org/10.17993/3cemp.2023.120151.324-344

Mustafa M. Al-Mukhtar and Ghasaq S. Mutar. 2021. Modelling of Future Water Use Scenarios Using WEAP Model: A Case Study in Baghdad City, Iraq. *Engineering and Technology Journal* 39, Part A (3): 488-503. https://doi.org/10.30684/etj.v39i3A.1890

IRAQ - PROJECT 6-74: CONSERVATION, RESTORATION AND CURRENT STATUS OF AQUATIC BIODIVERSITY IN SOUTHERN IRAQ

PI: Nadia Al-Mudaffar, Marine Science Centre
U.S. Partner: Brian Helmuth, Northeastern University, Marine Science Center
(Funded by the National Science Foundation)
Dates: August 2018 – May 2021

PROJECT OVERVIEW

Shrinking water reserves in Iraq have led to multiple challenges, including environmental changes, threatened biodiversity, and proliferation of invasive aquatic plants. This PEER project documented and cataloged patterns of biodiversity in the aquatic environments of Southern Iraq and enabled scientists at the University of Basrah Marine Science Centre (UBMSC) to adopt new tools for forecasting the effects of extremely rapid environmental change on the region's biodiversity. Building on a previously established partnership with Northeastern University's Marine Science Center (NUMSC), this project involved four primary goals: (1) creation of methods for surveying patterns of aquatic diversity in Southern Iraq; (2) collection of genetic samples to be cataloged with the Ocean Genome Legacy Center; (3) training of Iraqi scientists through short courses offered at NUMSC; and (4) training in modern physiological methods for measuring environmental stress in aquatic species.

FINAL SUMMARY OF PROJECT ACTIVITIES

The first phase of the project sought to catalog and map patterns of biodiversity, making comparisons against baselines obtained from the literature to detect any major changes in the aquatic ecosystems. Much of the historic information was contained in manuscripts in the UB library, and PEER support allowed the researchers to digitize and translate these manuscripts. In the second phase, the PEER team built on established methods for forecasting the effects of environmental change on biodiversity to predict which species in the region are at greatest risk. As part of the project, UB faculty have been approached by the Iraqi Prime Minister and the Ministry of Health and the Environment to help develop a biodiversity plan after the designation of the Basra Marshes as a UNESCO World Heritage Site.

In October 2018, Mr. Jihad Alzewar (senior graduate student) and Dr. Abdulamer Jassim (University of Basrah faculty) visited Northeastern for two weeks to take part in a training course, including a series of workshops, while eight other members of the Basra-based team participated online. Training topics focused on sample collection and processing of genetic material; techniques of environmental monitoring; and physiological approaches for measuring stress in key aquatic species. In most cases the equipment used was similar or identical to that purchased by the project and shipped to Iraq. The team was also provided with reference management software and an extensive PDF library of scientific literature not available in Iraq.

In March 2019, the Iraqi team deployed an Onset weather station in Shaat Al-Arab and began experiments of physiological stress using heartbeat and oxygen sensors. They also conducted field surveys of biodiversity in the mud flats at the intersection of Shaat Al-Arab and the Arabian Gulf. The

U.S. partners collaborated by providing advice on instrument set up, experimental design, and provision of literature. Growing civil unrest in Iraq unfortunately prevented the U.S. team from traveling there for additional collaboration, but they continued to provide assistance remotely in analyzing and publishing results of the field work.

Although the project could not be fully implemented due to the security challenges in Iraq, there were some policy impacts. In the summer of 2018, the Shatt al-Arab faced a severe shortage of freshwater input into the river, creating a wedge of saltwater advancing northwards from the Persian Gulf. This created a severe shortage of potable water, leading to about 18,000 water-related illnesses and public riots and disturbances demanding fresh, clean water. The project team was asked to prepare a report on the advantage of constructing a barrage on the Shatt Al-Arab to stop the advancement of salt water. They held four workshops on the impact of the saltwater wedge on the Shatt al-Arab river, inviting university departments, local NGOs, and government agencies to provide input and created an environment impact assessment study. The report, submitted to local governments and national ministries, recommended a temporary barrage until an agreement is reached on the best solution to the salinization issue, illustrating how the PEER project can reduce some of the large gap in environmental knowledge about the river itself.

PUBLICATIONS

J. Caviglia-Harris, K. Hodges, B. Helmuth, E. Bennett, K. Galvin, M. Krebs, K. Lips. M. Lowman, L Schulte-Moore, and T. Schuur. 2021. The six dimensions of collective leadership that advance sustainability objectives: Rethinking what it means to be an academic leader. Ecology and Society 26(3):9. https://doi.org/10.5751/ES-12396-260309

Malik Hassan Ali, Nadia Al-Mudaffar Fawzi, Hanaa Hussein Mohamed, Brian Helmuth, and Amanda M. Dwyer. 2021. Winners and losers: Post conflict biodiversity in the stressed ecosystem of Khor Al-Zubair, Iraq. Pakistan Journal of Marine Sciences 30(2): 76-95. https://www.pakjmsuok.com/index.php/pjms/article/view/98

IRAQ - PROJECT 6-72: REMOVAL OF HAZARDOUS MATERIALS FROM AQUEOUS SOLUTION USING NANOFIBER MEMBRANES

PI: Suhad Yasin, University of Duhok

U.S. Partner: Vince Beachley, Rowan University (Funded by the National Science Foundation)

Dates: March 2018 – March 2022

PROJECT OVERVIEW

This project focused on the study of the functions of nanofiber membranes and their use to remove heavy metals from aqueous solutions. In the short term, the researchers studied electrospinning parameters in order to design nanofibers from available waste materials in Kurdistan Region. Long-term goals included broadening the technology of electrospinning nanofiber membranes as an option to conventional membranes and polymer beads. The electrospun membrane, in particular, may be successfully applied in water treatment and biotechnology, where the removal of toxic materials requires materials with a high surface area. In addition to the high surface area, changes in the surface chemistry of the nanofibers may also do wonders for their performance.

Nanofiber technology has hugely impacted both science and engineering disciplines. The motivations for the miniaturization process of polymers are based on producing nano-sized fibers with superior properties (for example, excellent mechanical properties and a large surface area per unit mass) compared to microfiber and film. The functionalities of the polymers plus the unique characteristics of nanofibers originated from them and being engineered in various forms have allowed nanofibers to be used in advanced applications such as filtration, multifunctional membranes, composite reinforcement, tissue engineering scaffolds, drug delivery, and wound dressings. As for water purification, a very important application in water-scare areas such a Iraq, adsorption is a technique that can potentially achieve high yields of heavy metal removal even for low concentration effluents. It can be a more cost-effective process to remove and recover heavy metals, based on the choice of adsorbent material. This PEER award supported fundamental research into a new adsorbent prepared from waste polymers. It was the first research project in nanotechnology carried out at the University of Duhok. By providing opportunities for several researchers to gain firsthand experience in nanotechnology research, the program also helped to improve the research infrastructure and enhance research collaboration both within the department and with the U.S. partner.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project focused very heavily on enabling and building a research community in Kurdistan. The first year of the project focused on establishing an electrospinning laboratory, which is the first lab in the Kurdistan region for producing nanofibers. This involved building a network internationally as the equipment and expertise needed was only available in the international research community. The second year saw the introduction and complications of COVID-19, but the team was still able to conduct their work with appropriate precautions and continued their collaborations virtually. In the third year of the project, the team established the Electron Microscope Laboratory, which is the first in Iraq. The two laboratories that have been established by PEER are considered the most important laboratories in the College of Science, which is busy with researchers and graduate students.

The team established several international partnerships, including with Al-Azhar University in Egypt, with whom the team collaborated on a number of endeavors and jointly published research papers. The team visited many advanced research centers in multiple countries, which had a great positive impact on their scientific knowledge. From starting with research in nanofibers, the project team published ten research papers in high-impact factor journals related to water treatment from pharmaceuticals, heavy metals, and dyes, as well as one book chapter. The team was also invited to, and participated in, international organizations such as the Arab-German Young Academy, AGYA, the German Academic Exchange Service (DAAD), and the International Women in Science Conference.

IRAQ - PROJECT 2-455: SOIL WATER RETENTION TECHNOLOGY TO IMPROVE VEGETABLE PRODUCTION AMONG HIGHLY PERMEABLE SOILS UNDER WATER SCARCITY AND DRY CLIMATE CONDITIONS IN IRAQ

PI: Mahdi Ibrahim Aoda, Baghdad University
U.S. Partners: G. Phillip Robertson and Alvin J.M. Smucker, Michigan State University
(Funded by the National Science Foundation)
Dates: August 2013 – October 2016

PROJECT OVERVIEW

Water scarcity is becoming more acute in Iraq, primarily due to the high evapo-transpiration rates and the fact that previous international water sources increasingly are being retained in large dams and canal systems in Syria and Turkey. Surface flooding and canal irrigation continue to result in the loss of more water, promoting soil salinity. Since water is the most limiting input for agricultural production, and its resources are declining, new approaches beyond additional irrigation are needed to retain more water in the root zones of plants.

Subsurface water and nutrient retaining membranes, combined with surface and subsurface drip irrigation tapes, can minimize surface water losses and deep leaching losses of water and nutrients below the root zone. Such water-saving and drought avoidance technologies have been highly successful with cucumbers, green peppers, and corn in Michigan; grass in Turkey; and cotton in Texas. Just under 20% of Iraqi soils are sandy, often exposed to shifting sand dunes, and using soil water retention technology in Iraq is essential for rehabilitating sandy soils for use in growing agricultural products, many of which are currently imported.

The primary goal of this project was to use this proven technology to double food production and reduce irrigation in arid regions of Iraq, while consolidating and expanding the research collaboration and student training activities involving Michigan State University and universities in Iraq.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER researchers planted tomato and pepper crops in sandy soils at research fields at Baghdad and Kufa Universities. Each crop was split into four experimental treatments: a full configuration of soil water retention technology (SWRT) membranes, chiseled soil with a layer of applied organic matter added at 35 cm depth, chiseled soil without SWRT and organic matter, and non-chiseled natural soil. The PEER team took baseline soil samples to identify the best fertilization regiment, installed soil water probes, and analyzed soil nitrogen and carbon levels following the cropping season. The researchers sampled the growing plants several times during the season to identify plant biomass, evaluate water use efficiencies on the leaf area and plant mass, and identify total plant carbon and nitrogen. Soil water measurements were combined with rainfall data to identify deep soil drainage among all replications and treatments.

The PEER team saw positive results from the tomatoes and peppers and selected corn as their next test crop. They found that for all crops planted, SWRT resulted in a 50% reduction of irrigation water and fertilizers applied, as well as an increase in water use efficiency, plant growth, and crop yields.

Two doctoral students completed their dissertations as part of this project. Graduate and undergraduate students from both universities visited the experimental crops and learned about the project as part of field trips, and special topics on irrigation technologies, soil physics, and soil water conservation were added to some soil science courses. The researchers disseminated their results through publications, technical presentations, a TV interview, and a Facebook project page.

PUBLICATIONS

Mahdi I. Aoda, Alvin J.M. Smucker, Shatha S. Majeed, Hussein A. Mohammed, Fadhel H. Al-Sahaf, and G. Philip Robertson. 2021. Novel root zone soil water retention improves production with half the water in arid sands. Agronomy Journal 113: 2398–2406. https://doi.org/10.1002/agj2.20648

Mahdi Ibrahim Aoda, Alaa Salih Ati, Shatha Salim Al-Rawi, and Alvin J.M. Smucker. 2018. Subsurface Water Retention Technology (SWRT) for Water Saving and Growing Tomato in Iraqi Sandy Soils. Journal of Zankoy Sulaimani *Part A* 7: 127-134. http://dx.doi.org/10.17656/jzs.10659

M.A. Abed, R.J. Mohammed, K.A. Saliem, and D.F. Hassan. 2017. Studying the chemical, morphological, and physical properties of the Middle Euphrates gypsum soil. Iraq Journal of Agricultural Research (Special Issue) 22(7): 139-152. [in Arabic with English abstract] https://www.iasj.net/iasj/download/9cc5cec437fdf303

IRAQ - PROJECT 2-24: PEER RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU): FRESHWATER SCIENCE AND POLICY IN THE HUMAN-DOMINATED TIGRIS RIVER BASIN

PI: Christy Jo Geraci, The American University of Iraq, Sulaimani

U.S. Partners: Ann Rypstra and David Berg, Miami University of Ohio (Funded by the National Science Foundation)

Dates: August 2013 – January 2015

PROJECT OVERVIEW

The PI and U.S. partners created a Research Experiences for Undergraduates (REU) program in freshwater science and policy in the Tigris River Basin. The REU was linked with a new curriculum and research opportunities for students at the American University of Iraq, Sulaimani (AUIS) about water resources and development.

This program immersed undergraduates in science via inquiry-based learning. Students learned and taught about argument, scientific method, statistics, research, and scientific writing—all in the context of water resources. The training aimed to be broadly scientific and to push students to be able to formulate research questions, deploy the scientific method to seek answers, employ appropriate tools and techniques to collect data, use statistical methods and software to analyze data, approach these processes critically, place them in the larger contexts of politics and development, and, at the end, competently present their findings.

FINAL SUMMARY OF PROJECT ACTIVITIES

The learning community of 10 students at AUIS took two full-semester courses, Freshwater Science and Research/Technical Writing, as well as a two-day Freshwater Science Research Methods Workshop. Each of the 10 students enrolled in the Technical Writing and Freshwater Science courses worked on a research proposal on a topic of his or her choice, in addition to smaller assignments such as an ethics memo and synthesis and presentation of water quality data. Freshwater Science and another new course created by the PI under this project—Water Policy in Iraq—both addressed advanced topics, such as water science, use, policy and management in Iraq and other countries of the Middle East and North Africa. In these courses, students had the opportunity to do hands-on research and gain their first firm experience in being scientists and policy analysts. The Freshwater Science course prepared students for basic research by giving them laboratory and field experience, while the Water Policy in Iraq course gave them a foundation in policy research. Both courses pushed students to think critically about how the Tigris River basin is linked to regional development.

As part of the coursework, students took several field trips to local streams and rivers to practice techniques for biological assessment, including trips to the Lesser Zab River and one of its feeder streams, Sarchinar Stream, Zalm Stream, Mawat River, and Choman River near the new Halgurd-Sakaran National Park. During these field trips, the researchers and students collected fewer aquatic invertebrates than expected, which could reveal increasing pollution in these streams or the fact that the emergence patterns of aquatic insects are timed for later in the spring than originally expected. The final activity of the semester was a group field trip to the Choman - Rwanduz River Festival sponsored by NatureIraq. The festival was the kickoff event for a public outreach activity aimed at raising awareness of the value of conserving the Rawanduz River. PEER students presented posters to the public and gave hands- on demonstrations of water chemistry sampling and aquatic invertebrate identifications using portable microscopes purchased by AUIS.

The concept of the Learning Community is now being applied to other areas of study, and the ENG 203 course led to new methods of teaching being implemented in the International Studies capstone course taught by a team member. Students displayed their capstone projects for the first time to the broader AUIS community and defended their theses in an interactive question and answer session.

The PEER team also collaborated with NatureIraq's RiverWatch program during the spring semester. Students learned how to use their HACH colorimeter device and YSI water chemistry probe. The data they collected will contribute to the RiverWater public dataset available on their website.

In July 2014, three AUIS students successfully completed four weeks of training at the Miami University of Ohio, where they conducted research in ecology of human dominated landscape. During their U.S. visit, the AUIS students collected aquatic insects from the Mad River watershed in Ohio, completed morphological identifications of the specimens after receiving training on aquatic insect morphology and taxonomy. In the final two weeks of their visit, the students learned how to carry out DNA extraction, PCR amplification, and gel electrophoresis using specimens from the Ohio Mad River specimens.

JORDAN

JORDAN - PROJECT 5-91: THE OCCURRENCE AND FATE OF PHARMACEUTICAL RESIDUES FROM THEIR SOURCES TO WATER BODIES AND FOOD CHAIN

PI: Othman Almashaqbeh, Scientific Research Center / Royal Scientific Society
U.S. Partner: Shannon Bartelt-Hunt, University of Nebraska-Lincoln (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: December 2016 – April 2021

PROJECT OVERVIEW

Jordan is facing a future of very limited water resources, among the lowest in the world on a per capita basis. Water scarcity is the single most important natural constraint to the country's economic growth and development. Therefore, wastewater reuse is increasingly viewed as the primary long-term strategy for conservation of limited freshwater resources. In Jordan, the reuse of treated wastewater for irrigation has been practiced since the 1980s to overcome the severe water shortage. In 1998, the Ministry of Water and Irrigation commenced a wastewater management policy, stating that wastewater is a resource and cannot be treated as waste. More than 129 million cubic meters of wastewater is treated and reused for irrigation in agriculture activities, which are considered as one of the highest reuse rates among the Arab countries (95%). The treated wastewater is mixed with freshwater at the dams and then used for unrestricted irrigation in Jordan. Given these water reuse practices, the potential threats posed pharmaceuticals and personal care products (PPCPs) in treated wastewater to water resources and the food chain through plant uptake merit evaluation.

The results of this project provide a comprehensive overview of the occurrence and behavior of PPCPs in the Middle East and North Africa region. The research team assessed information on the impacts of wastewater irrigation on water quality and human health in the region and established a baseline on the level of pharmaceutical contamination in Jordan's water supply, irrigation water specifically, and vegetables grown using it. Moreover, this project should also help the water authorities in Jordan and worldwide take effective measures to protect water resources (groundwater and surface water), protect public health from the impact of PPCPs, and facilitate the rational reuse of treated wastewater in agriculture.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project conducted in Jordan aimed to address the issue of emerging contaminants, specifically pharmaceutical and personal care products (PPCPs), which have received inadequate attention and data in Jordanian water systems. Over a three-year period, the project monitored the occurrence of PPCPs in various sources including water resources (surface and groundwater), wastewater treatment plants (WWTPs), soil, manure, and irrigated vegetables using treated wastewater. Key findings revealed that domestic WWTPs, such as As-Samra and Wadi Al-Seer, were significant sources of PPCPs, with 15 compounds detected in wastewater samples. Some compounds, notably caffeine and carbamazepine (CBZ), showed higher concentrations than reported elsewhere, indicating incomplete removal by conventional WWTPs. The study also identified PPCPs in sludge from these WWTPs, where substances like caffeine predominated due to high absorption rates.

Livestock manure from chicken and cow farms was another source of PPCPs, with specific substances detected in each type of manure. These contaminants were found to transport through water resources and into the food chain, evidenced by detections in groundwater aquifers, drinking water treatment plants (WTPs), and surface water dams. Additionally, vegetables irrigated with treated wastewater were found to contain PPCPs, highlighting potential human exposure pathways.

Efforts to mitigate PPCP contamination included testing Jordanian natural adsorbents like raw zeolitic tuff (RZT), though initial tests showed limited effectiveness in removing CBZ. Surface modification of RZT using a surfactant method improved removal efficiency to some extent, demonstrating potential for future application in water treatment.

Beyond scientific investigations, the project focused on raising public awareness and engaging policymakers through seminars, workshops, and training sessions. These activities aimed to underscore the risks associated with PPCPs in water and food sources and promote strategies for protection and mitigation.

Overall, the project underscored WWTPs as primary sources of PPCPs in Jordan, exacerbated by the widespread reuse of treated wastewater for agriculture. As a response, the establishment of the Emerging Pollutants Research Unit aimed to advance research, consulting, and policy initiatives regarding PPCPs in Jordan, including proposals for take-back programs to reduce PPCP levels in households.

JORDAN - PROJECT 4-369: ASSESSMENT OF PREFERENTIAL SUBSURFACE FLOW AND TRANSPORT IN SOILS NEAR THE ZARQA RIVER BASIN

PI: Michel Rahbeh, University of Jordan

U.S. Partner: Raghavan Srinivasan, Texas A&M University (Funded by the United States Department of Agriculture/ Agricultural Research Service)

Dates: October 2015 – August 2018

PROJECT OVERVIEW

Treated wastewater has become a major resource for agriculture in Jordan due to the overall scarcity of water. However, irrigation with treated wastewater increases the leaching potential of pesticides and fertilizers, in addition to the heavy metals already present in irrigation wastewater. Soil has always been viewed as the sieve that separates the surface from the subsurface in that it protects the vulnerable groundwater from organic and inorganic contaminants. The soil can retard the downward movement of contaminants, and the indigenous microorganisms concentrated in the first meter of the soil profile can assimilate the inorganic and degrade the organic contaminates. However, various factors associated with the chemical composition and texture of the soil can affect the downward flow of water. Water can also flow preferentially through macropores created by the activity of earthworms and plant roots, cracks and fissures in shrinking clay soils, and pathways formed due to subsurface erosion (Hillel 1998).

The researchers in this project studied the contamination of surface and ground water via subsurface preferential routes. Their findings should be useful to decision makers (for example, the Jordanian Ministry of Water and Irrigation) in efforts to protect the ground and surface water within the study area from pollution. The study results could also facilitate the adoption of new irrigation methods and practices and reconsideration of irrigation water quality. The ultimate goal is providing accountable and sustainable management options for the use of wastewater in irrigation and therefore maintaining the long-term sustainability of surface and ground water in the study area.

FINAL SUMMARY OF PROJECT ACTIVITIES

This was the first research in Jordan that considered preferential flow of irrigation water in soils, and Dr. Rahbeh and his team shared their findings with the Jordanian Ministry of Water and Irrigation, as well as with farmers, in an effort to protect the ground and surface water within the study area from pollution. The research team undertook several types of experiments to quantify contamination of the surface and ground water and soil preferential flow, including tension infiltrometer readings along sites on the river, dye tracer field experiments and lab tests of soil samples for transport of bromide, nitrate, dimethoate and lead. The researchers also compared two models – the Soil Water Assessment Tool (SWAT) and HYDRUS — to evaluate preferential flows on a small selection of the study area.

Three female laboratory assistants received training as part of the grant and two assistants obtained full-time employment using the skills learned. Graduate students also attended a workshop on the HYDRUS model, and one female Ph.D. student attended advanced training at the U.S. partner institution, Texas A&M, and received feedback on her research proposal.

The PI presented results at two international conferences: the Soil Water Assessment Tool International Conference held in Warsaw, and at the 18th International Conference on Diffuse Pollution and Eutrophication in Los Angeles. As a result of the PEER grant, the PI was appointed the head of the Land, Water, and Environment Department at the University of Jordan. Laboratory equipment purchased as part of the PEER grant will continue to be used for further research and training for graduate students.

PUBLICATIONS

Michel Rahbeh, Raghavan Srinivasan, Rabi Mohtar. 2019. Numerical and conceptual evaluation of preferential flow in Zarqa River Basin, Jordan. Ecohydrology & Hydrobiology 19(2): 224-237. https://doi.org/10.1016/j.ecohyd.2019.04.001

Michel Rahbeh. 2019. Characterization of preferential flow in soils near Zarqa river (Jordan) using in situ tension infiltrometer measurements. PeerJ 7: e8057. https://doi.org/10.7717/peerj.8057

M., Rahbeh. 2017. Assessment of preferential subsurface flow and transport in soils near Zarqa river basin, The 18th International Conference on Diffuse Pollution and Eutrophication Los Angeles, USA, August 13-17, 2017

JORDAN - PROJECT 3-47: THREE CIRCLES OF ALEMAT: CREATING COLLABORATIVE MULTICULTURAL NETWORKS FOR WOMEN IN THE SCIENCES

PI: Rana Dajani, Jordan Society for Scientific Research
U.S. Partner: Gillian Bowser, Colorado State University (Funded by the National Science Foundation)
Dates: September 2014 – July 2017

PROJECT OVERVIEW

Women are underrepresented in the academic sciences worldwide. In many developed countries, women are also part of the scientific diaspora who could provide critical encouragement to women and girls back in their home countries. Research suggests that by providing social networks and peer support, the number of women participating as professionals in the science fields can be increased. This project focused on creating a new generation of women scholars and promoting multidisciplinary and multi-cultural research that combines all fields of science. The research team developed a framework model of mentoring designed to be evaluated first within a country and leading towards a replicable model for engaging women and women of the diaspora in science globally. Three Circles of Alemat (Arabic for female scientists) used social networking analyses to explore the strength and persistence of networks of women across multiple cultures. The Three Circles of Alemat collaborative partnership aimed to tie mentoring to and among cultures and gather women of the STEM diaspora across the international boundaries. Circle 1 (DEMN), within Jordan, investigated whether mentoring networks work within a specific country where a pilot framework is designed locally. Circle 2 (BAYN) is among cultures, and the team investigated how mentoring networks engage across multicultural landscapes. Circle 2 brings women scientists together from different cultures to create a mentoring network based on the elements from Circle 1. Circle 3 (TAJAMUGH) addressed the question of how to engage women of the STEM diaspora within and among countries to gather (TAJAMUGH) women into the sciences globally. DEMN, BAYN and TAJAMUGH represent three cohorts built over a stepwise process of creating mentoring networks that can successfully span international boundaries. Thus, the program included a mentoring circle and mentoring activities over a period of three years creating three interlinked cohorts within Jordan (DEMN), among cultures (BAYN), and globally (TAJAMUGH).

FINAL SUMMARY OF PROJECT ACTIVITIES

This three-year project was completed in July 2017. The project results and impacts include: (1) **Database** of female scientists in Jordan, Arab world and U.S. Diaspora; (2) **Quantitative and qualitative research** on the mentoring program; (3) **Website**: the website has different resources for mentoring as well as a database for networking and sharing stories; (4) **The policy report**, which includes lessons learned as well as recommendation for institutionalization of mentoring so that organizations can implement mentoring in their workplace; (5)**Toolkit**, which includes step by step guidelines for individuals and organizations intending to adopt mentoring and is available online on the **website**. (6) **A film** capturing the essence of mentoring as an important vehicle to personal and professional growth; (7) A gallery of **images** on the meaning of mentoring from all over the world; (8) **Social media**, through which interested individuals can share stories and ideas through Facebook, LinkedIn, Twitter, Research Gate, and YouTube; and (9) Material to write books about the project. In Rana Dajani's words, “the impact of the project is long term and is exhibited in the female scientists who have been part of the program and who will disseminate the program to others. The impact of the program on these scientists is both on the personal level and the professional level. The research impact and policy brief impact will affect policy makers and decision makers by adopting and incorporating mentoring into their organizations and institutions.”

Under the patronage of Ms. Majd Shwaikai, the Minister of Telecommunication and IT, and Minister of Public Sector Development, Three Circles of Alemat launched the mentoring tool kit and policy report and an inspirational video on June 31, 2017, at the end of PEER project, with 50 journalists and academics in attendance. A policy report was also written to share with stakeholders, including government and private organizations both academic and non academic. The report was translated into Arabic for dissemination among stakeholders. The mentoring tool kit was further refined and uploaded onto on the Three Circles of Alemat website. Dr Rana Dajani's video about the PEER project may be accessed at https://www.youtube.com/watch?v=cRA3-XBwBj4.

JORDAN - PROJECT 3-39: ENHANCING WATER EDUCATION AT THE UNIVERSITY LEVEL IN JORDAN BY INCORPORATING AN INNOVATIVE MULTI-AGENT MODELING AND ANALYSIS TOOL

PI: Samer Talozi, Jordan University of Science and Technology
U.S. Partner: Steven M. Gorelick, Stanford University (Funded by the National Science Foundation)
Dates: September 2014 – October 2017

PROJECT OVERVIEW

Adaptation of water resources planning techniques into a class-teaching setting is challenging and requires accurate procedures. Previous water resource studies in Jordan inspected particular hydrologic elements and suggested potential strategies, but before this project there had been no comprehensive water policy evaluation tools. In all previous efforts, representation of the multifaceted institutional environment that constrains interactions among water users, distributors, and managers was either absent or highly generic. The research team of the Jordan University of Science and Technology (JUST) therefore aimed to create a teaching and a training module based on the model produced by the U.S. partner and then to incorporate it into a university course and a training workshop for water professionals. The modules were introduced to the students and water professionals to evaluate and compare a diverse set of short- and long-term water-policy interventions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main developmental target of this PEER project was education. The team aimed to enhance education methods with the utilization of new and sophisticated models and hydroinformatic tools, in order to upgrade courses from merely theoretical content to hands-on application type of courses. Hydroinformatic tools were integrated into the curriculum of GIS and water resources undergraduate classes and a graduate-level course was also created. GIS, SWAT, and WEAP tools were implemented in new educational content thus enhancing and upgrading educational methodology and practice.

The goal to enhance courses with local content in order to create more awareness about water and environmental issues in Jordan was also successfully completed. While most course content is based on international text-book examples and data, the research team designed and created educational content based on local data and experience, thus, enhancing the awareness and experience of students in a local context and issues as previously there was a disconnect between water courses and local water problems and issues. Six modules were designed to cover various geographical areas of Jordan including: the Yarmouk River Basin, the Zarqa River Basin, and the four northern governorates of Jordan, namely Irbid, Jerash, Ajloun, and Mafraq. The modules were also created to cover surface and groundwater issues.

Furthermore, three modules were designed to inform policy and decision makers. The WEAP module was designed to allow students and professionals to run various scenarios, such as population growth or climate change, to allow students to see the role of hydroinformatic tools in guiding and advising sound water policy in Jordan. Two modules, 5 and 6, target groundwater protection and management. Module 5 demonstrated the varying rates of groundwater vulnerability to contamination, thus guiding planning for various land use activities. In module 6, multi-criterion analysis was used to select the optimal location for a landfill. One criterion was to minimize harm to groundwater.

PUBLICATION

Katja Sigel, Christian Klassert, H. Zozmann, Samer Talozi, Bernd Klauer, and Erik Gawel. 2017. Helmholtz-Zentrum für Umweltforschung - UFZ (Ed.): Socioeconomic surveys on private tanker water markets in Jordan: objectives, design and methodology. Leipzig (UFZ Discussion Papers 4/2017). http://nbn-resolving.de/urn:nbn:de:0168-ssoar-52823-3

JORDAN - PROJECT 2-366: OPTIMIZING WATER USAGE OF IRRIGATION SYSTEMS USING WIRELESS SENSOR NETWORKS IN JORDAN

PI: Samer Samarah, with Co-PI Mohammed Ghazi Al-Zamil, Yarmouk University
U.S. Partner: Mehmet Can Vuran, University of Nebraska-Lincoln (Funded by the National Science Foundation)
Dates: August 2013 – November 2015

PROJECT OVERVIEW

Jordan faces a limited supply of water resources, an issue expected to become more significant as the country's population increases. Researchers are looking for practical solutions for water saving in the agriculture sector, of which the largest use is irrigation water. The aim of this PEER project was to develop an automatic irrigation system using a wireless sensor network, collecting readings from different layers of soil to prevent under or overwatering. Deploying sensor nodes capable of determining the field capacity at each layer within a planted field helps to determine the optimal amount of water that should be pumped. The project's wireless sensor network generated data from the field and controlled the irrigation process. The researchers also developed a model to analyze collected data to help understand irrigation patterns and optimize the use of water resources.

The Jordanian researchers collaborated with a partner from the United States who had implemented a similar project previously. Cooperative activities involved exchange visits and the organization of summer workshops at the University of Nebraska for the graduate students working on the project and a workshop at Yarmouk University. The project also developed a website and mobile application with real-time data, summaries, and timely recommendations intended for individuals and institutions interested in irrigation in Jordan.

FINAL SUMMARY OF PROJECT ACTIVITIES

In approaching the project, Dr. Samarah and his colleagues reviewed similar systems across different countries and developed project requirements to match the culture of farmers in Jordan and available resources. Agriculture specialists analyzed available soil, water resources and decided on field design for the project, while a wireless network specialist developed an abstract network design that specified the best places for the sensors in order to communicate with the data logger. The team installed the wireless sensor network and controllers to operate the smart irrigation system and planted the field with tomato crops. Dr. Samarah and his team then used data mining and machine learning techniques to analyze the collected data and extract behavioral patterns that model the automatic irrigation process. They also analyzed data collected from the field to minimize power consumption, prolonging the lifetime of the sensor's battery. A software engineering specialist and a programming student helped design the main website and mobile applications, adding additional services to the app to enhance data visualization and thus better serve both expert and amateur users alike.

The team presented five research papers at international conferences based on their results, focusing on integration of wireless sensor networks with cloud computing infrastructure and concurrency issues that arise as a result of simultaneous interactions among different software components. The papers help support basic technical solutions to the smart irrigation process in Jordan. To further disseminate their work and promote linkages with other PEER-supported researchers, in April 2015 Dr. Samarah and his group also organized the second Jordanian PEER Science workshop jointly with another PEER team from the Jordan University of Science and Technology. As for capacity building, the PEER project provided research opportunities and training for ten undergraduates and three Master's students, and the researchers designed a new syllabus for a special topics course based on Web services created during the lifetime of the project. The course focuses on creating Web services based on mobile applications. The infrastructure at Yarmouk University was also enhanced thanks to PEER-funded equipment, including a new greenhouse, computers, software, and the wireless sensors and data loggers used in the research.

PUBLICATIONS

Samer Samarah. 2015. A Data Predication Model for Integrating Wireless Sensor Networks and Cloud Computing. Procedia Computer Science 52, 1141-1146. https://doi.org/10.1016/j.procs.2015.05.148

Mohammed Gh. Al Zamil. 2015. Verifying Smart Sensory Systems on Cloud Computing Frameworks. Procedia Computer Science 52, 1126-1132. https://doi.org/10.1016/j.procs.2015.05.130

Samer Samarah and Mohammed Al Zamil. 2014. The Application of Wireless Sensor Smart Irrigation Systems in Jordan: Case Study. In Proceedings of ICNGCCT 2014, Dubai, UAE.

Mohammed Al Zamil and Samer Samarah. 2014. The Application of Semantic-based Classification on Big Data. In Proceedings of the 5th International Conference on Information and Communication Systems (ICICS 2014*)*, Jordan.

Mohammed Gh. Al Zamil and Samer Samarah. 2014. Application of Design for Verification to Smart Sensory Systems. In Proceedings of the Qatar Foundation Annual Research Conference, Issue 1, November 2014, Volume 2014, ITPP0366. https://doi.org/10.5339/qfarc.2014.ITPP0366

JORDAN - PROJECT 2-357: EVALUATING CLIMATE CHANGE IMPACTS ON THE ARID LANDS AND WATER RESOURCES IN JORDAN

PI: Yaser Jararweh, Jordan University of Science and Technology
U.S. Partner: George Jenerette, University of California, Riverside (Funded by the National Science Foundation)
Dates: August 2013 – December 2015

PROJECT OVERVIEW

In Jordan, more than 75% of the land is arid or semi-arid, and it is estimated that only 7% of the country's land is arable. Jordan faces many environmental challenges, including limited natural freshwater resources, desertification, and endangered species. These challenges are further compounded by factors such as a rapidly expanding population, industrial pollution, depletion of natural resources, and intermittent unrest. The impacts of climate change are only likely to aggravate the situation further in the future.

This project aimed to design an intelligent system to monitor and track environmental changes in Jordan, evaluating the impact for various regions and classifying them accordingly. The overarching objective of this project is to enhance the capabilities and options for Jordanian government agencies and decision makers to help them better understand and respond to climate change. This includes identifying environmentally threatened regions and resources and proposing immediate reverse actions to prevent possible environmental declines for the other regions. To address these goals, the researchers developed foundations, principles, and metrics to assess vulnerability, impacts, problems, and variations to climate change in the arid and semi-arid lands of Jordan. From these metrics, they built integrated assessment models for the impacts of climate change on arid lands, vegetation, animal species diversity and distribution, water resources, hydrology, land topography, and pollution, as well as human adaptations to these changes. The PEER project also aimed to build an environmental monitoring infrastructure to collect environmental data, to be used with various other data sources such as satellite imagery, sensor networks, pollution statistics, and historical data sets.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers built three sensor networks within different locations inside the Jordan University of Science and Technology (JUST) Campus, with the sites selected in consultation with the U.S. partner during his exchange visit. The sensor nodes were designed and developed through a collaboration between the PEER researchers and a small electronics company in Jordan (including a team of five engineers and designers) with a cost of less than $300 per node, while the price of the same node in the world market was more than $550 at the time of the project. The researchers also collected data from stations managed by the Ministry of Agriculture near the JUST campus to compare with data collected inside. The team also conducted several surveying studies and awareness sessions for climate change at the university level.

Results of the project were presented at several conferences, including the 2014 IEEE/ACS 11th International Conference on Computer Systems and Applications, the IWA Water and Development Congress, Arab-American Frontiers Symposium, and the International IBM Cloud Academy Conference. The PI Dr. Jararweh and his team also worked with JUST, the Royal Scientific Society, and the University of California, Riverside intellectual property team on filing a patent based on the PEER project, entitled "Energy Optimized Design for Networked Environmental Sensors."

On the capacity-building front, the project helped several Master's students to conduct large-scale sensor experiments using sensor stations and led some of them to explore new ideas for their theses. The PEER project has also influenced the curriculum of three graduate level courses taught by the PIs.

PUBLICATIONS

Yaser Jararweh, Mahmoud Al-Ayyoub, Izzat Alsmadi, and Darrel Jenerette. 2015. Climate Change above the Cloud: Accelerating Climate Change Research with Cloud Computing Infrastructure. Proceedings of ICACON 2015: 3rd International IBM Cloud Academy Conference.

Manar Jaradat, Moath Jarrah, Abdelkader Bousselham, Yaser Jararweh, and Mahmoud Al-Ayyoud. 2015. The Internet of Energy: Smart Sensor Networks and Big Data Management for Smart Grid. Procedia Computer Science 56: 592-597. https://doi.org/10.1016/j.procs.2015.07.250

Yaser Jararweh, Ala Darabseh, Mahmoud Al-Ayyoub, Abdelkader Bousselham, Elhadj Benkhelifa. 2015. Software Defined Based Smart Grid Architecture. Proceedings of the Conference: Second International Workshop on Internet of Things, Systems, Management and Security (IoTSMS). https://doi.org/10.1109/AICCSA.2015.7507269

Yaser Jararweh, Izzat Alsmadi, Mahmoud Al-Ayyoub, Darrel Jenerette. 2014. The Analysis of Large-Scale Climate Data: Jordan Case Study. Proceedings of the 11th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA'2014*)*. https://doi.org/10.1109/AICCSA.2014.7073211

JORDAN - PROJECT 1-146: FLOODWAVE PROPAGATION AND INFILTRATION IN DESERT REGIONS: THE AZRAQ BASIN, JORDAN

PI: Mo'ayyad Shawaqfah, Al Al-Bayt University
U.S. Partner: Mark Stone, University of New Mexico (Funded by the National Science Foundation)
Dates: June 2012 – July 2014

PROJECT OVERVIEW

Providing a secure water future for Jordan in the face of rapid population growth and decreasing availability of water will require innovative progress in all aspects of water resource management, including the identification of underutilized resources. This project investigated holistic management of floodwaters in Jordan to better understand how this natural hazard can instead be viewed as a valuable natural resource.

A combination of modeling exercises and field observations were used to advance the application of knowledge for this critical issue. This project assisted Al al-Bayt University in its efforts to build its water resources research and outreach capabilities. A broader training component was also included, with approximately 100 water resources professionals benefitting from the outreach and dissemination activities.

FINAL SUMMARY OF PROJECT ACTIVITIES

Data collected by the research team was used to produce two coupled models—one describing flood wave movement from storm events and a second investigating baseline and potential enhancements to infiltration and groundwater recharge. The team prepared three papers as part of their findings and participated in the Global Conference on Energy Soil, Water, Air and Environment, held in Antalya, Turkey.

The PEER project team held technical workshops to share results and presentations on water resources and groundwater recharge for various stakeholders. In addition, a short course on groundwater recharge was organized for six undergraduate and two graduate students. The course covered well recharge types, objectives, water sources, and wellhead and wellfield designs. It also examined aquifer storage recovery (ASR) systems in aquifers with either freshwater or impaired groundwater. Instructors led the participants through the planning, design, operation, and management phases of artificial recharge systems. Team members also attended a groundwater modeling course in the United Arab Emirates.

The team continued to gather new sets of data and developed a new course entitled “Applied Groundwater Modeling,” which was offered by the Civil Engineering Department at Al al-Bayt University. They also met the community in the local study area several times and shared results of the project with them.

PUBLICATIONS

M. Shawaqfah, I. Alqdah, and O.K. Nusier. 2015. Water Resources Management Using Modeling Tools in Desert Regions: The Azraq Basin, Jordan. International Journal of Modeling and Optimization 5(1):55-58. https://doi.org/10.7763/IJMO.2015.V5.436

Moayyad S. Shawaqfah and Ibtihal T. Alqdah. 2014. Modeling the Flash Flood and Infiltration in Desert Regions: The Azraq Basin, Jordan. In: SimHydro 2014. New Trends in Simulation. 11-13 June 2014 Ecole Polytech' Nice (France). https://www.persee.fr/doc/jhydr_0000-0001_2014_act_36_1_2336

LEBANON

LEBANON - PROJECT 9-331: ASSESSMENT OF THE RESILIENCE OF LOCAL BALADI GOAT IN LEBANON: A VIABLE SUSTAINABLE SOLUTION TO A CHANGING CLIMATE IN A TRANSHUMANT SYSTEM

PI: Pauline Aad, Notre Dame University
U.S. Partner: Joan Burke, United States Department of Agriculture/Agricultural Research Service (Funded by USDA/ARS
Dates: May 2021 – January 2024

PROJECT OVERVIEW

The Baladi goat, an alpine-type, highly resilient animal, is managed in a pastoral transhumant system in Lebanon, traveling long distances in cold, wet winters or hot, dry summers. Some rangelands could harbor pathological parasites that infect goats, while other rangeland environments may have plants with secondary compounds that mitigate parasite infection. However, these plants could have detrimental effects on the animal, reducing feed intake, inducing nutritional deficiencies, and triggering neurologic effects.

The Lebanese rangeland needs to be further assessed for the presence of such compounds and their impacts on the grazing patterns of the Baladi goat. Therefore, this PEER project sought to analyze the resilience of Baladi goats to environmental changes, food stress, and challenges. The overarching research goal was to determine the best management strategies for optimal milk production, natural treatment of parasites, and improved reproductive efficiency, as well as possible markers for selection of resilient goats in the transhumant system. The project team also established extension services in collaboration with their local governmental collaborator, the Lebanese Agricultural Research Institute (LARI), as well as local transhumant communities and the private agro-farming sector. Farmers were able to observe firsthand the impact and level of parasite infestation, as well as receive brucellosis testing for their livestock, a service that was instrumental in breeding planning.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers studied the prevalence of helminth parasites in 90 Baladi goats raised under three different management systems: intensive/managed, extensive/pastoral, and semi-intensive/agro-pastoral. During two summer periods of heat stress, the researchers recorded various data points for each system, including an assessment of fat and muscle levels, anemic state, nostril discharge, stool character, and bottle jaw edema. The PEER team also collected fecal samples to analyze for fecal nematode eggs and protozoan oocyte count.

The results showed that the goats' body condition was not altered between heat stress periods, but decreased in intensively managed flocks due to the lack of availability of high quality feed. Anemic state did not differ. All fecal samples tested showed HOTC (*Haemonchus, Ostertagia, Trichostrongylus*, and *Cooperia* complex) egg-type nematodes, while 98% showed *Eimeria spp*. with the occasional occurrence of *Skrjabinema* nematodes and *Moniezia* tapeworms. The parasitic burden of HOTC was low at 17 % of total FEC, while high for *Eimeria* at 98% for all management systems.

Though the effect of summer heat stress was not obvious on endoparasite prevalence in Lebanese Baladi goats, the confounding effects of resilience to gastrointestinal nematodes, nutritional stress, and heat stress in these locally resilient goats require further investigation.

In the following year, the researchers screened for these parasites year-round in the same flocks, as well as for parasite prevalence across various Lebanese regions, including Bekaa, North Lebanon, Akkar, Mount-Lebanon, and Kesrouan. They sampled blood from 300 goats to genotype for parasite resilience. The findings showed low to medium prevalence and a high genotype variability in Lebanese Baladi goats. The team also undertook fat analysis of goat milk, which showed effects from lactation and management-style on fatty acids. Further investigation is required to select one or two important traits to be adopted by farmers for genetic improvement.

The PEER team held an event on the increasing threat presented by goat parasites in a changing climate in May 2022 and hosted a genomic analysis workshop in July 2023 attended by 15 participants. The PI also attended a LibanVet-organized conference on the utility of genomic data in large dairy farms and presented briefly on the PEER project.

As for capacity building, the project team also trained many graduate students from the various agricultural schools in Lebanon who are now working as extension specialists, supporting farmers in their development. The researchers also received four additional grants worth $41,000 total for related and other work and built a technical guide for farmers and for technicians on parasite analysis in both Arabic and English.

PUBLICATIONS

L.F. Schütz, A.M. Hemple, B.C. Morrell, N.B. Schreiber, J.N. Gilliam, C. Cortinovis, M.L. Totty, F. Caloni, P.Y. Aad, and L.J. Spicer. 2022. Changes in fibroblast growth factor receptors-1c, -2c, -3c, and -4 mRNA in granulosa and theca cells during ovarian follicular growth in dairy cattle. Domestic Animal Endocrinology 80: 106712. https://doi.org/10.1016/j.domaniend.2022.106712

L.J. Spicer, L.F. Schütz, and P.Y. Aad. 2021. Effects of bone morphogenetic protein 4, gremlin, and connective tissue growth factor on estradiol and progesterone production by bovine granulosa cells. Journal of Animal Science 99 (11): skab 318. https://doi.org/10.1093/jas/skab318

LEBANON - PROJECT 7-101: ADVANCING ANAEROBIC DIGESTION IN THE UPPER LITANI BASIN FOR INDUSTRIAL WASTEWATER TREATMENT

PI: Mahmoud Wazne, Lebanese American University
U.S. Partner: Haluk Beyenal, Washington State University (Funded by the National Science Foundation)
Dates: January 2019 – December 2022

PROJECT OVERVIEW

This PEER project sought to advance the use of anaerobic digestion in the upper Litani basin in Lebanon to improve treatment for organic industrial wastewater discharge. The researchers demonstrated the applicability of anaerobic digestion and tested co-digestion of combined waste streams. While mono-digestion (using a single substrate) may fail or achieve low yield, co-digestion of wastewater from multiple industries can provide a balance in substrate nutrients. Co-digestion of combined waste streams can also provide potential collaborative treatment modalities among the industrial wastewater generators resulting in the reduction of the required capital cost.

Dr. Wazne and his team also enhanced anaerobic digestion treatment performance with a newly developed, integrated, bio-electrochemical reactor technology, building on complementary expertise of the PEER team and the U.S. partner. The project involved undergraduate and graduate students and prepared them for careers in fields associated with anaerobic digestion treatment.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers conducted mono-digestion and co-digestion batch experiments using field-collected samples of whey, canned food, and poultry slaughterhouse wastewaters. The co-digestion experiments resulted in improved methane yield, likely due to the complementary characteristics of the wastewaters, which aided in balancing the anaerobic digestion process. Co-digestion also helped achieve greater biodegradability, reaching a level of approximately 84%.

The PEER team also undertook two bioelectrochemical enrichment experiments to improve the performance of the upflow anaerobic sludge blanket (UASB) reactors, one as a control and the other one using enriched microorganisms. The enriched UASB (UASB-E) yielded higher volumetric daily methane production and methane yield and resulted in significant removal of oxidizable pollutants. Observable methane production was noticed almost immediately in UASB-E compared with the control run (UASB-C). Furthermore, the enriched UASB run achieved stable chemical oxygen demand (COD) removal (85% total and soluble COD removal) in a shorter period of time as compared with a control run.

Both of the digestion experiments were published as part of a journal article, and the PI gave a presentation on his project at the 17th World Conference on Anaerobic Digestion held in June 2022 at the University of Michigan. The PEER team also organized two workshops to raise awareness about the applicability of anaerobic digestions for the treatment of industrial wastewaters, which were attended by about 100 people. Overall, the PEER project built research capacity in the fields of anaerobic digestion and bioelectrochemistry at Lebanese American University, helped support two graduate students in their work on anaerobic digestion, and provided training for several other graduate and undergraduate students, research assistants, and a postdoc. The PI also developed a new graduate course titled Environmental Water Chemistry to provide students with advanced training pertaining to environmental engineering.

As for the future, based on the published results demonstrating the applicability of anaerobic digestion for the treatment of industrial wastewater discharge in the upper Litani basin, Dr. Wazne reports that private industry has shown interest in application of the technology. The next step would be moving the technology from the lab to pilot-plant scale.

PUBLICATION

M. Abdallah, S. Greige, H. Beyenal, M. Harb, and M. Wazne. 2022. Investigating microbial dynamics and potential advantages of anaerobic co-digestion of cheese whey and poultry slaughterhouse wastewaters. Scientific Reports 12: 10529. https://doi.org/10.1038/s41598-022-14425-1

LEBANON - PROJECT 5-56: HAZARDOUS EFFECT OF POLLUTANTS IN DEIR KANOUN DUMP ON THE SYRIAN REFUGEES AND THE LEBANESE PEOPLE

PI: Jamila Borjac, Beirut Arab University
U.S. Partner: Diane Blake, Tulane University (Funded by the National Institutes of Health)
Dates: December 2016 – June 2019

PROJECT OVERVIEW

The aims of this project were to identify chemical and microbiological pollutants present in Deir Kanoun Ras el Ein dump that are leaking into surrounding soil and water and then to assess their hazardous effect on the Syrian and Lebanese people living in that area. Cancer and respiratory, skin, and other diseases are occurring at an increasing rate in that area, which covers more than ten villages. Water from this dump leaks into a canal that irrigates a large agricultural area. Identification of these pollutants, both chemical and microbiological, should contribute to finding a solution to protect the people living in the area. Using various advanced analytical chemistry techniques, the researchers focused on identifying the toxic metals and cancer-inducing chemicals deposited into the dump by factories. Microbiological techniques were also used to identify the types of microorganisms growing in the dump, and clinical and biochemical techniques were applied to analyze the extent of health damage suffered by people living near the dump. The ultimate goal was to document the comprehensive environmental and health impacts of the dump and then find a solution to eliminate the health-damaging effects on local residents. This project linked university students, many of them female, to social problems, especially in rural regions.

FINAL SUMMARY OF PROJECT ACTIVITIES

Throughout the project, the research team was successful in several areas, including the following:

1. **Identification of microbial contaminants in studied samples from leachates and canal water**. *Enterobacter, Serratia, Shigella, Citrobacter, Bacilli, Vibrio, Klebsiella*, and *Escherichia* species were among the identified bacteria. Extending along the canal, a significant increase in bacterial count was noticed due to anthropogenic activities rather than due to the dump's leachates.

2. **Assessment of the levels of organic pollutants and heavy metal in collected samples.** The results revealed that water samples collected from dump and canal were heavily polluted by Cd, As, Hg, phthalates, bisphenol A, and PAHs caused by pyrogenic and petrogenic sources. The concentrations of the found heavy metals were far above the maximum tolerable levels set by different guidelines. The findings suggest that the studied water sources are not safe neither for irrigation or drinking and have serious implications on the health of inhabitants both the Lebanese and the Syrian refugees.

3. **Determination of levels of some heavy metals and organic compounds in different soil samples collected from the dump and along the canal**. The results confirm high levels of contamination in the collected soil samples by both heavy metals and organic compounds. The levels of heavy metals also

exceeded the average maximum permissible levels for sewage sludge and agricultural land. These findings suggest the need for mitigation measures by the Lebanese authorities for new and efficient waste management programs to resolve the problems associated with uncontrolled dumping of solid wastes in Lebanon.

4. **Investigation of the effect of pollutants on the oral and dental health of the Lebanese and Syrian refugees living in proximity of the dump**. Results highlighted the prevalence of several oral and dental diseases among Lebanese and Syrian inhabitants that are related to environmental, social, and economic determinants and not just by individual behaviors. It also showed gaps of oral and dental health knowledge that recommend implementing health systems that focus on preventing oral diseases.

5. **Investigation of the associations of living in the studied polluted area and the abnormal trends of cell blood count parameters**. This component of the study emphasized the damaging effect of Deir Kanoun Dump on all inhabitants of the surrounding region, and on this basis the researchers called for immediate intervention from the Lebanese government to find solutions. Results showed abnormal levels of many blood parameters indicating hematological disorders such as anemia, infections, allergy, and inflammation. Similar trends of abnormal CBC parameters were observed among the three villages. The highest percentage of abnormal erythrocyte parameters was found in Klayleh, while for leukocyte parameters, the highest was in Smaiyeh. Significant differences were observed between sexes and nationalities, which may be associated with low income, environmental pollution and poor hygiene.

6. **Delivery of seminars in three schools and the villages to encourage students and inhabitants to recycle and sort at the source**. The team encouraged school students in the area studied to think about problems associated with pollution and its effect of their health and to learn the importance of their acts on their society. The aim was to make these inhabitants actively involved with their society and minimize unnecessary dumping.

7. **Engagement of undergraduate and graduate students in diverse activities related to the project both at the social and research levels**. A large number of students were involved and gained experience in the tasks they were assigned. Many still follow up with the PI to see if they can be involved in additional projects.

PUBLICATIONS

Jamilah Borjac, Manal El Joumaa, Lobna Youssef, Rawan Kawach, and Diane A. Blake. 2020. Hindawi the Scientific World Journal 2020: Article ID 8151676. https://doi.org/10.1155/2020/8151676

Jamilah Borjac, Manal El Joumaa, Mohamad Darwiche, and Diane Blake. 2020. Hematological Parameters of Lebanese and Syrian Refugees Living in Proximity of Deir Kanoun Ras El Ain Dump in Lebanon. BAU Journal - Health and Wellbeing: 3(1): article 4. https://doi.org/10.54729/2789-8288.1049

Jamilah Borjac, Manal El Joumaa, Rawan Kawach, Lobna Youssef, and Diane A. Blake. 2019. Heavy metals and organic compounds contamination in leachates collected from Deir Kanoun Ras El Ain dump and its adjacent canal in South Lebanon. Heliyon 5: e02212. https://doi.org/10.1016/j.heliyon.2019.e02212

J. Borjac, S. Badr, M. ElJoumaa, I. Daas, and R. Kobeissi. 2019. Oral and dental status of Lebanese and Syrian refugees living in proximity to Deir Kanoun Ras El Ain dump in Lebanon. Journal of the International Society of Preventive and Community Dentistry 9:409-16. https://doi.org/10.4103/jispcd.JISPCD_214_19

Jamilah Borjac, Mariam Shaheen, Mohammad Nsaif, Sara Abou Khalil, and Diane A. Blake. 2018. Bacterial Analysis of Dump Leachates and Irrigation Water from a Canal in Deir Kanoun Ras El Ain in Lebanon. Poll Res. 37 (4): 886-893.

LEBANON - PROJECT 5-18: ENHANCING WATER QUALITY MONITORING AND IMPROVING WATER DISINFECTION PROCESSES IN LEBANON

PI: Antoine Ghauch, American University of Beirut
U.S. Partner: David Sedlak, University of California, Berkeley (Funded by the National Science Foundation)
Dates: December 2016 – November 2021

PROJECT OVERVIEW

Relative to its neighbors, Lebanon has often been considered as a water-rich country. Unfortunately, the combined effects of climate change, population growth, and infrastructure underinvestment are creating considerable water stress in Lebanese cities. Specifically, an extended drought coupled with increased water demands from the arrival of large numbers of Syrian refugees is increasing the potential for water supply problems and degradation of water quality. International support for capacity building came first from USAID, which funded three municipal wastewater treatment plants to serve the population in the Beqaa and rehabilitated the main water establishments in the country by improving existing infrastructures. These efforts improved water quality, but significant unmet needs still remained. Development of existing but underdeveloped and new water resources would require consideration of the potential impacts of water pollution due to chemical contaminants and infectious disease pathogens. Currently, a lack of inexpensive water quality monitoring tools and the absence of advanced treatment technologies for industrial waste, hospital effluents, solid waste leachates, and municipal wastewater limit Lebanon's ability to respond to challenges posed by water pollution.

This project was designed to improve water technologies and expand local capacity to monitor organic contaminants (OCs) and eradicate pathogenic bacteria in drinking water supplies. Previously, the research team received a PEER Cycle 1 award to investigate the use of activated persulfate (PS) to degrade trace concentrations of OCs in wastewater and water supplies. Dr. Ghauch and his colleagues also developed a room-temperature phosphorimeter (RTP) capable of detecting special dyes used for verifying the authenticity of official papers such as banknotes. The first generation RTP was used for this application because it lacked the sensitivity needed to detect low concentrations of chemicals with low phosphorescence yields. In this new PEER Cycle 5 project, the team worked to develop an innovative instrument to detect trace amounts of OCs in water by using a solid surface to pre-concentrate the OCs. After verifying its accuracy and precision, they used this new instrument to assess the performance of different types of water treatment systems and to monitor some OCs in Lebanese waterways that pose potential health risks (for example, polycyclic aromatic hydrocarbons produced by cars and solid waste incineration). Experience obtained from studies with the new apparatus and different types of treatment systems was used to develop a miniaturized prototype of the RTP, with the main goal of creating an inexpensive, robust sensor for monitoring trace OCs and the performance of water treatment systems.

FINAL SUMMARY OF PROJECT ACTIVITIES

During the five years of the project (2016-2021), the research outcomes exceeded all expectations at many levels. Below are the main achievements in terms of impacts on research development, student and faculty career progress, and benefits to society:

1. Capacity Building

PI Ghauch's laboratory benefited from exceptional capacity building by purchasing standard analytical heavy instruments necessary to sustain research development within WASH topics such as chromatography, including COD and BOD analyzers along with spectrometers. Moreover, a very advanced iCCD detector was acquired for the detection of very low signals emitted by water pollutants upon excitation with UV light. This innovative piece of equipment allowed the team to create a new instrument with its autosampler fully developed in house. The apparatus is versatile, and the team can build on new ideas to make it more performant by changing in the excitation source, the sample holder, and the acquisition time to tackle species having very low lifetime under UV excitation.

2. Student Training

Many undergraduate and graduate students received training on cutting edge chromatography techniques with high sensitivity detection using diode array detectors for absorbance measurements and photomultiplier for fluorescence measurements. The laboratory became one of the most solicited laboratories by graduate students asking to perform research and prepare their Master's degrees. Moreover, students who worked on the project received many awards from both AUB and internationally after obtaining PhDs in North America. The rate of acceptance of project students for PhDs abroad was 100% based on their record as attested by the peer-reviewed publications they co-authored with the PI in international high impact journals such as *Chemical Engineering Journal* (IF 12.312).

3. International Recognition

The latest worldwide classification of researchers across the globe by Stanford University at California placed PI Ghauch at the top 2% of cited researchers in the field of environmental sciences. This classification was entirely based on the publications that emerged from PEER projects since 2012 (PEER 1-84 and PEER 5-18). Many of these papers received the label of highly cited papers as per Clarivate Web of Science putting them at top 1% in their field. Results were published in more than 10 papers in specialized high impact journals. PEER results were disseminated at more than 10 international conferences mainly the National Meetings of the American Chemical Society. Moreover, PEER results were also presented in local and regional conferences and symposia such as the Arab-American Frontiers, a program developed and implemented by the National Academy of Sciences, Engineering and Medicine for the Arab countries.

4. Impactful Research Topic

The PI addressed a very important issue not yet solved in Lebanon about industrial wastewater. The results obtained on actual industrial effluents showed high potential for decontamination at low cost. The advanced oxidation technology developed and based on persulfate chemistry was validated and promoted across end users and funding agencies. This facilitated the obtainment of additional grants such as the Stakeholder Analysis and Stakeholder Engagement Plan funded by USAID through RTAC. This grant was crucial to draw a road map for the PI in order to better implement PEER outcomes. Moreover, the PI received the support of USAID through MEPI TLP Tomorrow's Leaders College to

Work Pipeline program. This grant is under implementation and will produce a demonstration prototype serving as minimum viable product to be considered by stakeholders for potential funding toward scaling up.

5. Stakeholder Attraction

The PEER award was a catalyst for stakeholder attraction because of the excellent outcomes of the hot topics addressed, such as the improvement of the quality of drinking water through preservation and decontamination. Moreover, the counterfeiting detection topic attracted a large audience in view of its application at large scale to solve the problem of corruption in Lebanon and other countries around the world.

PUBLICATIONS

Suha Al Hakim, Saly Jaber, Nagham Zein Eddine, Abbas Baalbaki, and Antoine Ghauch. 2020. Degradation of theophylline in a UV_{254}/PS system: Matrix effect and application to a factory effluent. Chemical Engineering Journal 380: 122478. https://doi.org/10.1016/j.cej.2019.122478

O. Tantawi, A. Baalbaki, R. El Asmar, R., and A. Ghauch. 2019. A rapid and economical method for the quantification of hydrogen peroxide (H_2O_2) using a modified HPLC apparatus. Science of The Total Environment 654: 107–117. https://doi.org/10.1016/j.scitotenv.2018.10.372

Maya Amasha, Abbas Baalbaki, and Antoine Ghauch. 2018. A comparative study of the common persulfate activation techniques for the complete degradation of an NSAID: The case of ketoprofen. Chemical Engineering Journal 350: 395-410. https://doi.org/10.1016/j.cej.2018.05.118

Abbas Baalbaki, Nagham Zein Eddine, Saly Jaber, Maya Amasha, and Antoine Ghauch. 2018. Rapid quantification of persulfate in aqueous systems using a modified HPLC unit. Talanta 178: 237-245. http://dx.doi.org/10.1016/j.talanta.2017.09.036

Maya Amasha, Abbas Baalbaki, Suha Al Hakim, Rime El Asmar, and Antoine Ghauch. 2018. Degradation of a Toxic Molecule o-Toluidine in Industrial Effluents using UV_{254} / PS System. Journal of Advanced Oxidative Technologies 21(1). https://doi.org/10.26802/jaots.2017.0099

Antoine Ghauch, Abbas Baalbaki, Maya Amasha, Rime El Asmar, and Omar Tantawi. 2017. Contribution of persulfate in UV-254 nm activated systems for complete degradation of chloramphenicol antibiotic in water. Chemical Engineering Journal 317: 1012-1025. http://dx.doi.org/10.1016/j.cej.2017.02.133

Antoine Ghauch. 2017. Editorial: The importance of advanced oxidation processes in degrading persistent pollutants. Journal of Advanced Oxidative Technologies 2017: 20160197. https://doi.org/10.1515/jaots-2016-0197

LEBANON - PROJECT 4-270: LANDSLIDE RISK INDEX MAPPING FOR LEBANON

PI: Grace Abou-Jaoude, Lebanese American University
U.S. Partner: Joseph Wartman, University of Washington (Funded by the National Science Foundation)
Dates: October 2015 – March 2017

PROJECT OVERVIEW

Landslides threats have traditionally been considered in the context of hazard (the likelihood or annual frequency of occurrence) rather than risk, which is a function of both hazard and the resulting consequences. This project aimed to develop risk-based landslide maps, thus advancing the state of the practice in regional-scale landslide assessment. Products from the U.S. Government-supported partner's work on landslide vulnerability were applied in this international collaborative effort. Specifically, the research team worked to quantify the effects of landslide damages on residential and commercial structures based on the outcomes of the U.S. partner's research. These include the fragility relationships relating landslide characteristics to building, community, and infrastructure damage, as well as risks to life-safety. Modifications were made to these vulnerability characteristics as appropriate for building styles and construction practices in Lebanon. This research represented the first time these techniques were applied over regional scales in Lebanon using spatial databases of geology, topography, and building styles.

FINAL SUMMARY OF PROJECT ACTIVITIES

Building upon a previous PEER grant, the research team developed comprehensive landslide risk index maps in Lebanon to identify areas with high risks of human loss and infrastructure damage associated with rainfall and earthquake-induced landslides. The landslide risk index was based on a multi-modal approach, decided in collaboration with the U.S. partner and his team, to assess landslide impacts on structures and identify elements at risk.The project was important on a national scale to reduce and mitigate disaster risks. The results can ultimately be used to properly manage urban growth away from the identified critical zones**.**

After an extensive literature review, the two teams settled on research methodologies to assess hazards from rock falls, debris flows, and sliding. Hazard maps identifying falling rock and debris flow hazards were generated by the team at Lebanon American University, specifically research assistant Miriam Tawk. The team evaluated risk by identifying elements exposed in susceptible areas, including demographic and socio-economic factors. The research team also identified three main types of areas at risk: the road network, urbanized areas within villages, and informal settlements. The main occupants of the informal settlements are Syrian refugees and field visits by the PEER team clearly showed these settlements are at very high risk in the event of any natural disaster.

The Lebanese and U.S. research teams met twice across the grant period, including when the University of Washington team came to Lebanon. During the UW team's visit, they participated in a second PEER project workshop and joined ground-truthing visits in two areas where the project predicted high hazards and risks. The field visits confirmed many of the predicted locations.

The PEER project team's dissemination workshop was well attended by government officials, faculty, students, and practitioners. Among the participants were representatives from the National Disaster Risk Reduction and Management Unit, the Order of Engineers and Architects, the National Research Council, the Civil Defense, and the Council for Development and Reconstruction.

The researchers also collaborated with the RUMMARE team, part of the National Research Council, to conduct work related to mass movement hazards and risks in Lebanon. The sub-committee on landslide hazards at the Lebanese Parliament has expressed interest in the results of the work. A representative from the Disaster and Risk Management Unit in Lebanon showed high interest in the developed maps to help them identify the villages that are prone to the highest landslide risks and take the necessary mitigation actions**.**

PUBLICATIONS

A. Grant, J. Wartman, G. Abou-Jaoude. 2016. Multi-Modal Method for Coseismic Landslide Hazard Assessment. *Engineering Geology* 212: 146-160. https://doi.org/10.1016/j.enggeo.2016.08.005

A. Saade, G. Abou-Jaoude, and J. Wartman. 2016. Regional-scale co-seismic landslide assessment using limit equilibrium analysis. *Engineering Geology* 204: 53-64. https://doi.org/10.1016/j.enggeo.2016.02.004

LEBANON - PROJECT 3-26: ASSESSMENT OF REAL EVAPOTRANSPIRATION AND RECHARGE PROCESSES ON TWO KARST PILOT GROUNDWATER CATCHMENTS (LEBANON) USING AN INTEGRATED SPATIALLY DISTRIBUTED NUMERICAL MODEL: APPLICATIONS FOR WATER RESOURCES MANAGEMENT PURPOSES

PI: Joanna Doummar, American University of Beirut
U.S. Partner: Jason G. Gurdak, San Francisco State University (Funded by the National Science Foundation)
Dates: September 2014 – December 2018

PROJECT OVERVIEW

About 25% of the freshwater worldwide originates from karst aquifers. These aquifers are a source of a very important supply but are also highly heterogeneous. They are characterized by a duality of recharge and flow, which directly influences the groundwater flow and spring responses. Given this heterogeneity in flow and infiltration, karst aquifers are very difficult to conceptualize, as they do not always obey standard hydraulic laws. Estimates of real evapotranspiration and recharge to aquifers are needed in the computation of the water balance of an aquifer catchment area. Karst aquifers are the predominant type of aquifer in Lebanon, and an accurate estimation of input parameters (recharge, real evapotranspiration) in catchment areas is not available for the appropriate assessment of groundwater resources at a national level. Prior to this project, only a few groundwater-distributed/lumped numerical models had been done on selected catchments in Lebanon due to the scarcity of data and the difficulty in simulating highly heterogeneous karst aquifers.

This project aimed to estimate real evapotranspiration and recharge on karst aquifers and validate it using numerical simulation using physical data, with experimental sites set up in Lebanon for water quantity and quality monitoring and used as pilot areas for further studies. This study set the ground for delineating recharge areas and identifying zones of high vulnerability to contamination, and consequently, enabling establishment of adequate measures for water protection and management.

FINAL SUMMARY OF PROJECT ACTIVITIES

The objective of the project was to set up two pilot areas and conduct high-resolution, long-term monitoring for research and water supply purposes. The data collected over the four years throughout the project on two pilot areas was used to simulate flow in an integrated numerical distributed and semi-distributed models and to understand flow mechanisms in the system and predict future flow at the spring under varying climatic scenarios. The final objective was to conduct detailed sensitivity analysis on key-vulnerability parameters and refine the weights attributed to them in qualitative vulnerability mapping methods.

The PEER project provided the opportunity to set up a hydrogeological division at AUB, and students benefited greatly from this experience. Students who have graduated after being involved in this project have succeeded in landing jobs in engineering or hydrological firms. Applied materials from two courses, GEOL318 and GEOL330K (hydrogeology and hydrology of fractured and karst rocks) taught in several semesters at AUB, were based on this research project. The applications included in a new graduate course (Applied methods in hydrogeology: GEOL 330I) were mainly related to the pilot sites of this project as well.

In terms of potential development impacts, the developed integrated hydrological model could be presented to decision makers as a tool to forecast needs for alternative water supply resources for the future, in the face of climate change conditions and increasing urbanization.

To ensure implementation of this project and its continuity, during the last months of the project, the PEER team: (1) finalized and validated the vulnerability assessment; (2) collected and processed data from the monitoring network, as well as updated the models with new data; (3) refined the catchment characterization, especially the parameters playing a role in model output and vulnerability. (4) used the results of the vulnerability study to tailor guidelines for groundwater catchment protection in karst system for Lebanon; and (5) convened a dissemination workshop with the municipalities of Bikfaya and Kfarzebbiane and various water establishment stakeholders to increase awareness in terms of water quality and quantities.

PUBLICATIONS

J. Doummar, A. Kassem, and J. Gurdak. 2018. Impact of historic and future climate on spring recharge and discharge based on an integrated numerical modelling approach: Application on a snow-governed semi-arid karst catchment area. Journal of Hydrology 565: 636-649. https://doi.org/10.1016/j.jhydrol.2018.08.062.

J. Doummar and M. Aoun, 2018. Assessment of the origin and transport of four selected emerging micropollutants sucralose, Acesulfame-K, gemfibrozil, and iohexol in a karst spring during a multi-event spring response. Journal of Contaminant Hydrology 215: 11-20. https://doi.org/10.1016/j.jconhyd.2018.06.003

J. Doummar and M. Aoun. 2018. Occurrence of selected domestic and hospital emerging micropollutants on a rural surface water basin linked to a groundwater karst catchment. Journal of Environmental Sciences 77: 351. https://doi.org/10.1007/s12665-018-7536-x

E. Dubois, J. Doummar, S. Pistre, and M. Larocque. 2020. Calibration of a lumped karst system model and application to the Qachqouch karst spring (Lebanon) under climate change conditions, Hydrology and Earth Systems Science 24(9): 4275–4290. https://doi.org/10.5194/hess-24-4275-2020

LEBANON - PROJECT 2-514: HEALTH ASSESSMENT OF EARTH DAMS IN LEBANON: TOWARDS SUSTAINABLE DEVELOPMENT

PI: Naji N. Khoury, Notre Dame University-Louaize
U.S. Partner: Michael A. Mooney, Colorado School of Mines (Funded by the National Science Foundation)
Dates: August 2013 – October 2016

PROJECT OVERVIEW

The PEER project team studied earth dams in Lebanon in order to advance scientific and applied knowledge about best practices for building and monitoring earth dams, including identifying deficiencies through visual inspection, using geophysical techniques to monitor their integrity, and modeling internal erosion using a support vector machine. The researchers developed models to help predict the performance and health of earth dams and add to existing models on the erosion characteristics of soils. In addition to the research work, the program recruited and mentored high school and undergraduate students, particularly women and persons with disabilities, to help them gain experience in engineering research and sustainable practices in civil engineering. Other educational components of this project gave remote communities access to information about building and maintaining earth dams.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team visually inspected more than 20 dams for deficiencies and found many of them to be deficient. They also undertook soil studies to determine which types of soils are best for constructing earth dams and to develop a database on the physical and engineering properties, hydraulic characteristics, and erodibility indices of more than twenty soils. Dr. Khoury and his group then used geophysical techniques to assess two dams and monitor their health. One dam had a potential seepage zone, and the results showed that electrical resistivity was a good technique for detecting anomalies in earth dams.

The team modeled internal erosion of earth dams using a support vector machine and finite element methods. Among the analyses of the dams were internal erosion evolution and erodibility indices of soils. Development of these models helped predict the performance and health of earth dams and adds to existing models on the erosion characteristics of soils.

This PEER project recruited 14 undergraduate research assistants (URAs) to be involved in this project as an educational and mentoring project, and they carried out the various tasks described in the research plan under the supervision of the PI Dr. Khoury. The URAs assisted in submitting manuscripts for possible publication and presentation at national and international conferences, including one paper published by a URA. Three high school students (HRAs) were also recruited through events at NDU organized by the Office of Admissions. The HRAs spent one summer in the PI's lab working closely with the undergraduate students and the PI's research team.

The PEER team developed “Engineering Their Future," a program to introduce high school students and persons with disabilities to sustainable practices in civil engineering. Participants visited the PI’s laboratory during the academic year for a series of hands-on lessons about earth dams, laboratory testing of electrical resistivity and erosion. The team sought to expose students to civil engineering practices, in particular sustainable engineering in a fun and exciting format to encourage them to pursue a degree in engineering. They also developed a series of interactive workshops on sustainable engineering for the public. Students presented their research and laboratory activities, and the wider team discussed deteriorating infrastructure and possible solutions to these problems. The workshops reached remote communities, including the Hasroun and Shouf areas.

Soil mechanics and engineering design courses at the university were modified to incorporate competition-like projects on the sustainable design of earth dams. The PI presented results of the project at GeoAmericas 2016 Miami in April. While in the United States, he also received training on recently purchased Multichannel Analysis of Surface Waves (MASW) and Audio Magnetotellurics (AMT) devices.

PUBLICATIONS

Yara Maalouf, Grégory Bièvre, Christophe Voisin, and Naji Khoury. 2022. Geophysical monitoring of a laboratory-scale internal erosion experiment. Near Surface Geophysics 20: 365–383. https://doi.org/10.1002/nsg.12215

Yara S. Maalouf and Naji N. Khoury. 2016. The use of geo-electrical and geotechnical techniques to assess a small earth dam in remote areas. Proceedings of Geo-Chicago 2016, Chicago, Illinois, August 14-18, 2016. Track C45.

Yara Maalouf and Naji Khoury. 2016. Use of MASW and electrical resistivity in assessing a small earth dam in remote area. Proceedings of the 3rd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA), Zouk Mosbeh, Lebanon, July 13-15, 2016. https://doi.org/10.1109/ACTEA.2016.7560116

LEBANON - PROJECT 1-228: ASSESSMENT OF THE TROPOSPHERIC HONO BUDGET: INSTRUMENTAL DEVELOPMENT AND FIELD MEASUREMENTS

PI: Charbel Afif, Université Saint Joseph de Beyrouth

U.S. Partner: Sebastien Dusanter, University of Indiana (Funded by the National Science Foundation)

Dates: June 2012 – May 2014

PROJECT OVERVIEW

Climate change is one of the most important environmental concerns of the 21st century, and reliable climate projections will depend on how well models of atmospheric chemistry can forecast concentrations of greenhouse gases, whose lifetimes depend on the global concentration of the hydroxyl (OH) radical. Recent studies focusing on the chemistry of nitrous acid (HONO), an important source of the OH radical, indicate that model-predicted concentrations of HONO do not agree with field measurements performed in various environments (urban, rural, forests, etc.). These results suggest that our understanding of HONO chemistry is incomplete and call into question our ability to model the atmospheric oxidative capacity and therefore our ability to predict future changes in the atmosphere.

This project supported construction of a reliable NitroMAC instrument at the Université Saint Joseph de Beyrouth (USJ) to measure atmospheric HONO concentrations. The principal investigator and the U.S. partner gathered data during field campaigns in both countries. Furthermore, the project initiated air quality studies in Lebanon and will help promote the development of efficient strategies for pollution control.

FINAL SUMMARY OF PROJECT ACTIVITIES

In the first phase of the project, the PI and team built and customized their NitroMAC system, designing it specifically for portability and shorter sampling time for field campaigns. The researchers and team met with the U.S. partners in Indiana to share knowledge and prepare for their respective field samplings. The PI undertook a field campaign with the U.S. partner, measuring HONO, NO_x and ozone for several days near the Indiana University Golf course.

The team purchased NO_x and CO_2 analyzers and shipped the NitroMAC back to Lebanon to analyze the data collected in Indiana. The raw data collected using these instruments during the August 2013 Indiana field sampling campaign were analyzed. The project team tested the instruments for several days in the lab before launching the ambient air field campaign at the suburban site at the Science and Technology Campus at Saint Joseph University. They were also granted a permit to drive a mobile unit equipped with air quality analyzers both in and outside the Salim Slam tunnel, a 500-meter tunnel that constitutes the south entry to Beirut and the main road to Beirut International Airport. The methodology consisted of alternating measurements of the different pollutants for around 30 minutes inside and outside the tunnel in order to be able to determine HONO emission factor in respect to NOx and to the quantity of fuel burned. The field campaign was successful and was also used as input data for the modeling study of the ambient field campaign.

The PI gave two seminars on the PEER project—one for faculty members at University of Indiana and one at the USJ-Faculty of Sciences—covering HONO chemistry and its link to climate change, as well as gaps in our understanding and knowledge of HONO. A meeting was also held with the Ministry of Environment concerning the outcomes of the project. Part of the results will be implemented in an on-going government project regarding air quality.

PUBLICATION

C. Abdallah, C. Afif, S. Sauvage, A. Borbon, T. Salameh, A. Kfoury, T. Leonardis, C. Karam, P. Formenti, J.F. Doussin, N. Locoge, K. Sartelet. 2020. Determination of gaseous and particulate emission factors from road transport in a Middle Eastern capital. Transportation Research Part D: Transport and Environment 83: 102361. https://doi.org/10.1016/j.trd.2020.102361

LEBANON - PROJECT 1-163: EARTHQUAKE-GENERATED LANDSLIDE HAZARD IN LEBANON

PI: Grace Abou-Jaoude, Lebanese American University
U.S. Partner: Joseph Wartman, University of Washington (Funded by the National Science Foundation)
Dates: June 2012 – May 2015

PROJECT OVERVIEW

Lebanon is located in a relatively high seismic zone and has a rugged topography, making it vulnerable to hazards from earthquakes and landslides. Records about seismic events in the country go back to 303 AD and contain descriptions about such damages as houses and monuments destroyed and widespread fires, but they offer few, if any, details about collateral damages from landslide hazards associated with earthquakes. Although Lebanon has not experienced any major earthquake since 1956, the recent discovery of an active thrusting fault close to its coastline has significantly raised its risk of being hit by a high magnitude earthquake. Past studies on seismic hazards in Lebanon have focused on seismic zoning and its impact on structural engineering design. Although many researchers have assessed slope stability hazards in Lebanon based on various static conditions, no effort had been undertaken prior to this effort to assess the impact of a seismic event on triggering landslide hazards in the country.

This project aimed to produce a hazard map of Lebanon that clearly shows the critical areas prone to earthquake-induced landslides. Ultimately the project should help Lebanese cities to identify areas with high natural hazard potential so they can plan urban growth appropriately, thus preventing damage to critical infrastructure and saving lives in the event natural disasters strike.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team studied seismic landslide hazards of Lebanon based on three methods and chose two for further modeling and analysis to account for the different slip surface geometries and various modes of slope failure. During a PEER grant visit, the PI and U.S. partner took part in “ground-truthing” in two areas in Lebanon where high hazards were predicted from both methods of analysis and took part in a dissemination workshop to present results of the project and international perspectives on landslide hazard and risk mapping.

The ground truthing field visits, conducted on confirmed many of the predicted high hazard locations. The team continued their work on developing landslide hazard maps in a separate PEER grant.

PUBLICATIONS

A. Saade, G. Abou-Jaoude, and J. Wartman. 2016. Regional-Scale Co-Seismic Landslide Assessment Using Circular Slip Surfaces. *Engineering Geology* 204: 53-64. https://doi.org/10.1016/j.enggeo.2016.02.004

Grace Abou-Jaoude, Angela Saade, Joseph Wartman, and Alex Grant. 2016. Earthquake-Induced Landslide Hazard Mapping: A Case Study in Lebanon. Geo-Chicago 2016. https://doi.org/10.1061/9780784480120.019

A.R. Grant, J. Wartman, and G. Abou-Jaoude. 2014. A Terrain classification system for coseismic landslide hazard analysis: Lebanon, A Case Study. In 2014 GSA Annual Meeting in Vancouver, British Columbia. http://hdl.handle.net/10725/7167

LEBANON - PROJECT 1-121: A COLLABORATIVE APPROACH TOWARDS INTEGRATED WATER RESOURCES MANAGEMENT IN THE LITANI RIVER BASIN: OPPORTUNITIES FOR CLIMATE CHANGE ADAPTATION AND SOCIOECONOMIC GROWTH

PI: Mutasem El Fadel, American University of Beirut

U.S. Partner: James Smith, Princeton University (Funded by the National Science Foundation)

Dates: June 2012 – June 2017

PROJECT OVERVIEW

Building on USAID's past and on-going programs in the Litani river basin in Lebanon, this project studied the vulnerability of the Litani to climate change with an emphasis on water resources and quality, agriculture productivity and food security, and public health protection. These researchers worked to provide a framework integrating climate change vulnerability assessment and adaptation using advanced simulation tools with decision support systems. The data were then applied to develop policies and investment options tied to socioeconomic improvement through cost benefit analyses. The project was designed to enhance water quality management in the Litani basin while providing a collaborative platform for application and adaptation of new technologies as well as capacity building.

FINAL SUMMARY OF PROJECT ACTIVITIES

Activity 1: High-resolution dynamic downscaling to assess the impacts of climate change in regions of complex dynamics

High resolution dynamical downscaling was conducted for the past and the near future climates under two Representative Concentration Pathways (RCP4.5 and RCP8.5) over Lebanon, using the Weather Research and Forecast (WRF) model forced by the High-Resolution Atmospheric Model (HiRAM). For this purpose, WRF performance for the study area was evaluated by downscaling National Centers for Environment Prediction Final Analysis model results, for a mild and wet year and a hot and dry year, to three horizontal resolutions of 9, 3 and 1 km. Temperature, precipitation and wind were compared at different time scales against observational data in the study area. Then, a set of ten downscaling simulations at 3 km resolution were performed using WRF driven with HiRAM, to generate future climate projections of annual and seasonal temperature and precipitation changes over Lebanon. Two past years were simulated to evaluate the model and to serve as a baseline scenario. The simulations results were finally used as weather input to a soil-plant growth simulator (CropSyst) to characterize silage maize agricultural yield and water balance in a pilot area located in the semi-arid central inland region.

Activity 2: Reservoir eutrophication dynamics: the role of excessive nutrient loading and temporal changes in climate forcing

Eutrophication of freshwater bodies is a major concern that has been hampering water management efforts globally. Remote sensing has the potential to assess changes in eutrophication status in infrequently monitored systems. In this study, empirical Landsat-based algorithms were developed for Qaraoun Reservoir in Lebanon in an effort to measure chlorophyll-a, total suspended solids, and secchi disk depth from spectral reflectances. Developed empirical algorithms were then used to hindcast changes in water eutrophication status, water temperature and reservoir volume across the Landsat image record (1984-2015). Field physio-chemical and biological data were used to understand the driving forces responsible for the marked increase in cyanobacteria in the reservoir. A Structural Equation Model (SEM) was developed to link cyanobacterial biovolume to the physio-chemical conditions in Qaraoun.

Activity 3: Efficacy of algaecides on algal blooms in hypereuthrophic lakes
Cyanobacterial blooms are an emerging problem worldwide, affecting many important freshwater systems. The proliferation of these blooms has been linked to public health concerns and to the impairment of the designated uses of several freshwater systems. Several studies have linked the increase in bloom frequency to anthropogenic activities, particularly increased nutrient loading. While basin-level management measures that aim to control nutrient loading are the most effective on the long-term, they are hard to implement given socio-economical constrains. As such, the use of chemical algaecides can provide a viable short-term mitigation measure that aims to control these blooms. In this study, the efficacy of three algaecides, namely Copper Sulfate, Potassium Permanganate, and Diquat, was examined with regards to controlling two toxin-releasing cyanobateria, *Aphanizomenon flos-aquae* and *Microcystis aeruginosa*. The efficacy of each algaecide was quantified under laboratory conditions over a range of selected dosages.

Activity 4: Dew as an adaptation measure for climate change
Dew is a frequent atmospheric phenomenon in which water droplets naturally condense upon passively cooled surfaces. Pilot studies showed small yet significant yield, particularly in their contribution to the water budget. This activity coupled knowledge from hydrology, geostatistics, modeling, and instrumentation to assess the long term potential of dew and its feasibility for crop and reforestation irrigation.

Activity 5: Watershed modeling using integrated hydrologic information system
Projected climate changes are expected to influence the hydrologic regimes of most river basins and increase the vulnerability of water resources systems worldwide. The Upper Litani River Basin (ULRB), with a semi-arid climate, is expected to be equally influenced by projected climate change. The need to assess these changes is critical for the development of adaptation strategies and management plans for the basin. The successful implementation of such an assessment requires the implementation of a National Hydrologic Information System (NHIS) framework and the development of a National Hydrologic Geodatabase (NHG) for the evaluation of catchment hydrology and water resources. As such, an integrated hydrologic and water resources model for the ULRB was established using the Soil Water Method (SWM) under the Water Evaluation and Planning (WEAP) model. The model was calibrated (1952-1962) and validated (1962-2010) against streamflow using an integrated WEAP-PEST approach.

Activity 6. Dissemination
The project results were disseminated at both the national and international levels through 12 peer reviewed publications (papers, book chapters, proceedings), presentations at conferences, workshops, and a video production.

LEBANON - PROJECT 1-91: TOWARDS A BETTER ASSESSMENT AND MANAGEMENT OF WILDFIRE RISK IN THE WILDLAND-URBAN INTERFACE IN LEBANON: GAINING FROM THE US EXPERIENCE

PI: George Mitri, University of Balamand
U.S. Partner: David McWethy, Montana State University (Funded by the National Science Foundation)
Dates: August 2012 – October 2016

PROJECT OVERVIEW

Increasingly, Lebanon's forests are exposed to degradation due to urbanization, fires, climate change, human neglect, improper management, outdated laws, and poor law enforcement. During the last decades, changes in traditional land-use and lifestyles, depopulation of rural areas, decreases in grazing pressure and wood gathering, and increases in the urbanization of rural areas are leading to the recovery of vegetation and an increase in accumulated fuel. Land-use changes are occurring in parallel with increases in fires, which have gone from being few in number and affecting small areas to becoming numerous and affecting large areas yearly.

This project looked to develop the capacity of stakeholders in Lebanon to assess and manage wildfire risk in Lebanon's wildland-urban interface (WUI) in light of future climate change and human development in wildland areas. Another goal of the project was to improve knowledge and understanding among university students, local community groups, and municipalities about the nature and risks of wildfire in Lebanon's WUI. Specific project activities included investigating the feasibility of developing a wildfire-climate model for Lebanon that simulates the interactions among climate change, expansion of human development into wildland areas, and wildfire risk. The researchers identified data needs and partnerships necessary for future development of a wildfire-climate model for Lebanon and then developed materials that would demonstrate how such a model can be used by Lebanese stakeholders to adaptively manage wildfire risk in the WUI for future climate and land use changes. They also developed the capacity of the community of interest (i.e., land and wildland fire management agencies, homeowners, and community and regional planners) to assess and manage wildfire risk and incorporate their research results into educational products to increase understanding of wildfire risk by the broader community.

FINAL SUMMARY OF PROJECT ACTIVITIES

Key dissemination activities included two workshops with nearly one hundred participants from academia and government ministries, who were exposed to wildfire risk management fundamentals. The project team also created a project website and an online wildfire monitoring and data collection platform, and they authored five publications pertaining to wildfire risk management. The results of this project led directly to the following four initiatives:

- An agreement was signed between in 2012-2013 between the Institute of the Environment, University of Balamand (IOE-UOB) and Lebanon Reforestation Initiative (LRI) to mainly design a pilot Firewise program for Lebanon in addition to other associated activities.

- In 2014, another agreement was signed between IOE-UOB and LRI to implement a pilot Firewise program in the village of Kaftoun in North Lebanon.
- A project was conducted with the support of UNDP-Lebanon to develop the chapter on emissions/removals from the Land Use, Land Use Change, and Forestry (LULUCF) and mitigation analysis for the Third National Communication to UNFCCC.
- A new project entitled “Assisting Reforestation and forest Development Activities in partnership with local Communities (ARDAC)” funded by the EU through the Ministry of Agriculture of Lebanon has started in 2014.

In early 2016 the team was awarded PEER Evidence-to-Action supplemental funding. The supplemental project objective was to increase fire danger preparedness in vulnerable areas in Lebanon by enhancing the Fire Lab tool capacity through design and implementation of the advanced fire danger index, to be used in combination with the forecasted fire weather index. Dr. Mitri and his team conducted an inventory of fire danger warning data and produced daily reports.

LEBANON - PROJECT 1-84: INVESTIGATION INTO PERSULFATE/ PEROXYMONOSULFATE OXIDATION OF MICRO-CONTAMINANTS TOWARD WATER SUSTAINABILITY: MECHANISM, KINETICS, AND IMPLEMENTATION

Pi: Antoine Ghauch, American University of Beirut

U.S. Partner: Richard Luthy, Stanford University (Funded by the National Science Foundation)

Dates: April 2012 – June 2016

PROJECT OVERVIEW

Persulfate activation has attracted great interest within the scientific community as a way of producing short-lived sulfate radicals, which are powerful oxidants against organic contaminants and more selective than the hydroxyl radicals often used for water and waste treatment. Using this approach, it may be possible to remove recalcitrant organic contaminants from water that are difficult to oxidize with existing treatment methods. The development of novel approaches for contaminant oxidation is critical to future efforts to secure water supplies in rapidly growing countries in arid climates. The issue of water quality is particularly important to Lebanon, where water shortages strike the Lebanese capital during August through November each year.

In this study, organic compounds that pose risks to human health and aquatic systems were subjected to treatment with persulfate activation in various ways: thermally, photochemically (via sunlight) and chemically. This project took several variables into account, such as ionic strength, sunlight intensity, concentrations of organic compounds, and chemical activators. Catalysts for persulfate activation were studied using various metals and minerals, including some collected from Lebanese soils and waterways. These new chemical activators should be able to progressively activate persulfate and peroxymonosulfate into sulfate radicals to destroy organic micro-contaminants. This project aimed to contribute to the education of the Lebanese population, help promote economic development, environmental protection, and capacity building among Lebanese researchers.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Ghauch and his colleagues tested advanced oxidation processes (AOPs) across several pharmaceutical contaminants, including bisoprolol, ibuprofen, methylene blue, sulfamethoxazole, naproxen, and ketoprofen. In the thermal application, results showed complete degradation. In testing various chemical activations, results showed plated iron particles were most efficient and sustainable toward degradation. The researchers undertook co-activation tests using heat and iron particles in order to study synergistic effects. Researchers also applied these processes to leachates of solid waste samples from a composting pilot. Preliminary data showed excellent results for potential application of such decontamination technique on leachates effluents before their discharge into waterways.

Overall results showed persulfate-based AOPs can be implemented to improve water quality in Lebanon and can be scaled up for the treatment of hospital effluents, as well as leachates in the absence of any wastewater treatment plant operational in coastal cities like Beirut, Tripoli, and Jounieh.

The PI and research team shared results of their PEER work at a variety of conferences, including the American Chemical Society annual meeting, IWA Specialist Conference on Assessment and Control of Micropollutants/ Hazardous Substances in Water, and the Arab American Frontiers of Sciences meeting.

In addition to his research efforts, Dr. Ghauch also reinstated a graduate-level chemistry course at his university and introduced elements of the ongoing PEER work into two courses in the Chemistry Department. By the time the project ended, he had secured $54,000 in additional grants, including from USAID's American Schools and Hospitals Abroad program. As an unexpected side benefit from his PEER-supported research, while trying to track contaminants in water and improve water quality, the PI developed a new instrument that can also detect special dyes and pigments used in valuable documents, for example, banknotes, passports, visas, etc., thus improving security features and limiting fraud and counterfeiting activities. This instrument received a provisional patent from the U.S. Patent and Trademark Office in January 2015.

PUBLICATIONS

S. Naim and A. Ghauch. 2015. Ranitidine abatement in chemically activated persulfate systems: assessment of industrial iron waste for sustainable applications. Chemical Engineering Journal 288: 276-288. https://doi.org/10.1016/j.cej.2015.11.101

A. Ghauch, A.M. Tuqan, and N. Kibbi. 2015. Naproxen abatement by thermally activated persulfate in aqueous systems. Chemical Engineering Journal 279: 861-873. https://doi.org/10.1016/j.cej.2015.05.067

A. Ghauch. 2015. Iron-based metallic systems: an excellent choice for sustainable water treatment. FOG Freiberg Online Geology 38. https://tu-freiberg.de/sites/default/files/2023-08/fog_volume_38.pdf

G. Ayoub and A. Ghauch. 2014. Assessment of bimetallic and trimetallic iron-based systems for persulfate activation: application to sulfamethoxazole degradation. Chemical Engineering Journal 256: 280-292. http://dx.doi.org/10.1016/j.cej.2014.07.002

A. Ghauch and S. Naim. 2013. Rapid elimination of Ranitidine in water by Fe0 Activated persulfate systems. Proceedings of the 8th Micropol and Ecohazard Conference, IWA-11779R, 208-209.

MOROCCO

MOROCCO - PROJECT 8-230: EVALUATION OF A NOVEL SS-LAMP ASSAY FOR RAPID, LOW-COST DIAGNOSIS OF TUBERCULOSIS IN MOROCCO

PI: Hassan Ait Benhassou, Moroccan Foundation for Advanced Science Innovation and Research, in Partnership with Université Mohammed V
U.S. Partner: Adithya Cattamanchi, University of California, San Francisco
(Funded by the National Institutes of Health)
Dates: October 2020 – October 2021

PROJECT OVERVIEW

Tuberculosis (TB) is one of the deadliest infectious diseases worldwide. Each year, about 1% of the world's population is newly infected, about 9 million develop the disease, and approximately 2 million of them die. In Morocco, as in most developing countries, where the timely and accurate diagnosis of TB remains a great challenge, the disease constitutes a major public health threat, with 30,000 new cases each year. Currently, the conventional methods used routinely to diagnose the disease, such as microscopy and culture, are complex, unreliable, labor-intensive, technically challenging, and time-consuming. Although semi-automated PCR (Xpert MTB/RIF) is now available, it has high device and consumable costs and requires stable electricity. The laboratory of the PI Dr. Ait Benhassou has developed a novel assay called SS-LAMP (Single Step Loop Mediated Isothermal Amplification) for the diagnosis of TB. SS-LAMP provides a number of advantages over microscopy, including superior sensitivity and significantly less operating time, and compared to GeneXpert it does not require expensive instrumentation or electricity. Furthermore, SS-LAMP has the advantage of being able to be directly used without the need of sputum processing steps and to be easily integrated into a portable, battery-powered Lab-on-Card device developed in the PI's lab. Their SS-LAMP is proposed to provide a low-cost, more accurate, and more convenient alternative to sputum smear microscopy for the detection of pulmonary TB in limited resource settings.

In this last mile pilot study supported by PEER, the researchers evaluated on a large population the clinical accuracy and operational features of the SS-LAMP for the detection of pulmonary TB in clinical settings in Morocco. They compared the performance of the SS-LAMP assay with sputum smear microscopy and XpertMTB/RIF. The project involved the enrollment of 700 consenting individuals with typical TB symptoms in Casablanca and Tangier. Three sputum samples were collected from each of these TB presumptive cases. The single SS-LAMP test was compared with GeneXpert MTB/RIF, using mycobacterial culture as a reference standard.

FINAL SUMMARY OF PROJECT ACTIVITIES

Given that the project focused on infectious disease diagnostics, it was significantly impacted by the COVID-19 outbreak and subsequent shutdowns, particularly as the PI and his team were drawn into Moroccan pandemic mitigation efforts. In the project ramp-up, two preparation meetings and a one-day training on the use of the MAScIR TB SS-LAMP solution were organized for the Laboratory of Tuberculosis technicians of the Pasteur Institute (PI) of Morocco. Patients were then enrolled in the

Laboratory of Mycobacteria and Tuberculosis of Casablanca, but the Laboratory of Mycobacteria Genetics of Tangier was excluded from the study due to COVID-19 restrictions and lack of staff. Patients with suspected pulmonary TB were included, and each patient recruited submitted samples for both Acid-Fast Bacillus (AFB) test and the MAScIR TB-LAMP and the Xpert MTB/RIF test to compare the effectiveness of the new kit. This study demonstrated that the MAScIR TB SS-LAMP had a high accuracy (95%) in the detection of pulmonary tuberculosis. The AFB results were used as a reference.

Given this success and to promote the team's solution among stakeholders, as well as ensure its implementation on the ground, the team met with different national and international private companies, universities, institutions, government representatives, diplomatic delegations, and the local USAID mission in Morocco. During October 2020, the team held four virtual brainstorming technical meetings with Tronico Alcen (France) regarding the industrialization of the LAMP-TB/ Lab-on-Card for the diagnosis of the tuberculosis. During COVID-19, Tronico developed a device called EasyCov similar to the project team's lab-on-card for the rapid diagnosis of COVID-19. In collaboration with this company, the team submitted a pre-proposal in response to a grant call launched by the Moroccan CNRST institute/OCP/UM6 Polytechnic University.

The project team also launched a discussion with the French start-up C4Diagnostics. The focus was a potential collaboration for the development of an assay based on LAMP technology for the diagnosis of COVID-19. C4Diagnostics is a biotech start-up specialized in the development of diagnostic kits, and they wanted to take advantage of the PI's lab expertise in the development of the LAMP-based tuberculosis assay for the development of their COVID-19 test. An agreement was signed to launch the collaboration.

The team also signed a partnership agreement with Laprophan Laboratories for medical R&D projects in line with the country's health needs. MAScIR and Laprophan sought to meet the current needs of Moroccan industry and economic operators to promote "Made in Morocco". The team also met with Pharma5 to discuss the capabilities and logistics for the production of 1 million MAScIR TB SS-LAMP test kits. Pharma5 has been the leading supplier of 100% Moroccan Tuberculosis treatments for over 35 years. Alongside the public authorities, the laboratory is participating in national efforts to raise awareness and treat this disease, which is still very prevalent in Morocco. In the frame of this scope and by integrating the PEER team's solution, Pharma5 is planning to provide a diagnosis/treatment package against TB.

At the academic and research levels, the team closely interacted with national universities, including Mohammed V University. Despite the pandemic, the project developed a new course entitled "A promising LAMP technology: Perspectives and Challenges in diagnostics" at the Faculty of Science of Rabat.

The team also received delegations from the Sheikh Khalifa Ibn Zaid Al Nahyan Foundation, the Mohammed VI International University Hospital, the National Reference Laboratory, and the Mohammed VI University of Sciences of Health - UM6SS. The visitors learned about the various projects of the MAScIR Foundation, including their SS-LAMP/Lab-on-Card solution. They also met with Imperial College London and Istanbul Koc University who have a project for the diagnosis of TB among Syrian refugees in Turkey and are interested in signing a technology transfer contract with MAScIR in order to use their SS-LAMP/Lab-on-Card solution.

As the team contributed greatly in the efforts of the Moroccan government to resolve the COVID-19 pandemic by providing cost-effective RT-PCR kits, they had the privilege of demonstrating their work to high-ranking government representatives. Stakeholders expressed particular interest in the SS-LAMP/Lab-on-Card tuberculosis diagnostic solution. Furthermore, the team received the head of the Moroccan Laboratory of Forensic Sciences at the General Directorate of National Security and his team. They are interested in adapting and testing the SS-LAMP solution for forensic identification of bodily fluids. Beyond Moroccan officials, the team met with representatives of United Nations agencies, the African Development Bank, and the World Health Organization, and prospects for upscaling of the team's work appear promising. The research work was, and continues to be, disseminated as well through workshops, meetings, social and other online media, and newspapers. Publications are still under review.

MOROCCO - PROJECT 7-246: FACILITATING ACCESS TO REPRODUCTIVE HEALTH SERVICES FOR REFUGEE WOMEN IN MOROCCO

PI: Ali Idri, University of Mohammed V in Rabat
U.S. Partner: Leanne M. Redman, Pennington Biomedical Research Center (Funded by the National Institutes of Health)
Dates: January 2019 – December 2022

PROJECT OVERVIEW

The PEER project sought to improve comprehensive reproductive health services dedicated to refugee women in Morocco, including contraception, prenatal/obstetric, and postpartum care services**.** The researchers developed and evaluated pregnancy monitoring mobile Personal Health Records (mPHR) and Electronic Health Records (EHR), as well as a set of gamification techniques for contraception and postnatal mobile applications. They also developed and evaluated a datamining-based intelligent system for the management and prioritization of software requirements according to each stakeholder's profile (patient, caregiver, etc.) and used an ISO 25010-based framework for the quality evaluation of pregnancy mPHR and HER.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers developed three mobile system apps for both Android and iOS systems in three languages, Arabic, French, and English. The apps, MyContraception, MyPregnancy, and Mama&Baby, were also evaluated by graduate students in the Internet of Things and Web and Mobile Engineering programs. The PEER team collaborated with the reproductive health center, "Les Oranges," at the University Hospital Avicenne in Rabat, to first identify the requirements needed for these apps and then tested them with gynecologists and patients of the center.

The team presented their research at several conferences, including the Artificial Intelligence for Development Conference (AI4D), and published several articles on functionalities, technical features, and software requirements for pregnancy-related public health records. The project also supported two PhD theses, one Master's thesis, and seven first-year final projects for student researchers at the PI's institution. One PhD student won a fellowship grant from Microsoft to extend research into breast cancer diagnosis through deep ensemble learning.

PUBLICATIONS

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MOROCCO - PROJECT 5-648: DATA SCIENCE FOR IMPROVED EDUCATION AND EMPLOYABILITY IN MOROCCO

PI: Ghita Mezzour, International University of Rabat
U.S. Partner: Kathleen Carley, Carnegie Mellon University (Funded by the National Science Foundation)
Dates: February 2017 – January 2020

PROJECT OVERVIEW

The mismatch between the job supply and demand creates major social, political, and economic problems in Morocco. Every year, many graduates are unable to find jobs, and the resulting youth unemployment causes major social and political tensions. Paradoxically, at the same time, employers are unable to find candidates with the required skills, and this skills shortage results in missed economic opportunities for the country. Despite the importance of studying the skill mismatch in Morocco, the topic attracts very limited attention in the literature. Moreover, there is a lack of large data sets that researchers can use to systematically study the issue and identify effective interventions to alleviate it.

The goal of this project was to measure the skill mismatch in Morocco and identify measures to align university training with the job market. More specifically, these researchers collected and analyzed multiple large data sets about higher education and the job market in Morocco. They built profiles of university graduates and job openings in Morocco and identified areas of misalignment between the two. They also interviewed human resources staff from multiple organizations to learn about their concerns in more detail. Finally, they collected traditional and social media discussions about higher education and jobs in Morocco in order to learn about the general population's concerns about the topic.

FINAL SUMMARY OF PROJECT ACTIVITIES

To reduce the problem of skill mismatch, it is important that higher education institutions have information about job market needs and adapt their curricula accordingly. Youth also need to be aware of job market needs in order to choose education paths that maximize their chances of finding a job. To examine whether higher education institutions and youth receive information about job market needs, the PI and her team analyzed the extent of collaboration between employment stakeholders using surveys and Social Network Analysis. A total of 79 representatives of the private sector, public sector, youth, universities, recruitment agencies, and funders took the survey in three major Moroccan cities. The team's analysis reveals that higher education institutions receive very little information about job market needs from the private sector. Similarly, youth receive limited information about job market needs from the private sector and higher education institutions.

The researchers collected and analyzed official reports and tweets by employment stakeholders (private sector, public sector, universities, vocational schools, and youth) to identify the mental model and priorities of these stakeholders. They found that universities are concerned about education and research but pay little attention to employment. On the other hand, companies are concerned about their products and services but think little of education. The different mental models of stakeholders probably impede collaboration between them.

To help higher education institutions and youth have access to job market information, the team collected novel data sets about the Moroccan job market and developed new techniques to analyze such data. More specifically, on a weekly basis they collected job ads posted in 10+ top recruitment Moroccan websites. Analyzing job ads would reveal job market needs and trends in Morocco, but such analysis is challenging because the majority of these ads are non-structured or semi-structured. Moreover, duplicate ads need to be removed, but those duplicates are difficult to automatically identify because they appear under different formats in different websites. In this project, the researchers used a variety of Natural Language Processing (NLP) techniques to remove duplicate ads and to extract and standardize job attributes from job ads. For example, they developed a novel NLP technique to extract and standardize soft skills that achieved a 0.84 F-score compared to the 0.54 F-score achieved in prior work (F-score is an accuracymeasure that is between 0 and 1). Other than soft skills, they extracted and standardized the job title, location, languages, recruiting company, education level, experience level, and hard skills. They focused on analyzing the needs of three promising sectors for the Moroccan economy: automobile, offshore and cybersecurity.

Overall, this project has increased awareness about (1) the importance of building ties between the private sector and higher education institutions, (2) the importance of analyzing job market needs and taking such needs into account when designing curricula, and (3) interest in using a data science approach to analyzing job market needs that can provide real-time analysis in a cost efficient manner. The PI and her team have increased such awareness by organizing stakeholder meetings at the International University of Rabat, giving talks at various venues, and meeting individually with various decision makers.

PUBLICATIONS

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MOROCCO - PROJECT 5-398: TOWARDS SMART MICROGRIDS: RENEWABLE ENERGY INTEGRATION INTO SMART BUILDINGS

PI: Mohamed Riduan Abid, Alakhawayn University, with co-PI Mohamed Bakhouya, International University of Rabat
U.S. Partner: Driss Benhaddou, University of Houston (Funded by the National Science Foundation)
Dates: December 2016 - November 2021

PROJECT OVERVIEW

Besides being a global concern, energy efficiency is growing as a potential market with very promising development and environmental impacts. Smart Grids (SGs) promote energy efficiency in electrical grids, mainly via the integration of renewable energy (thus minimizing greenhouse gas emissions) and via the leveraging of Information and Communication Technology (ICT). ICT is a key element in the optimization of the Demand/Response (DR) variance, which stipulates a real-time dissemination of data between SG components, namely, smart meters at the production site (i.e., renewable energy sources), sensors measuring electricity consumption at the consumer site, and actuators. The interconnection of these components needs a reliable network: the Advanced Metering Infrastructure (AMI).

This project leveraged energy efficiency in smart buildings by promoting “context awareness” whereby the switching on and off of electrical appliances is based on the context, i.e., temperature, number of people in rooms, humidity, light, and so forth. To this end, these researchers deployed a holistic platform that implements a real-world microgrid testbed at a building on the Alakhawayn University campus. The deployed smart microgrid model will be promoted for deployment by other organizations at the national level, especially since Morocco is adopting a promising policy for renewable energy integration. In the medium term, the team hopes to promote this technology in sub-Saharan countries as well, given Morocco's geographical location. Supporting research in renewable energy can foster the growth of the green economy in Morocco and in the longer term create job opportunities for Moroccan youth.

FINAL SUMMARY OF PROJECT ACTIVITIES BY AUI PEER TEAM

The main output of this project by AUI team has been the establishment and deployment a Smart Grids Testbed at Alakhawayn University in Ifrane, According to project PI Dr. Abid, it, is the sole Smart Grids testbed/lab of its kind in Morocco. The testbed was deployed in the Solarium Lab in Building 7 of AUI and was given the name of "NAS-USAID Smart Grids Lab." The lab is operational and the deployed architecture and acquired knowledge will be further tweaked by recently recruited PhD students who will continue their research at the lab. Currently, the PEER team are negotiating with governmental agencies regarding funding to deploy and test this technology in the city of Ifrane and in the region. The PEER team’s PhD student Bouali Ettaibi is determined to build a start up in the field, while another PhD student Safae Bourhnane, who has been very engaged in this PEER project, successfully defended her PhD thesis in December 2021 and thanks to her active involvement was offered a lecturer's position at AUI.

FINAL SUMMARY OF PROJECT ACTIVITIES BY IUR PEER TEAM

The team members at Chouaib Doukkali University (UCD) and the International University of Rabat (UIR) collaborated since the first year of the MIGRID project with the main aim to achieve the assigned tasks, while supporting two PhD students, Sofia Boulmrharj and Abdellatif El Mouatamid, in finalizing their thesis work. The team members developed and deployed a holistic and hybrid approach that takes into consideration three major aspects of the building, including passive building systems (e.g., envelope), active building systems (e.g., HVAC, ventilation), and the integration of renewable energy sources (e.g., photovoltaic panels, thermal panels, wind turbines) and storage devices, such as batteries, hot water tanks, hydrogen storage and related equipment, mainly hydrogen electrolyzers and fuel cells for cogeneration in buildings. The main aim of this holistic approach was to minimize the buildings' energy consumption (i.e., electrical and thermal energy) and reduce their greenhouse gas emissions while maintaining suitable comfort for the occupants.

The team first deployed the EEBLab (a small Energy Efficient Building Laboratory) in order to validate the strategies they developed in real-life scenarios. For large-scale deployment, and with the aim to exploit and disseminate the knowledge gained in the framework of this PEER project, the team participated in the Solar Decathlon Africa (SDA) competition, which was held in Ben Guerir August 21-September 27, 2019, together with other students from the UIR, the Technische Hochschule Lübeck (THL) and a consortium of academic of Dakar. The team designed, constructed and deployed a smart and energy efficient house, named AFRIKATATERRE. Solar Decathlon Africa also presented an opportunity for the team members to test and deploy on a large scale (i.e., in a real house) the technologies, approaches and platforms developed in the course of the project. During the SDA competition, visitors, including private companies, local USAID officials, funding agencies, and policy and decision makers, visited the house where the team presented all deployed solutions. The AFRIKATATERRE house won the first prize in the Architecture contest and the second prize in the sustainability contest. All SDA houses are currently grouped together to create the green and smart building park.

The project helped its involved members (PhD, Master's, and undergraduate students) via training, scholarships, and meeting events to exchange ideas and results related to the project concepts and its related technologies. Mainly, the training activities were performed through the mechanisms of joint undergraduate/Master's/PhD program and their related events, such as open days and seminars, new courses, and job fairs. As of November 2023, the researchers involved in this project had published 73 papers or conference abstracts regarding their PEER-supported work.

MOROCCO - PROJECT 5-198: SEAMLESS SOLAR PV INTEGRATION IN MOROCCAN BUILDINGS

Pi: Mounir Ghogho, International University of Rabat (Co-Funded by National Instruments)
U.S. Partner: Paul Flikkema, Northern Arizona University (Funded by the National Science Foundation)
Dates: December 2016 – May 2022

PROJECT OVERVIEW

A high density of installed solar photovoltaic (PV) systems poses challenges, including excessive ramps and peaks of solar power into low-voltage grids that may cause blackouts. The penetration of roof-mounted PV in Moroccan buildings is still very low, despite estimated potential power generation of 10 TWh (terawatt hours), or 40% of the country's total electricity consumption. Two main obstacles are capital investment cost, as no financial incentives are offered yet by the government, and the conservative attitude of the national electricity utility company toward PV injection in the low-voltage grid.

To optimally design a battery-supported PV system, realistic household load profiles in Morocco must be used. This PEER project built a statistically significant dataset of household electricity consumption profiles in Morocco and made it available as open data to the scientific community. Team members analyzed the data using machine learning to assess and classify power quality at the household level. Through their open data and outreach activities, the project team aimed to contribute to the promotion of clean energy adoption in buildings and the modernization of the Moroccan electric grid.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Ghogho and his colleagues developed an integrated system for monitoring and processing of electricity consumption in both residential and industrial settings. They used this system to build a dataset of Moroccan households' electrical consumptions, with the aim of determining typical energy consumption profiles of households of different types (apartments, semi- detached, and detached houses) and different socioeconomic status, developing load forecasting algorithms, creating electrical consumption disaggregation algorithms, and determining power consumption by individual appliances.

The team's dataset includes the electricity consumption of 13 households of different socioeconomic status over the course of the project, as well as power consumption data for the individual appliances used in the households. The dataset is the first of its kind in Africa and could be used by both researchers and engineers for various projects, including the design of PV systems for residential buildings.

From this dataset and others, the PEER team developed a novel method for multi-horizon forecasting of residential electricity consumption, with a maximum prediction horizon of 24 hours and an energy management system (EMS) for a microgrid consisting of a grid-tied building, PV panels, and a battery.

The performance of the EMS on the system was tested via simulations and designed to maximize the benefits of the residential smart grid without injecting energy into the electrical grid.

The PI and PEER team presented their project and findings at several national and international events, including The Mediterranean Symposium on Smart City Applications. They also developed strong ties with IRESEN, a public agency in charge of promoting research and development in renewable energy in Morocco. IRESEN was particularly interested in datasets on electricity consumption in Morocco, and the PEER team presented the merits of a battery-backed PV system in Morocco's urban areas.

As a result of the project, the co-PI received a $45,000 grant to continue work on energy consumption in smart cities, funded by a French-Moroccan cooperation program), and the PI received a $335,000 grant to work on solar PV-powered electric vehicle charging systems, funded by the Rabat-Sale-Kenitra regional government.

PUBLICATIONS

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MOROCCO - PROJECT 3-106: TOOLS AND RESOURCES TO IMPROVE DEAF EDUCATIONAL ACCESS TO SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

PI: Abdelhadi Soudi, Ecole Nationale de l'Industrie Minérale
U.S. Partner: Corinne Vinopol, Institute for Disabilities Research and Training, Inc.
(Funded by the National Science Foundation)
Dates: October 2014 – September 2016

PROJECT OVERVIEW

This research project addressed the challenging research problem of meeting the educational needs of the deaf, who are underserved in education in general, and in STEM literacy, in particular. In Morocco, there is no secondary education for the deaf. There is a severe lack of instructional resources: all scientific information is Arabic/French audio and text-based, and there is no interpretation available into Moroccan Sign Language (MSL). There is no STEM content material available in MSL, and accordingly, there are no resources that interpret STEM from MSL to Standard Arabic. Deaf individuals who rely on sign language for communication present a unique communication challenge in education, since sign languages have no written representation as do oral languages; sign languages can only be represented via video, graphics, and animation. As a result, reading achievement scores of deaf individuals usually fall far short of those found among hearing children of comparable abilities.

This project was an effort to bridge the gap for the deaf, who are greatly underserved in science education. This research project will focus on creating the first MSL STEM thesaurus, enhanced by a concordancing software. The thesaurus will enable deaf individuals to describe signs and obtain Arabic word equivalents, concept graphics, and definitions in both MSL and Arabic. The thesaurus will be supported by a concordancer for better illustration and disambiguation of STEM terms. The project was designed to contribute to improving the technology for generating linguistically accurate sign language in general in the form of animations and video and graphic formats. The tools and resources developed will significantly improve the education of the deaf and will provide them with a better access to basic concepts in STEM fields.

FINAL SUMMARY OF PROJECT ACTIVITIES

This research project aimed at developing tools and resources to facilitate Moroccan Deaf children's access to STEM. A Moroccan Sign Language STEM Thesaurus and a morphologically-enhanced Arabic Concordancer were developed. The MSL thesaurus operates by having MSL users identify the four cheremes for each hand for the STEM sign for which they want to find Arabic equivalents by using drop-down pictorial menus. The program searches the database for the sign that most closely matches the chereme choices. If the cheremes selected do not exactly match how the sign is coded in the database, the program will provide options of signs that are described similarly (the chereme version of spell-check). Accurately described signs and sign options are displayed as graphics and videos. Once users verify their intended sign, the program will display, in addition to the sign graphic and video, the comparable Arabic word(s) and the Arabic word definition(s) in text, MSL definition(s) in video, concept graphic(s), and word forms. This will help deaf students discern, when writing on STEM topics, which Arabic word to use for their sign. Users can choose a variety of output options for the depicted MSL sign (1. Main Graphic Sign which includes the corresponding Standard Arabic term, the concept and the Graphic sign; and 2. MSL video clip of the sign, 3. MSL definition, Standard Arabic definition, the concept graphic). The Concordancer enables the users to enter a STEM term or phrase and search for examples of how that term or phrase is used. The novelty of the Concordancer the team developed resides in its incorporation of morphological analysis into the software. This tool provides a list of examples of a particular term or combination of terms in its/their contexts drawn from a science corpus.

The tools developed by the project have been well received by the government, country educators, and has even received additional support from USAID. Future plans will expand upon the software and trainings with the goal of integrating them into the national curriculum. To this end, USAID is funding the expansion of these technological tools and trainings to 10 deaf schools across Morocco. The project has already had a significant impact on:

1. Directors of deaf schools and educators who are introduced to new techniques
2. Policy makers who formulate decisions regarding education of deaf students
3. Educators of deaf students
4. Members of deaf associations
5. Family members of deaf students

MOROCCO - PROJECT 1-375: ASSISTIVE TECHNOLOGY FOR IMPROVING LITERACY AMONG THE DEAF AND HARD OF HEARING

PI: Abdelhadi Soudi, Ecole National de l'Industrie Minerale
U.S. Partner: Corinne Vinopol, Institute for Disabilities Research and Training, Inc
(Funded by the National Science Foundation)
Dates: May 2012 – February 2014

PROJECT OVERVIEW

Moroccan Sign Language (MSL) is a poorly resourced language with communication problems compounded by a severe lack of interpreters. The high rate of illiteracy among the deaf community and the lack of sign language interpreters often deprives members of this community of critical information, with serious consequences to their welfare, safety, health, opportunities, and rights.

This project was carried out in collaboration with the U.S.-based Institute for Disabilities Research and Training, Inc., which is currently developing a translation engine that provides reciprocal translation between American Sign Language (ASL) and English. The project is aimed at creating a robust assistive technology at accessible cost for deaf individuals in Morocco and their families, service providers, educators, or businesses that employ them or have them as customers.

The technology should be able to function as both an instructional tool to improve the literacy of deaf children and adults and as a real-time translation device between MSL and standard written Arabic. This translation technology will accommodate a variety of input and output options, including input for standard Arabic text (typing, scanning, screen text transfer); input for MSL (a sensor-enabled glove capable of reading the finger and hand movements of sign language and camera integration); output for standard Moroccan text (standard Arabic text); and output for MSL (sign graphics, sign video clips).

FINAL SUMMARY OF PROJECT ACTIVITIES

As part of the engine development, the PI and team created a database of 3,000 MSL signs and 8,500 Arabic words. The work included, among other elements, drawing sign graphics and videotaping sign clips, incorporating Natural Language processing tools into the engine and testing the technology at deaf schools in different parts of Morocco. In addition to the development of the translation engine, the research team published several proceeding papers and the project was featured in *Odyssey*, an award-winning children’s science magazine.

The team has established ongoing connections with several Deaf associations in different regions in the country The research team also developed a set of useful educational resources for the Moroccan Deaf community and their parents: a quiz-maker with automatic Arabic-to-MSL translation, introductory instruction in MSL for parents and service providers, stories and interactive instructional games for Deaf students in both Arabic and MSL.

The researchers have also begun investigating a new research direction in using 3D avatars to produce signs in the translation engine. As part of the project, the Moroccan PI taught the software engineer and the Standard Arabic linguist Natural Language Processing techniques. The project's sign language interpreter and linguist and the deaf signers and graphic artist explored many issues on the mechanics and linguistics of Moroccan Sign Language that were previously unexplored, and the results of this work will be disseminated to sign language linguists and educators in deaf schools.

The PI and team organized a project awareness day in Rabat to present the outcomes of their project which was attended by over 350 deaf people, 20 organizations, and USAID Morocco Mission Director Dana Mansuri. The government ministry in charge of the disabled is coordinating the formal integration of the technology into mainstream educational courses.

PUBLICATIONS

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TUNISIA

TUNISIA - PROJECT 8-015: OPTIMIZATION OF PERENNIAL GRASSES TO IMPROVE FORAGE PRODUCTION IN TUNISIA (OPGIFPT)

PI: Salma Sai Kachout, National Institute of Agronomy Research of Tunisia
U.S. Partner: Niall Hanan, New Mexico State University (Funded by the National Aeronautics and Space Administration)
Dates: June 2020 – September 2022

PROJECT OVERVIEW

The Mediterranean climate of North Africa is characterized by hot and dry summers and cool wet winters, and most global climate models show water supply will be much lower and the air temperatures significantly higher in the coming decades, especially during the summertime. Crop productivity and biomass are typically low under low-rainfall dryland agricultural systems due to abiotic stresses and low input levels. Moreover, more frequent droughts and other climatic risks further exacerbate these trends. This is evident in Tunisia, where wheat and barley production in 2010 was down 33% over the five-year average, due to low rainfall. Livestock production also plays an important socioeconomic role, but limited access to year-round forage for livestock is a major constraint. Perennial grasses grown for livestock are generally drought resistant and require relatively low inputs. They have recently attracted steady interest due to their extensive environmental benefits both at global and agricultural community-scale.

The main objective of this PEER project was to identify high-yielding perennial grasses suitable for Tunisian conditions, optimizing the production chains in order to provide a stable source of biomass to ruminants. To do this, the principal investigator Dr. Salma Sai Kachout and her colleagues researched genetic diversity and physiological traits of plants suitable for Tunisia; studied agricultural practices that are intended to increase the yield, quality, and income of farmers; identified appropriate ruminant diets based on perennial grasses to meet energy and protein requirements; and developed capacity for mapping the grazing lands and trends in forage production in Tunisia. The team sought to enhance livestock performance, provide the basis for a sustainable farming system, and contribute to the empowerment and livelihoods of rural communities.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PEER team developed their research through a variety of workstreams. In the first, they conducted a field survey to assess management practices for fodder production and feed production for small ruminants. They collected and characterized endemic perennial grasses, new plant varieties, seeds of perennial grasses, and soil samples. Part of this work was to develop pasture mapping capabilities and forage production trends in Tunisia in the long term.

The team used the SRAP molecular marker technique to study the genetic diversity in four forage species of Tunisian perennial grasses, finding high polymorphism information content and high variability, supported in particular by low gene flow.

The researchers conducted growth trials to optimize the production of perennial grasses, identifying accessions of high-yielding grass species and studying the physiology of plants and leaves of perennial grasses. A graduate research trainee was heavily involved in this area, focusing on responses to water stress and the development of molecular markers linked to tolerance to drought.

In addition to their work in the lab and field, the researchers carried out surveys of selected farms to understand their production system for animal feed, including nutritional value and digestibility. They also undertook a socioeconomic analysis to assess the profitability of forage production using perennial grasses and the sustainability of rangelands and their effect on total livestock factor productivity. As part of the PEER project, the PI and team developed a three-year partnership agreement with the laboratory of Molecular Genetics, Immunology, and Biotechnology at Faculty of Sciences of Tunis, University of Tunis El Manar, which will help sustain their efforts even after the end of PEER support.

PUBLICATIONS

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TUNISIA - PROJECT 8-094: EVALUATION OF NEW CITRUS ROOTSTOCKS FOR THEIR ADAPTATION IN DIFFERENT GROWING ENVIRONMENTS IN TUNISIA

PI: Hajer Snoussi Ep. Trifa, National Institute of Agronomy Research of Tunisia
U.S. Partner: Violeta Tsolova (Previous PI: Anthony Ananga), Florida A&M University (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: March 2020 – February 2024

PROJECT OVERVIEW

In Tunisia, the citrus sector is a strategic component of the overall national economic development program. Citrus production covers 27,000 hectares and is the main source of income for more than 12,000 farmers. Citrus fruits are among the most consumed fruits in Tunisia and constitute the most common and most affordable fruit in the Tunisian diet from September through May. Citrus production in the country is facing a complex combination of abiotic constraints like drought and salinity, as well as biotic threats such as Citrus Tristeza Virus (CTV). Citrus growing farmers would be poorly resilient in the case of a breakthrough of CTV, and potential risks are increasing given the current climate change trajectory. If this problem is not tackled, it would impact the entire citrus value chain, including producers, retailers, exporters, and consumers and would be a matter of food security as well. The most sustainable and environmentally friendly strategy is to promote combinations of a given commercial variety with a specific rootstock, conferring adaptation to the abiotic stresses and tolerance to CTV.

This PEER project applied morphological, physiological, and molecular analysis to various rootstock/cultivar combinations in multi-location field trials to gain a better understanding of the impact of the rootstock/cultivar relationship on physiological processes such as toxic ion uptake, ion translocation, ion homeostasis, water uptake, osmotic regulation, and photosynthesis resilience.

Commercial orchards usually contain more than one variety and/or citrus species. This is done because farmers often have to fulfill contracts to provide products over an extended period. In addition, this allows better management of the human resources at the farm, particularly for harvesting. Nurserymen are therefore called on to provide several location-specific rootstock/cultivar combinations in order to answer farmers' demands. The project sought to offer farmers the best citrus combinations (rootstock/variety) to replace the current ones while ensuring the adaptation of these new combinations to local conditions to secure a good profit.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers undertook serological analyses on 1,790 trees in Menzel Bouzelfa, 1,614 trees in ben Khalled, and 855 trees in Soliman (the most important citrus-growing regions), which showed a worsening contamination of CTV in these regions. They also assessed the agronomic performance of rootstock trials set up since 2017 in different production regions, including trials of four CTV-tolerant rootstocks (*C. volkameriana, Citrumelo, Citrange carrizo*, and *Citrange C35*), with the sour orange as the control, and three citrus varieties: two orange varieties (New Hall and Washington navel) and one mandarin variety (Hernandina). These trials showed a generalized superiority of *C. volkameriana* rootstock in all trial sites, between 16 and 33% depending on the site and variety for growth. *Citrus volkameriana*'s superiority for cumulative yield is more evident with oranges, where it varies between 12% and 72%. *Citrumelo swingle* was the least efficient rootstock.

The PEER team undertook a study of the rootstock physiological responses to abiotic stresses, including soil and irrigation water analysis, symptomatic analysis of chlorosis related to salt stress leaf mineral status, and leaf chlorophyll content. They also studied orange by-products, including methanolic extracts from fruit pulp.

Finally, the team carried out surveys with farmers who had adopted new rootstocks and developed a database of characteristics of the surveyed farms, management variables, and farmers' perceptions of CTV risks and experience in adopting tolerant rootstocks.

The PI and her colleagues organized a workshop on adoption of alternative rootstocks to sour oranges, in which they presented their findings and demonstrated the various alternative rootstocks and cultivation techniques. They also presented their findings at a seminar held at FAMU Viticulture Center during a visit to the U.S. partner in Florida. One of their impacts through connections with private industry is 80% of citrus nursery growers are currently producing plants on new rootstocks and the Tunisia state land office has authorized PEER continue surveying the extent of the disease's spread in its orchards in Cap Bon, and to collect data to assess its impact on the profitability of the activity and the value of adopting new rootstocks.

TUNISIA - PROJECT 8-175: AN INTEGRATED MODELING APPROACH FOR SUSTAINABLE DEVELOPMENT FOR THE ICHKEUL LAKE (ECO-TOURISM AND AQUACULTURE): IMAS-ICHKEUL

PI: Béchir Béjaoui, National Institute of Marine Sciences and Technologies
U.S. Partner: Hamidreza Norouzi, The City University of New York, New York City College of Technology (Funded by the National Aeronautics And Space Administration)
Dates: December 2019 – November 2023

PROJECT OVERVIEW

In northern Tunisia, near the shore of the Mediterranean Sea, Ichkeul Lake and its wetlands are among the most productive ecosystems in Tunisia. It is an important stopping point for migratory birds, and it is also an ecologically sensitive environment exhibiting enormous diversity due to its geographical location, hydrology, biodiversity, and soil characteristics. Several dams have been built on rivers flowing into the lake, and the resulting decrease in the incoming freshwater supply has allowed for a greater backflow of water from the sea, thus impacting the main fishing activity in the lake by decreasing the eel stock. During the dry season, the water level falls to 30 cm depth while the salinity increases significantly. Fish production decreased from 110 tons in 2007 to 43 tons in 2011. In addition, the decrease of the water level has affected the food supply for migratory birds in the area.

This PEER project was focused on water management in the Ichkeul region. The PI and his colleagues investigated interrelationships among constraints on water and the supporting ecosystems under conditions of global climate and socioeconomic change. The team developed an advanced class of integrated models and support tools for decision makers, taking into account biophysical and socioeconomic drivers and governance integration for the management of Ichkeul.

Stakeholder engagement was a key priority for this project. The researchers are embedded in an active and engaged network of Tunisian scientists at three public institutions with a long history of research and development and regular cooperation with private stakeholders, governmental agencies, and local NGOs. Throughout the project, a participatory approach was used in order to implement feasible scenarios such as freshwater input, fishing controls, and infrastructures to be set up.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers carried out several field surveys, in the lake and watershed, recording in situ parameters and collecting water samples. As part of calibrations for the hydrodynamic model, they deployed a meter in the Tinja channel to gauge water exchange between the lake and the lagoon. Other field campaigns were carried out to measure eel stocks. Following the field surveys, the team undertook laboratory analysis and then numerical analysis to understand the functioning of the lake.

The PEER team developed a numerical model based on Random Forest theory to estimate the impact of climate change on eel production in the lake. In addition, the data collected were used to set up the LOICZ model of Lake Ichkeul, a user-friendly tool that the team shared with several stakeholders.

The team also carried out a separate study on the socioeconomic development of the region, exploring biological, hydrological, and socioeconomic data and the potential for tourism activities.

The U.S. partners on the project, Dr. Reginald Blake and Dr. Hamid Norouzi, visited Tunisia for a week in April 2023 to collaborate with the project team and take part in a workshop organized in collaboration with fellow PEER PI Dr. Fatma Trabelsi and her U.S. partner Dr. Amir AghaKouchak. The PI Dr. Béchir Béjaoui and his co-PI Dr. Sihem Chairat Ep. Ben Abdallah of the Centre des Recherches et des Technologies des Eaux (CERTE) visited the New York City College of Technology in June 2023 to continue collaborative discussions and present their work at a seminar. As part of this project, the PEER team also established connections with organizations like the National Environmental Protection Agency (ANPE), the Water Center (CERTE), the General Directorate of Fisheries and Aquaculture (DGPA), as well as several private companies involved in shellfish farming in the Bizerete lagoon.

As part of their dissemination efforts, the project team created the Bassiana database. which includes chemical, hydrological, and physico-chemical data and a trophic resource on the region. This database will be useful for collecting and sharing data with other institutions and researchers around the world, and the data will help policymakers, researchers, and stakeholders to mitigate the impacts of dams and climate change on the water balance and salinity of Ichkeul Lake. As an example, the team used the data through a coupled model to predict the effects of climate change and anthropogenic pressures on the fishery resources of Ichkeul Lake, in particular on the European eel species *Anguilla Anguilla*, which constitutes 60% of the total production of the lake. Another key dissemination activity was the conference the team organized on Sustainable Water Resources Management under Climate Change, which included presentations on various aspects of sustainable water resources management influenced by climate change. They also shared their findings in a variety of conferences, including the 3rd Symposium of Young Researchers and the International Conference on Innovation and Technological Advances for Sustainability. Going forward, the team has received an additional $145,000 grant to continue research through IHE-Delft.

PUBLICATIONS

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Sabrine Sahbani, Rachid Toujani, Nabiha Ben M'Barek, Ennio Ottaviani, Eva Riccomagno, Enrico Prampolini, Hechmi Missaoui, and Bechir Bejaoui. 2022. Effect of Climate Change and anthropogenic pressures on the European eel *Anguilla anguilla* from RAMSAR Wetland Ichkeul Lake: prediction from the Random Forest model. In Ninth International Symposium "Monitoring of Mediterranean Coastal Areas: Problems and Measurement Techniques," pp. 756-765. https://doi.org/10.36253/979-12-215-0030-1.72

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B. Béjaoui, L. Basti, D.M. Canu, et al. 2022. Hydrology, biogeochemistry and metabolism in a semi-arid mediterranean coastal wetland ecosystem. Sci Rep 12, 9367 (2022). https://doi.org/10.1038/s41598-022-12936-5

B. Brik, M. Shaiek, M., L. Trabelsi, et al. 2022. Quality Status of Surface Sediments of Lake Ichkeul (NE Tunisia): an Environmental Protected Area and World Heritage Site. Water Air Soil Pollut 233, 260 (2022). https://doi.org/10.1007/s11270-022-05648-z

TUNISIA - PROJECT 7-444: THE USE OF MODELING, MONITORING AND SMART METERING FOR SUSTAINABLE GROUNDWATER MANAGEMENT IN A TUNISIAN COASTAL AQUIFER

PI: Adel Zghibi, University Tunis El Manar
U.S. Partner: Ali Mirchi, University of Texas at El Paso (Funded by the United States Department of Agriculture/ National Institute of Food And Agriculture)
Dates: December 2018 – November 2021

PROJECT OVERVIEW

The sustainability of agricultural production in the Cap-Bon region of Tunisia is threatened by severe groundwater depletion and seawater intrusion. In the long run, these problems will limit the ability of the farming community to maintain agribusinesses. This PEER project sought to turn the threat of climate change impacts and groundwater depletion in coastal areas of Tunisia into an opportunity for socioeconomic development using novel technological solutions for optimizing agricultural production. The PI and his team used smart energy and water meters (SEWMs) paired with traditional agricultural extension approaches to addressing the problem of unsustainable agricultural water use. The researchers piloted a stakeholder-centered groundwater management network in Cap-Bon region and the Chiba watershed, used water resources modeling approaches to diagnose major causes of the groundwater table decline and investigated the potential of smart agricultural water management as an innovative strategy for creating new agribusiness opportunities.

FINAL SUMMARY OF PROJECT ACTIVITIES

During field visits, some of which included the participation of the U.S. partner Dr. Ali Mirchi and technical representatives of the SEWM manufacturer, the research team installed SEWMs for 25 local farmers, allowing them to control their energy and water consumption. They also gathered data on land use, land cover, irrigation techniques, pump characteristics, and hydrodynamic parameters of the farms. In follow-up visits, students engaged farmers in follow up questionnaires, recorded several water and energy measurements, and collected several water samples from the equipped wells.

The researchers, including a PhD student on the PEER team, used many types of water resource models, such as WEAP (Water Evaluation and Planning model) and SWAT (Soil and Water Assessment Tool), to study the sustainability of regional water resources management strategies. Students involved in the Tunisia Smart-Water project helped prepare cartographic layers to build the Chiba Basin model using ARC-GIS (such as climatic stations, tributaries, hydrometric stations, dams, sub-basins, etc.).

The team saw improved groundwater management at the farm and regional levels, as well as increased technology transfer and community engagement. The project also helped train water resources researchers and professionals in Tunisia on advanced water management technologies and provided research opportunities to students in Tunisia.

Team members presented their project at the 3rd Atlas Georesources International Congress online (AGIC2021), and the 3rd Euro-Mediterranean Conference for Environmental Integration, as well as published several academic papers. The PI received a new research grant for related work from the Franco-Tunisian joint committee for university cooperation.

PUBLICATIONS

Adel Zghibi, Amira Merzougui, Abubakarr S. Mansaray, Ali Mirchi, Lahcen Zouhri, Anis Chekirbane, Mohamed Haythem Msaddek, Dhekra Souissi, Amina Mabrouk-El-Asmi, and Abdelmadjid Boufekane. 2022. Vulnerability of a Tunisian coastal aquifer to seawater intrusion: insights from the GALDIT model. Water 14, 1177. https://doi.org/10.3390/w14071177

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Adel Zghibi, Ali Mirchi, Mohamed Haythem Msaddek, Amira Merzougui, Lahcen Zouhri, Jean-Denis Taupin, Anis Chekirbane, Ismail Chenini, and Jamila Tarhouni. 2020. Using analytical hierarchy process and multi-influencing factors to map groundwater recharge zones in a semi-arid Mediterranean coastal aquifer. Water 12(9):2525. http://dx.doi.org/10.3390/w12092525

Adel Zghibi, Ali Mirchi, Lahcen Zouhri, Jean-Denis Taupin, Anis Chekirbane, and Jamila Tarhouni. 2019. Implications of groundwater development and seawater intrusion for sustainability of a Mediterranean coastal aquifer in Tunisia. Environmental Monitoring and Assessment 191: 696. https://doi.org/10.1007/s10661-019-7866-5

TUNISIA - PROJECT 7-400: SOUTHERN TUNISIA CLIMATE HUB (STCH)

PI: Bouajila Essifi, Institut des Regions Arides
U.S. Partner: Steve Ostoja, United States Department of Agriculture, Agricultural Research Service and the University of California, Davis
Dates: November 2018 – October 2021

PROJECT OVERVIEW

Desertification affects approximately one-sixth of the world's population, 25 percent of the global land area, and 70 percent of all drylands, amounting to 3.6 billion hectares. The most obvious impacts of desertification, in addition to widespread poverty, are (1) the degradation of 3.3 billion hectares of the total area of rangeland, constituting 73 per cent of the rangeland with a low potential for human and animal carrying capacity; (2) the decline in soil fertility and soil structure on about 47 per cent of the dryland areas constituting marginal rainfed cropland; and (3) the degradation of irrigated cropland, amounting to 30 per cent of the dryland areas with a high population density and agricultural potential. Combating desertification must be part of a sustainable development that takes into account the different economic, environmental, social, and institutional dimensions, and therefore, opens the way for the implementation of early warning systems and helps policy- and decision-makers to set out relevant strategies for sustainable development.

The aim of this project was to develop and utilize inclusive approaches to addressing natural resource management, including water management, soil conservation, and land management, as well as addressing general sustainable development issues in two counties in southern Tunisia: Medenine and Tataouine. These areas have been long affected by land and water mismanagement combined with persistent drought under changing climatic conditions.

FINAL SUMMARY OF PROJECT ACTIVITIES

The STCH project laid the foundation for a long-term collaboration initiative involving scientists, land managers, farmers, decision makers to utilize climate-specific and adaptive knowledge. This joint initiative provides actionable information to land users, land managers, and other stakeholders. The team used this this platform to also engage the private sector and build capacity for IRA researchers, technicians, extension workers, students, and professionals from partnering local institutions, improving competencies in techniques, including those of date palm cultivation, and aquifer management. They also co-supervised graduate students to work research themes related to water and land resources management, ecosystem services.

TUNISIA - PROJECT 7-349: MONITORING OF ANTIMICROBIAL RESISTANCE OF BACTERIA FOR A BETTER HEALTH OF ANIMALS IN TUNISIA

PI: Lilia Messadi, Ecole Nationale de Médecine Vétérinaire de Sidi Thabet
U.S. Partner: Charlene Jackson, U.S. National Poultry Research Center (Funded by the United States Department of Agriculture/ Agricultural Research Service)
Dates: January 2019 – October 2023

PROJECT OVERVIEW

Antimicrobial resistance (AMR) is a major risk for human, animal, and environmental health, with an increasing risk of moving towards a "post-antibiotic era" where common infections could kill humans and animals. According to one study, between 2000 and 2015, Tunisia ranked as the world's second highest country for consumption of antibiotics, which is very concerning, as there is a direct relationship between antibiotic consumption and AMR. As of the time this project was conducted, the country did not yet have a national strategy for monitoring the AMR of bacteria isolated from animals.

The objective of this PEER project was to survey AMR of bacteria at the animal/human/environment interface by targeting animals, food of animal origin, and pests (rats and cockroaches). By undertaking an epidemiological study of resistance, Dr. Lilia Messadi and her team sought to identify the risk factors in husbandry practices and in veterinary use of antibiotics and suggest corrective measures to reduce AMR. The researchers focused primarily on smallholder farmers with limited income, to provide them with added value through health education messages in order to improve hygiene and prevent infectious diseases of animals. The project also included practical training of laboratory technicians and students to improve monitoring methods, as well as workshops and seminars for students and veterinarians to improve the use of antibiotics to reduce the frequency of resistant bacteria.

FINAL SUMMARY OF PROJECT ACTIVITIES

The researchers studied phenotypic resistance to antibiotics using antibiograms and molecular PCR tests. During this work they optimized molecular methods to identify genes associated with the resistance phenotype of bacteria. These techniques will be available for other work done using PCR. The PEER team undertook AMR studies across different animal species, including production animals (broiler chickens, cattle, sheep, camels), pets (dogs, cats, horses, donkeys), harmful animals (cockroaches, flies and rats), and wildlife (wild boars).

The team took stock of the antimicrobial resistance of commensal bacteria, considered important sentinel bacteria to monitor for zoonotic risk, as well as bacteria of the *Staphylococcus* and *Campylobacter* genera. The bacteria studied present a risk for humans and animals, which corresponds to a zoonotic risk.

The PEER project supported a significant effort in terms of training, including supervising 28 doctoral theses in veterinary medicine, 19 of which were completed by women. Team members have already published a variety of articles and presented their results at eight conferences. The PI and her team led frequent practical training sessions on bacteriology, during which they raised the students' awareness of the risks presented by AMR. This practical work allowed the students to do their own manipulations in the lab, in particular on the antibiogram or antibiotic sensitivity test (AST). During the project period, the PEER team was also awarded two new grants for international collaborations with research teams in Germany, Canada, Spain and France.

PUBLICATIONS

Ghassan Tayh, Salma Mariem Boubaker, Rym Ben Khedher, Mounir Jbeli, Monia Dâaloul-Jedidi, and Lilia Messadi. 2023. Prevalence, characterization and antimicrobial resistance of non-O157 Shiga toxin-producing *Escherichia coli* isolates from healthy cattle in Tunisia. Acta Veterinaria Hungarica 71(2): 71-81. https://doi.org/10.1556/004.2023.00904

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Asma Ben Haj Yahia, Ghassan Tayh, Sarrah Landolsi, Elaa Maamar, Nejia Galai, Zbaida Landoulsi, Lilia Messadi. 2023. First report of OXA-48 and IMP genes among ESBL-producing *Escherichia coli* isolates from diarrheic calves in Tunisia. Microbial Drug Resistance 2023 Apr; 29(4):150-162. https://doi.org/10.1089/mdr.2022.0129

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TUNISIA - PROJECT 7-289: IMPROVING SUSTAINABLE GROUNDWATER MANAGEMENT: A MAJOR CHALLENGE IN THE OVER-EXPLOITED MEDJERDA BASIN (NORTH TUNISIA)

PI: Fatma Trabelsi, University of Jendouba
U.S. Partner: Clifford I. Voss, U.S. Geological Survey
Dates: January 2019 – June 2023

PROJECT OVERVIEW

Water scarcity and pollution are severe problems in Tunisia, seriously affecting socioeconomic development. In the northwestern regions of Tunisia crossed by the Medjerda River, groundwater resources are being increasingly exploited. Unfortunately, not only over-exploitation of groundwater but also agricultural and industrial practices in the region and saltwater intrusion into the coastal aquifers have led to significant water quality degradation. Moreover, the population is not sufficiently aware of how critical the water resources situation is to become positively involved in water resources management. The lack of accurate data on Medjerda basin groundwater resources undermines the capacity of decision-makers and water users to understand and sustainably manage water resources. In particular, when this project began, there was no existing GIS-based tool for Integrated Water Resources Management (IWRM) for the Medjerda River basin, which is Tunisia's main water resource. Surface and groundwater resource spatial data were scattered among various organizations and in formats that are difficult for non-experts to understand or use. The consequences of these factors are poor planning and unclear understanding of groundwater resources management by decision makers.

Thus, the key objective of this project was to implement an innovative approach to improve sustainable groundwater management for the Medjerda basin. The expected outcomes of the project are based on three main pillars: (1) overall initial assessment of groundwater resources availability and quality, (2) data management and numerical simulation of water resources, and (3) capacity development. The PI and her team aimed to implement a "smart" water monitoring system and develop a GIS-integrated modelling platform for simulation of groundwater quantity and quality that can be used by managers in water resource decision making.

FINAL SUMMARY OF PROJECT ACTIVITIES

The PI Dr. Trabelsi and her team developed a surface and subsurface geodatabase for the Lower valley of the Medjerda basin (LVM) and used it to establish a geospatial platform for strengthening evidence-based decision-making in the water resource management sector. This platform boasts several geospatial layers and a dashboard of statistical series with metadata records, bringing together geographic information and statistical data. It serves as a digital public good to create interactive data maps, analyze trends, and identify real-time gaps and opportunities. The researchers also created a Decision Support System Tool (DSS) by setting up a smart groundwater monitoring system to gather accurate time-continuous data needed for groundwater stakeholders. As of the project's completion date in 2023, this smart system is the first real-time groundwater system connected with the IoT platform set up in Tunisia, and it is is hosted on the website of the Ministry of Agriculture, Water

Resources and Fisheries of Tunisia. The PEER team has also created and honed models simulating groundwater flow and contamination and the impact of climate change on water resources.

This PEER project had a strong impact on capacity building in data science and modeling for several Tunisian researchers, professionals, and students through the large number of workshops and trainings organized by the project team. In total, the project organized three international conferences, two national conferences, six workshops, two summer schools, and four webinars. The project also produced a new course entitled Application of Remote Sensing and IoT in Water Management, which has been added to the curriculum of the research Master's program at the Higher School of Engineers of Medjez El Bab (ESIM). PEER funds also supported the visits of the U.S. partners, Clifford Voss and Amir AghaKouchak.

Furthermore, the project has strengthened the role of women scientists in water management by improving their participation in scientific events, training, and meetings with decision-makers. The project funded research activities that enabled several participants to obtain advanced degrees: one *Habilitation Universitaire* (a Tunisian degree beyond the PhD that allows its holder to lead research projects), two PhD, eight Master's degrees, and four engineering degrees. PEER funds supported a six-month fellowship in Spain by a female PhD student, Salsebil Bel Hadj Ali, as well as collaborative research and conference travel to France and the United States by the PI and other team members.

Additionally, the project has improved the scientific collaboration and synergy between young researchers and government, non-government, and private organizations. Stakeholder engagement and participatory approaches for water diplomacy were used during the implementation of project activities for developing trust, consensus, and communication and stimulating the water reform process. Dr. Trabelsi and her team convened numerous awareness and technical meetings and signed cooperative agreements to implement project activities. Thanks to the new groundwater sensor network funded by PEER and the database and decision support system Dr. Trabelsi and her colleagues have created, they are well positioned to contribute to the aim of better water resource management in Tunisia and beyond.

PUBLICATIONS

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Fatma Trabelsi and Salsebil Bel Hadj Ali. 2022. Exploring machine learning models in predicting irrigation groundwater quality indices for effective decision making in Medjerda River Basin, Tunisia. Sustainability 2022, 14, 2341. https://doi.org/10.3390/su14042341

TUNISIA - PROJECT 7-271: IMPACT OF ROOFTOP PV SYSTEM INTEGRATION ON TUNISIAN ELECTRICAL DISTRIBUTION NETWORK

PI: Ilhem Slama-Belkhodja, Ecole Nationale d'Ingénieurs de Tunis
U.S. Partner: Jonghyun Park, Missouri University of Science and Technology
(Funded by the National Science Foundation)
Dates: November 2018 – October 2021

PROJECT OVERVIEW

This project aimed to study rooftop photovoltaic (PV) system integration effects on Tunisian electrical distribution network (EDN). Solar PV energy has been promoted for residential use for several years in Tunisia, where electrical energy consumption in residential sector makes up more than 30% of total electricity consumption. In particular, the project used the Power Hardware-in-the-Loop (PHIL) approach to investigate some solutions considered as promising to cope with voltage and frequency variations due to PV system integrations in the EDN, considering Tunisian conditions. This project generated a dataset in the field of PV residential load profiles, which served as the basis for establishing Tunisian computer models. The project team ran these models in real-time while using a hardware test setup to validate a holistic PV-battery energy storage inverter. The control was then be applied across a Tunisian EDN under different loading scenarios and with varying penetrations of PV-only and PV-energy storage units combined. The PHIL-based testbed created will allow researchers and manufacturers to safely evaluate energy technologies performance and reliability, autonomous devices and their control parameters and their interaction with Tunisian EDN.

The global aim of the proposed project was to assist national policy makers and the main institutions responsible for the development of renewable energies in Tunisia to evaluate Tunisian PV rooftop capacity. The resulting analysis could be used to adopt more appropriate strategies to secure sustainable distribution in the future. It can also help provide private investors or manufacturers of energy technologies with an experimental platform for first evaluation of their new products. The project engaged, motivated, and trained Tunisian students as well, preparing them for the workforce in the interdisciplinary area of energy, power, and control through the development of various science activities.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project brought together numerous facets of research, modeling, training, technical design, and commercialization to develop its MICROGRID platform (MGP), a platform with state-of-the-art equipment and operation according to emerging concepts that involve researchers from several disciplines. It is a testbed environment to identify and develop Tunisia's electrical grid using modern components and concepts under complex scenarios. The details of the technical work, investigations, results and impact will be grouped in a technical public report available on the project website and on http://www.lse-qehna.tn/.

On the production side, the team worked to determine the IV characteristic of PV arrays under partially shaded conditions. The team was able to develop and accurate model to predict the output of a real PV array under complex operating conditions. These I-V curves can form a database and the comparison of a measured IV curve and those of the database can be used to determine the partial shadow condition and detect possible failures caused by soiling or the existence of an obstacle on the PV cells such as leaves or neighboring buildings. The model was tested on existing PV installations and case studies were done to minimize the impact of mismatching.

The team also researched energy storage technologies and developed an electro-thermal model that allows to follow the evolution of the battery states (voltage, current, internal temperature). The model, combined with a series of tests resulted in a battery energy storage system as a potential solution to mitigate impact of rooftop PV on distribution network. Further testing is ongoing to understand its efficiency and effectiveness.

From a consumption angle, the team designed and generated a “Home Appliances Electrical Signature Database” (HAESD) that provides users with data related to the electrical and harmonic behavior of different types of appliances. This database can be used to build data-driven model of home load behavior in microgrid energy management context. HAESD Database implementation and generation aimed at offering a platform including Hardware from National Instruments (data acquisition system, current and voltage sensors) and software namely LabVIEW, that can be used to acquire one or more periods of voltage and current that supply a given appliance and then to determine all its electrical and harmonic characteristics and signatures according to IEEE 1459-2010. This database is planned to interface with the existing grid. Tunisian grid data will be provided after MOU signature and the impact of grid faults will be investigated, particularly those due to rooftop PV. The home energy management system is under development based on MGP data with the participation of industrial Partners

The above work has been conducted with active engagement of both the private sector and government stakeholders. The team has met frequently regarding Tunisian standards and Tunisia’s strategic plan for integration of electric cars. The government is also interested in the creation of a common research services unit called the MICRPGRID Platform (USCR-MGP). It is a unit approved by the PI's supervising ministry that will allow them to evaluate their skills and the MGP developed within the framework of funded MOU, therefore allowing the team to raise funds to finance the maintenance of the platform and associated.

Private sector engagement has been consistent and diverse. The team met with the Tunisian Company of Electricity and Gas (STEG) which aims to develop an experimental platform for the training of its own technical staff and sought the project’s expertise. Similarly, companies like GAMCO Energy are interested in the team’s skills because they want to develop their business to sell microgrids and customized solutions for African market and Lightency.io which aims to develop customized EMS (Energy Management Systems), integrating the specific constraints of Tunisian, African, and European markets. This interest is being finalized by an MOU.

Beyond the commercial and societal aspects of the project, the team updated a number of course modules and has attracted students to work in the field with the possibility to perform investigations in the field with experimental validation. For example, a Thesis Agreement was signed with the STEG, which financing for theses on power quality improvement devices.

PUBLICATIONS

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TUNISIA - PROJECT 7-184: DEVELOPING ORGANIC SOIL MANAGEMENT TECHNOLOGIES TO ENHANCE CARBON CAPTURE, CLIMATE ADAPTABILITY, AND SUSTAINABILITY OF SMALLHOLDER FARMS IN TUNISIA

PI: Khaled Sassi, National Agronomic Institute of Tunisia
U.S. Partner: Anil Somenahally, Texas A&M Agrilife Research (Funded by the United States Department of Agriculture/ National Institute of Food and Agriculture)
Dates: November 2018 – March 2023

PROJECT OVERVIEW

Among many constraints for sustainable agriculture production on smallholder farms in Tunisia is the declining quality of soil resources and unsustainability and vulnerability of smallholder farms to yield loss and climate change effects. While there are some larger farms, most Tunisian farmers have around 10 acres or less. This project addressed water management, soil conservation, land management, biodiversity, and energy diversification in Tunisia. The researchers sought to develop novel soil management technologies to increase soil quality, carbon capture, and climate adaptability on smallholder farms of Tunisia, integrated with locally relevant crop rotations.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Sassi and his colleagues set up experiments in four different locations: Manouba, Sidi Bouzid, Sousse, and Gabes. In each location, they constructed three different kinds of composting windrows in pyramidal form and evaluated them for physico-chemical and microbiological characteristics. The composition of each windrow varied according to the most common agricultural wastes found in various study site locations. Among the findings were the multiple effects of date palm compost on the proteomic pattern of barley crops. The PEER team's results showed a complex regulatory network triggered by compost and provided new insight into the molecular mechanisms of plant responses to use of this organic fertilizer.

In a separate study, the researchers found date palm waste compost application resulted in significantly higher bacterial and fungal abundance, especially at the tillering and ripening barley growth stages. Greater fungal diversity and abundance of bacterial and fungal communities could play an important role in the capacity of compost-treated soils to inhibit soilborne plant diseases and promote beneficial microorganisms, in turn increasing the availability of essential nutrients to barley plants.

The researchers also evaluated the effects of two soil management systems—conservation agriculture (CA) and conventional tillage (CT)—on the grain composition and nutritional value of two durum wheat varieties grown over two cropping seasons. During the 2021-2022 cropping season, they worked on ten demonstration plots in two regions in northwest Tunisia: six plots under conservation agriculture based on no-tillage and minimum tillage in Gueboulat region and four plots for forage mixtures all including the vetch plant (vetch-triticale, vetch-oat and vetch-triticale-oat) in the Seres region. The team monitored soil organic carbon, soil microbial activity, soil moisture, biomass, and yield components. Among their results were enhanced soil fertility in conservation agriculture compared to conventional agriculture and an improvement in water use efficiency of cereal crops (wheat and barley) by 20%.

The PEER team published several papers on their findings and the PI presented the project results at the first U.S.-Africa Frontiers of Science, Engineering, and Medicine symposium. The PEER team and the PI's institution held a training on organic fertilization and composting in organic agriculture, which 35 people attended. There were also significant capacity building opportunities for individual team members. In November 2022, Dr. Yassine Hidri visited the U.S. partners at Texas A&M University for two weeks of training on the investigation and measurement of chemical, physical, and biological properties of soil that can be used to better design sustainable agricultural systems. He also participated in a soil sampling campaign using a specialized mechanical coring drill. PEER funds also supported two month-long research visits in 2021 and 2023 by Dr. Ghassen Abid to the Walloon Agricultural Research Center in Belgium. U.S. partners Dr. Anil Somenahally and Dr. Jeffrey Brady also visited Tunisia in January 2023 to visit demonstration fields and discuss the project and potential continued collaborations. The results from the project were integrated into four courses across three universities.

The PEER team has also begun collaborations with several NGOs and regional agricultural centers in Tunisia to work on developing new agricultural strategies and disseminating knowledge from the project. The equipment purchased with PEER support (a large compost grinder and a windrow turner) have enhanced the infrastructure available for continuing the work in the future.

PUBLICATIONS

Imene Kerbouai, Dorra Sfayhi, Khaled Sassi, Hatem Cheikh M'hamed, Houda Jenfaoui, Jouhaina Riahi, Slim Arfaoui, Moncef Chouaibi, and Hanen Ben Ismail. 2023. Influence of conservation agriculture on durum wheat grain, dough texture profile and pasta quality in a Mediterranean region. Agriculture 2023, 13, 908. https://doi.org/10.3390/agriculture13040908

Emna Ghouili, Khaled Sassi, Yassine Hidri, Hatem Cheikh M'Hamed, Anil Somenahally, Qingwu Xue, Moez Jebara, Rim Nefissi Ouertani, Jouhaina Riahi, Ana Caroline de Oliveira, Ghassen Abid, and Yordan Muhovski. 2023. Effects of date palm waste compost application on root proteome changes of barley (*Hordeum vulgare L.*). Plants 12, 526. https://doi.org/10.3390/plants12030526

Marwa Laribi, Amor Hassine Yahyaoui, Wided Abdedayem, Hajer Kouki, Khaled Sassi, and Sarrah Ben M'Barek. 2023. Characterization of Mediterranean durum wheat for resistance to *Pyrenophora tritici-repentis*. Genes 13, 336. https://doi.org/10.3390/genes13020336

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Emna Ghouili, Yassine Hidri, Hatem Cheikh M'Hamed, Anil Somenahally, Qingwu Xue, Ibrahim El Akram Znaïdi, Moez Jebara, Rim Nefissi Ouertani, Yordan Muhovski, Jouhaina Riahi, Ghassen Abid, and Khaled Sassi. 2022. Date palm waste compost promotes plant growth and nutrient transporter genes expression in barley (*Hordeum vulgare L.*). South African Journal of Botany 149: 247-257. https://doi.org/10.1016/j.sajb.2022.06.018

Imene Kerbouai, Hatem Cheikh M'hamed, Houda Jenfaoui, Jouhaina Riahi, Khaoula Mokrani, Sarra Jribi, Slim Arfaoui, Khaled Sassi, and Hanen Ben Ismail. 2022. Long-term effect of conservation agriculture on the composition and nutritional value of durum wheat grains grown over 2 years in a Mediterranean environment. Journal of the Science of Food and Agriculture 102(15): 7379-7386. https://doi.org/10.1002/jsfa.12105

TUNISIA - PROJECT 6-308: EVALUATION OF ALGAL TREATMENT OPTIONS FOR OLIVE MILL WASTEWATER TO PRODUCE ENERGY AND BIOFERTILIZER

PI: Sami Sayadi, Center of Biotechnology of Sfax
U.S. Partner: Anthony Siccardi, Texas A&M University (Original Partner: Walter Mulbry, Funded by the United States Department of Agriculture/Agricultural Research Service)
Dates: December 2017 – December 2022

PROJECT OVERVIEW

The conventional olive mill wastewater (OMW) treatment methods adopted in Tunisia are either costly or ineffective, causing environmental pollution. This project was aimed at developing an eco-friendly and cost-effective microalgal-based process for olive mill waste treatment and recycling. Such a process should result in the production of (1) treated and reusable OMW for ferti-irrigation use, contributing to resolving the water scarcity problem; (2) renewable biomass useful for clean energy production, particularly bio gas; and (3) bio-fertilizers for agricultural use, using the process by-products, bio char and sludge.

The project encompassed several disciplines and coupled physical and biological technologies to achieve the target objectives, including pyrolysis, physical adsorption, micro algae cultivation with OMW treatment and CO_2 mitigation, anaerobic digestion, and composting. The project also fostered linkages among the R&D sector (universities and research institutes) with enterprises involved in waste production (farms and olive mills), enterprises producing devices necessary for treatments, enterprises interested in the use of by-products, and farmers. This approach created a cooperative network for reducing agricultural waste impacts on the environment, exchanging know-how and market intelligence, and developing research capacity and new markets.

Beyond the technological aspects, the project also involved the collection and assessment of data to support decision-makers for the promotion of sound strategies and best practices for social, economic, and legislative measures at the regional and national levels regarding agricultural waste management. Going forward, it is expected to generate business opportunities and create jobs in small and innovative companies for commercializing the process outcomes.

FINAL SUMMARY OF PROJECT ACTIVITIES

The objective of this project, which ended on December 31, 2022, was the development of an eco-friendly and cost-effective microalgal-based process for olive mill waste (OMW) treatment and recycling for the production of (1) treated and reusable OMW for ferti-irrigation use, contributing to solving water scarcity problems), (2) renewable biomass useful for clean energy production, in particular, biogas, and (3) bio-fertilizers for agriculture use produced from the process by-product, the biochar, and sludge. Dr. Sayadi reports that his team's findings obtained during the project have facilitated the creation of a cooperative network of Tunisian researchers, international partners, and local NGOs for reducing the agricultural waste impact on the environment and exchanging know-how and market intelligence to develop research capacity. The project results also contributed to the development of a new sustainable concept for olive industry waste management and development of value-added by-products. For example, the production of biogas from the produced micro-algal biomass can be used to generate electricity and heat, as well as biodiesel production, ultimately reducing greenhouse gas emissions. High-added-value molecules (lipids, proteins, carotenoids, chlorophyll, etc.) can be extracted for biofuel, cosmetics, and nutraceutical applications. Sludge and biochar can be used for soil treatments and treated OMW for ferti-irrigation, thus contributing to preserving precious freshwater resources, especially in semi-arid countries like Tunisia.

The research carried out during the project's five-year term had resulted in four peer-reviewed publications by the time the final report was submitted in late January 2023. There were also valuable capacity building benefits for the 32 members of the project team, 26 of whom were female. These included four undergraduates and one Master's student who completed their required theses based on their research conducted as part of the project. The two U.S. partners on the project visited Tunisia in July 2019 to offer their guidance, and Tunisian postdoc Dr. Ahlem Jebali was supported to present her work at the IWAlgae conference in Spain in June 2019. PEER funds also provided for a substantial upgrade in the technical infrastructure at the PI's lab, including a fluorescent microscope, mixer mill, spectrophotometer, peristaltic pump, fume hood, universal light meter, pilot-scale pyrolysis reactor, photometer, and analytical balance.

Even now after the project has ended, Dr. Sayadi reports that his research group will continue working on microalgae cultivation using pre-treated OMW and characterization of microalgae biomass for potential high-value-added molecule recovery and biodiesel production. Their study of anaerobic digestion of algal biomass will be carried out in bioreactors. Under the PEER project, they began with anaerobic digestion of microalgae (*Senedesmus, Chlorella,* and *Picocystis*) produced on the different pretreated OMW (by ultrafiltration, biochar, and coagulation-flocculation treatments) in batch cultures, and they plan to develop an anaerobic up-flow fixed bed reactor for biogas production. The spent biochar from the pretreatment of OMW, the treated OMW, and the sludge produced from the anaerobic digestion will also be used as soil fertilizers in future planned studies. The development of bio-fertilizers for agricultural use produced from olive processing by-products, biochar, and sludge are still a work in progress. In order to reduce the impact of agricultural waste on the environment, the PI and his team plan to organize an open day to explain the utilization of olive mill by-products and train farmers on better exploiting these products in ferti-irrigation and soil fertilization. The ongoing work will be well supported thanks to grants awarded by the Tunisian National Ministry of Higher Education and Scientific Research and the German Federal Ministry of Education and Research.

PUBLICATIONS

Amina Maalej, Ines Dahmen-Ben Moussa, Fatma Karray, Mohamed Chamkha, and Sami Sayadi. 2022. Olive oil by-product's contribution to the recovery of phenolic compounds from microalgal biomass: biochemical characterization, anti-melanogenesis potential, and neuroprotective effect. Biomass Conv. Bioref. https://doi.org/10.1007/s13399-022-02640-9

Raida Karray, Wiem Elloumi, Rihab Ben Ali, Slim Loukil, Mohamed Chamkha, Fatma Karray, and Sami Sayadi. 2022. A novel bioprocess combining anaerobic co-digestion followed by ultra-filtration and microalgae culture for optimal olive mill wastewater treatment. Journal of Environmental Management 303 (2022) 114188.
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Ines Dahmen-Ben Moussa, Mohamed Ali Masmoudi, Sirine Choura, et al. 2021. Extraction optimization using response surface methodology and evaluation of the antioxidant and antimicrobial potential of polyphenols in *Scenedesmus sp*. and *Chlorella sp*.. Biomass Conv. Bioref. https://doi.org/10.1007/s13399-021-01850-x

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TUNISIA - PROJECT 5-518: DIAGNOSIS OF CUTANEOUS LEISHMANIASIS: DEVELOPMENT AND EVALUATION OF MULTIPLEX POC DNA ASSAYS

PI: Ikram Guizani, Institut Pasteur de Tunis

U.S. Partner: Steven Reed, Infectious Disease Research Institute (Funded by the National Institutes of Health)

Dates: March 2017 – January 2023

PROJECT OVERVIEW

In the Old World, 1 million cutaneous leishmaniasis (CL) cases are reported each year. Some 80% of these cases occur in the Middle East and North Africa (MENA) region, caused by the four *Leishmania* species: *L. major*, *L. tropica*, *L. infantum*, and *L. donovani*. The MENA region is also at an increased risk for disease emergence and epidemics. Parasite detection and identification is central to treatment, patient management, epidemiology, and control. Currently, diagnosis is done by direct examination of lesion smears, a technique lacking sensitivity that does not allow for parasite identification. Laborious PCR tests allow their identification in well-equipped settings.

This project team, which includes researchers from Tunisia, Morocco, and Lebanon, aimed to deliver a novel, sensitive, specific, rapid, and low-cost point-of-care (POC) CL diagnosis test to detect and identify the four *Leishmania* parasites in the Old World, using multiplexed isothermal Recombinase Polymerase Amplification (RPA) of DNA, coupled to lateral flow chromatography (LF) for the detection of the DNA products. They designed and selected species-specific primers and probes for sensitive amplification of DNA in single-target reactions. Upon screening, the most relevant RPA-LF tests were then be combined to amplify and detect multiple targets (multiplex RPA-LF) in a single assay, thus enabling simultaneous sensitive detection and identification of the four *Leishmania* species. Proof-of-principle evaluation of this test was carried out in the laboratory on clinical samples from selected sites in the MENA region with appropriate institutional review board approval. The newly developed test was then compared to direct examination and a valid real-time PCR screening for parasite detection and to PCR-RFLP assay of ITS1 genes for identification. This study also helped to strengthen capacity building and empower young researchers while tackling public health research and development priorities using novel technologies and networks for technology transfer, research translation, implementation, and commercialization.

FINAL SUMMARY OF PROJECT ACTIVITIES

The main aim of this study was to address needs in cutaneous leishmaniases (CL) diagnosis in the Old World (OW) for point of care (POC) diagnostic tests that are low cost, rapid (<1h), reliable, simple, sensitive, and species-specific. The researchers worked to develop lateral flow tests for concomitant detection and identification of the most prevalent *Leishmania* (*L.*) species in the OW: *L. major* (*L.m*), *L. tropica* (*L.t*) and *L. infantum* (*L.i*; expected cross-reaction with *L. donovani, L.d*). They also aimed at building capacity and networks for translation and POC test implementation in health structures.

The team adopted Recombinase Polymerase Amplification (RPA) with the detection of amplicons by lateral flow chromatography (LF). First, they developed the study protocol and procedures and had them reviewed by the Ethical Review Boards of the Institut Pasteur de Tunis, Institut Pasteur du Maroc, and Rafik Hariri Hospital, Lebanon, to ensure ethical standards and good practices across the consortium. Policies, procedures, and relevant training were put in place regarding research ethics, good lab practices, and data management and confidentiality. The sample and data collection were done at the study sites in Tunisia, Lebanon, and Morocco following a harmonized data collection sheet. For efficient data collection and management, the team developed a web-based application, Lesionia (www.lesionia.pasteur.tn), which provides all registered users with real-time data entry, retrieval, updating, and analysis. Then, they developed mLesionia, a mobile version that offers in addition an "on-the-go" advantage over Leisionia. It was provided to healthcare facilities and agencies for validation during the project closing workshops.

The team collected a total of 298 well-documented cutaneous samples from consented patients referred for routine diagnosis to parasitology departments in Tunisia (213), or treatment in Lebanon (14), or during field visits in endemic foci in Morocco (71). The DNA was then extracted from the samples and analyzed to identify markers for the various *L.* species and strains, after which primers and probes for each were designed. The researchers next focused on developing Multiplex RPA assays for simultaneous detection and identification of *L*. species. They set multiplex basic RPA tests by screening 11 primer combinations. For the LF detection, due to the timeline, high costs of development, and unavailability of multiple line antibody-based devices, they opted for customized multiline dipsticks for DNA-DNA detection. Two out of the 11 tested combinations were kept and used in a Taguchi experimental design adopted to define best reaction factors, which are now being studied.

Although the PEER project has ended, Dr. Guizani and her team will continue working on various aspects of the research. The available version of mLesionia will be tested for its ergonomic potential and stability by selected end users and will be subject to continuous enhancement to better meet their expectations. The developed tests will be applied to larger number of cutaneous samples, and samples with ambiguous results will be tested using other molecular tests to properly assign species to the corresponding samples. A Material Transfer Agreement will be signed to collect additional *L. infantum* samples from Morocco for use in further evaluations of the *L. infantum*-specific test. The team will continue working on the set-up of the multiplex RPA/LF assays and testing the reproducibility of the selected multiplex test on well characterized Leishmania DNA. The end goal, of course, is to produce a well-proven clinical diagnostic tool that can be put into practice in the healthcare system in Tunisia and beyond. In addition to the multiplex PCR developed in Dr. Guizani's lab, an algorithm will be elaborated and evaluated at the Clinical Investigation Center of the Institut Pasteur de Tunis. Additional workshops and training sessions will be organized to ensure the transfer of the developed tools to the team's partners at Hospital Farhat of Sousse, Tunisia, as a first step, after which it will be extended to other national and international partners. The researchers are finalizing research articles and a policy paper on the results from their project, and they plan to submit patent applications for the primers/probe sets developed as tools for *Leishmania* species diagnosis.

Following the research-to-action plan developing with guidance provided by USAID's Research Technical Assistance Center, Dr. Guizani and her colleagues have taken the initiative to gather and lead an African consortium dedicated to capacity building in research, training, and evidence-based policy to control leishmaniases. The consortium involves Algeria, Ethiopia, Mali, Morocco, Nigeria, Sudan, Tunisia, and Spain, with collaborators in Morocco, Tunisia, and the United States. Funding support for the consortium is being provided by a grant from the Science for Africa Foundation. Through this program, Dr. Guizani and her colleagues will be able to develop studies related to POC diagnostics evaluation, implementation involving control programs, cost-effectiveness analysis, and policy briefings. They will also promote the use of DNA tools to develop risk predictive and distribution maps and to support vector and reservoir control.

Beyond its research results, the project was also valuable for the scope of the opportunities it provided to its majority-female team for training, career progress, and networking. The project included hands-on training workshops on the cutting-edge DNA methods used in the project, on the Leisionia and mLeisionia platforms, and on the RPA LF tests developed. Thanks to their participation in the project, the younger researchers involved were encouraged and mentored in progressing in their careers and taking up new leadership roles as they engaged in networks and innovative projects and collaborations.

PUBLICATIONS

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Daoui O, Bennaid H, Kbaich MA, Mhaidi I, Aderdour N, Rhinane H, Bouhout S, Akarid K, Lemrani M. 2022. Environmental, climatic, and parasite molecular factors impacting the incidence of cutaneous Leishmaniasis due to *Leishmania tropica* in three Moroccan foci. Microorganisms 2022, 10, 1712. https://doi.org/10.3390/microorganisms10091712

Bel Hadj Ali I, Chouaieb H, Saadi Ben Aoun Y, Harigua-Souiai E, Souguir H, Yaacoub A, Oussaïma El Dbouni, Zoubir Harrat, Maowia M. Mukhtar, Moncef Ben Said, Nabil Haddad, Akila Fathallah-Mili, Ikram Guizani. 2021. Dipeptidyl peptidase III as a DNA marker to investigate epidemiology and taxonomy of Old World *Leishmania* species. PLoS Negl Trop Dis 15(7): e0009530. https://doi.org/10.1371/journal.pntd.0009530

Daoui O., M. Ait Kbaich, I. Mhaidi, S. El Kacem, L. Hjiyej Andaloussi, K. Akarid, and M. Lemrani. 2020. The role of sampling by cotton swab in the molecular diagnosis of cutaneous Leishmaniasis. Transbound Emerg Dis. October 22, 2020. doi: 10.1111/tbed.13886. Online ahead of print. PMID: 33094519

TUNISIA - PROJECT 5-195: POTENTIAL OF CURRENTS ALONG THE TUNISIA COASTS FOR RENEWABLE POWER GENERATION

PI: Ali Harzallah, National Institute of Marine Science and Technologies
U.S. Partner: Wassila Thiaw, National Oceanic and Atmospheric Administration
Dates: December 2016 – August 2021

PROJECT OVERVIEW

This PEER project developed a high-resolution modeling system for marine waters along the Tunisian coast using NOAA atmospheric and oceanic forcing fields. The modeling system includes maps of the marine areas where ocean energy can be potentially used for power generation. The project aimed to provide information on the circulation of water masses along and off the Tunisian coast, in particular information on circulation veins at a high resolution. The researchers also developed water temperature and salinity maps, and the model results were validated by direct observations in the sea using NOAA analytical tools.

Results from the project may help in the creation of renewable energy alternatives by the Tunisia Electricity Company, and as well as be helpful for several other applications, including offshore aquaculture production and impact studies for desalination plants. The project was a valuable opportunity for building the capacity at the National Institute of Marine Science and Technologies (INSTM), as the PEER research team and the broader INSTM community gained knowledge on the use of high-resolution ocean models and outputs and built valuable international linkages.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Harzallah and his group ran three 10-year simulations (2008-2017) for marine elements, including circulation alone; circulation and tides; and circulation, tides and waves. The three simulations allowed the team to separate out the relative roles of water circulation, tidal oscillations, and waves and their contributions to marine energy potential. In addition to the model simulations, they considered results from drifter trajectories using data from the Global Drifter Program NOAA-OSMC-PhOD, calculating and plotting the trajectories to evaluate their energy potential. For example, drifters accelerate when passing in front of the Cap Bon coasts in northeastern Tunisia, the main area of strong marine current power shown by the model simulations.

The researchers also analyzed offshore wind based on the most recent available data sets to examine locations where wind turbines can be installed. Based on their model results, the PEER team developed maps of water characteristics and circulation along the Tunisian coast with descriptions of where marine dynamics and offshore wind can be used for power generation. The main areas identified are as follows: offshore wind power using fixed turbines east-northeast of Kerkennah; offshore wind power using floating turbines north of Bizerte, north-east of Ghar El Melh coasts, and east of Djerba; a main water vein of the northeastern coasts of Cap Bon; and tidal-motive energy in certain channels and in the Gulf of Gabès.

The PI and team also began developing an application to forecast sea power in 10-day increments, and the PI participated in several workshops and meetings to present results and discuss potential future partnerships with the National Electricity Renewable Energy Company and other Tunisian government stakeholders. The PEER project also resulted in a formal agreement between INSTM and MEDREC (Mediterranean Renewable Energy Centre) to permit close collaboration between the institute and MEDREC in different aspects related to renewable energy. The PI also received a $25,000 grant from the Tunisian Ministry of Higher Education and Scientific Research to continue work on renewable energy. At the time of their final report, they were pursuing several potential funding opportunities from European and Tunisian sponsors.

PUBLICATIONS

Marwa Ouni, Avichal Mehra, and Ali Harzallah. 2021. The effect of the temporal resolution of the wind forcing on a central Mediterranean Sea model. Dynamics of Atmospheres and Oceans 96: 101262. https://doi.org/10.1016/j.dynatmoce.2021.101262

Sana Chaouch and Ali Harzallah. 2020. A zoomed 3D circulation model for the Monastir bay: comparison to operational analyses. Bull. Inst. Natn. Scien. Tech. Mer de Salammbô 47: 157-164. https://aquadocs.org/handle/1834/41475

TUNISIA - PROJECT 5-128: ENHANCED RESEARCH CAPACITY AND FISH HEALTH INFRASTRUCTURE TO ASSIST TUNISIAN AQUACULTURE

PI: Nadia Chérif, National Institute of Sea Sciences and Technologies (INSTM)
U.S. Partner: James Winton, United States Geological Survey
Dates: December 2016 – November 2019

PROJECT OVERVIEW

Aquaculture is the fastest growing food-production sector in the world, providing a significant supplement to aquatic organisms harvested from the wild. However, the high density of animals reared in intensive aquaculture frequently produces infectious diseases that have emerged as major constraints to the successful development of aquaculture in many areas of the world. The project supported both basic and applied research that generated tools and knowledge needed for promoting social acceptance and good governance of Tunisian aquaculture, as well as solutions for sustainable production. The project had three objectives: (1) establishment of a Phase-1 prototype aquatic health network, an initiative towards development of a National Aquatic Health Network (NAHN) for Tunisia; (2) development of improved surveillance tools and characterize host defense mechanisms; and (3) application of nodavirus RNA3 as a biosensor. Key benefits from the research include providing an enabling environment for sustainable aquaculture, protecting investments from aquatic diseases and pests, and increasing research capacity for the prevention, early detection, and response to aquatic disease threats.

FINAL SUMMARY OF PROJECT ACTIVITIES

This project, which concluded in December 2019, aimed to advance research supporting the social acceptance and effective governance of Tunisian aquaculture, while also providing solutions for sustainable production. In the first phase, the project focused on bolstering fish health surveillance, resulting in the establishment of a comprehensive National Zoo-sanitary Program covering diseases affecting farmed fish species. The virology laboratory at the National Institute of Sea Sciences and Technologies (INSTM) was designated as the National Reference Laboratory, marking a significant milestone in the country's aquaculture management. A successful pilot program with a farm led to the expansion of the surveillance program to encompass all active fish farming units, with ongoing efforts to create a Policy Document outlining guidelines for the national zoo-sanitary surveillance network.

In the second phase, the project developed innovative biosensor chips for diagnosing infectious aquatic animal diseases. Overcoming initial challenges, the team achieved promising results, particularly in detecting fish nodaviruses. Utilizing two distinct approaches, the project focused on detecting viral genomes and developing specific nanobodies to enhance nodavirus detection and potentially inhibit its infection.

The third phase centered on evaluating bioactive molecules as probiotics to enhance fish immune systems or inhibit aquatic pathogens. Probiotics isolated from fish and chitosan extracted from shrimp were tested for their ability to inhibit nodavirus in vitro, demonstrating encouraging results. However, the in vivo evaluation was delayed due to infrastructure constraints. Nonetheless, chitosan emerged as a promising therapeutic agent against fish nodavirus.

Throughout the project, extensive engagement with technicians and farmers facilitated the dissemination of vital information on fish health and aquaculture procedures. Training workshops on biosecurity measures, viral disease diagnosis, and networking further enhanced knowledge sharing and capacity building within the aquaculture community.

In conclusion, the project achieved significant milestones in enhancing fish health surveillance, developing innovative diagnostic tools, and evaluating bioactive molecules for disease prevention in Tunisian aquaculture. These findings offer practical solutions for stakeholders, ultimately contributing to the sustainability and productivity of the aquaculture sector.

PUBLICATIONS

Nadia Chérif, Mohamed Zouari, Fatma Amdouni, Marwa Mefteh, Ayoub Ksouri, Balkiss Bouhaouala-Zahar, and Noureddine Raouafi. 2021. Direct Amperometric Sensing of Fish Nodavirus RNA Using Gold Nanoparticle/DNA-Based Bioconjugates. Pathogens 2021, 10, 932. https://doi.org/10.3390/pathogens10080932

Nadia Chérif, Fatma Amdouni, Boutheina Bessadok, Ghada Tagorti, and Saloua Sadok. 2021. Chitosan Treatment of E-11 Cells Modulates Transcription of Nonspecific Immune Genes and Reduces Nodavirus Capsid Protein Gene Expression. Animals 2021, 11, 3097. https://doi.org/10.3390/ani11113097

Nadia Chérif, Rym El Jeni, Fatma Amdouni, Sabrin Zreilli, Hanem Djabou, Sana Khemiri, Ines Tliba, Balkiss Bouhaouala-Zahar, Kaouther Maatoug, Sami Zaafran, and David Groman. 2021. Phylogeography of betanodavirus genotypes circulating in Tunisian aquaculture sites, 2012–2019. Diseases of Aquatic Organisms 146: 53-63. https://doi.org/10.3354/dao03614

Nadia Cherif, Amdouni Fatma. Nodaviruses in Wild Fish Population Collected Around Aquaculture Cage Sites from Coastal Areas of Tunisia. Fisheries and Aquaculture Journal, 2017. hal-03632233

TUNISIA - PROJECT 2-12: CONTRIBUTION TO DROUGHT IDENTIFICATION AND ALERT IN NORTHERN TUNISIA

PI: Zoubeida Kebaili Bargaoui, Ecole Nationale d'Ingénieurs de Tunis
U.S. Partner: Kelly Caylor, Princeton University (Funded by the National Science Foundation)
Dates: September 2013 – February 2016

PROJECT OVERVIEW

Tunisia is a primarily agricultural country with sub-humid, sub-arid, and arid climate zones. As a result, the country's economy is very sensitive to the impact of droughts. This PEER project aimed to contribute to drought identification and alert systems in Tunisia using water budget modeling, which incorporates satellite information. The project built upon the experimental African Drought Monitor (ADM) system developed by Princeton University researchers in collaboration with UNESCO and installed in Niamey and Nairobi. North Africa is not currently well covered by ADM, so this project expanded drought monitoring in the region by incorporating local observations. The Tunisian research team developed a water balance model for recent years using ground-based local precipitation, air temperature, and soil data for runoff and evapotranspiration prediction. Data from the project was shared through a new project developed within the existing ADM web interface. Users were able to access maps of model outputs and to spatially averaged drought indicators. Overall, the project aimed to facilitate drought mitigation and adaptation efforts.

FINAL SUMMARY OF PROJECT ACTIVITIES

The team began this work by undertaking a hydrological study, assessing the water budget for the target watersheds: Joumine, Sejnane, Abid, Tessa Zouarines, Douimis, and Beja They used ground rainfall and runoff observations, as well as GIS information. Researchers also computed drought indicators at basin level, assessing the Standardized Moisture Deficit Index (SMDI) and the Standardized Evapotranspiration Index (ETDI) indicators. Time series of SMDI and ETDI were created at weekly resolution for every watershed.

In the first phase of the project, the Tunisian model was compared with ADM/VIC results to recreate a historic period of observation using runoff data (1960- 2010). Researchers then assessed the quality of satellite estimates and reanalysis data (rainfall in particular) to feed the VIC model by comparing them with historic ground estimations. In addition, the PEER team developed an application using ground observations and water balance modeling to evaluate drought indices' quality and ability to identify well-known past drought periods.

Researchers also undertook a study of remote sensing data for water balance quantification, assessing the water stress indicator and daily rainfall patterns using satellite data. The team developed tables and maps of drought indicators for both historical periods and more recent time periods in the six studied watersheds.

The researchers organized and attended several workshops to disseminate their results. At the first event, "Drought, Climate Change and Hydrological impacts," the project team reported the results from their PEER project and another ongoing project involving France and Morocco. At the second workshop, "Green Tunisia: The Role of Hydrological Monitoring in Achieving this Objective," the project team presented a drought risk assessment and water cycles in Tunisian forest zones and on societal engagement for enhancing vegetation cover. At the third event, "Drought identification and alert Northern Tunisia," researchers presented their results to the engineers within the Ministry of Agriculture and other ministries with concerns about drought, including the Ministry of Finance. Representatives of farmers also participated in this event to define their needs in terms of drought assessment and mitigation.

PEER funds supported international travel and training for several team members. In March 2014, researcher Ahmed Houcine, computer manager Wadid Foudhaili, and PhD student Saoussen Dhib spent 10 days at Princeton University for training on the installation and use of the African Drought Monitor System. Saoussen Dhib also completed a two-month exchange visit to Prague University, including taking courses to help her in analyzing precipitation data, particularly those gleaned through remote sensing. Other students made short-terms visits to universities in the Netherlands and France, and the PI and other senior researchers participated in several international conferences. The team also presented at the International Conference on African Large River Basins Hydrology and organized two field visits, where they met with the regional agriculture authority representatives and presented their modeling system.

Overall, Dr. Bargaoui notes that the project has contributed to build a sustained capacity at ENIT, also resulting in the installation of data sensors and weather stations in an important river basin and the enhancement of the skills of research personnel and students. It also resulted in increasing the competence of staff from the Ministry of Agriculture at the local level in Siliana and Bizerte regions. In addition, some fundamental research findings have been achieved, and the team published three papers on their work.

PUBLICATIONS

Saoussen Dhib, Nathaniel Chaney, Chris M. Mannaerts, and Zoubeida Bargaoui. 2021. Comparison of two bias correction methods for TRMM 3B42 satellite daily rainfall estimates over Northern Tunisia. Arabian Journal of Geosciences 14: 626. https://doi.org/10.1007/s12517-021-06916-8

Aymen Ben Jaafar and Zoubeida Bargaoui. 2019. Generalized Split-Sample Test Interpretation Using Rainfall Runoff Information Gain. Journal of Hydrologic Engineering 25(1). https://doi.org/10.1061/(ASCE)HE.1943-5584.0001868

N. Abid, C. Mannaerts, and Z. Bargaoui. 2019. Sensitivity of actual evapotranspiration estimation using the SEBS model to variation of input parameters (LST, DSSF, aerodynamics parameters, LAI, FVC). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W13, 2019 ISPRS Geospatial Week 2019, 10–14 June 2019, Enschede, The Netherlands. https://doi.org/10.5194/isprs-archives-XLII-2-W13-1193-2019

TUNISIA – PROJECT SG1-006: AIR2D: ALGORITHM FOR AN INTEGRATIVE REPURPOSING & DISCOVERY OF DRUGS AGAINST NEGLECTED TROPICAL DISEASES: LEISHMANIASES AS APPLICATION DISEASE

PI: Emna Harigua, Institut Pasteur de Tunis

Dates: September 2019 – August 2021

PROJECT OVERVIEW

The leishmaniases are a group of neglected tropical diseases (NTDs) endemic in Tunisia, and more broadly in the Middle East and North Africa. While novel treatments against this group of diseases is of utmost importance to the country, the private sector has taken little to no interest in them because they do not represent a lucrative market and end-to-end drug discovery processes are known to be long and costly. Innovative and cost-effective approaches are needed, including computational approaches and drug repurposing. This project aimed to develop cutting-edge computational approaches coupled to biological assays towards drug discovery and repurposing against leishmaniasis. The methodology can also be applied to other diseases, and with the advent of the COVID-19 pandemic, the team was able to rapidly and successfully adapt their approaches and technologies and participate in the universal research efforts to tackle COVID-19, through developing accurate algorithms for anti-coronavirus molecules.

FINAL SUMMARY OF PROJECT ACTIVITIES

Dr. Harigua and her fellow researchers developed datasets on molecules presenting anti-pathogenic activity for leishmania and SARS-COV-2, through literature review and database searches for ligand-based drug discovery. They considered multiple criteria in order to consider these datasets for artificial intelligence (AI) applications. The team implemented seven machine learning (ML) and four deep learning (DL) algorithms on both datasets. The trained algorithms were compared and those that performed best were used for modeling the potential repurposing of existing FDA-approved drugs. The team then set up infection models for drug discovery and identified molecules from FDA-approved drugs that were predicted as potentially active. Those drugs were then tested for their effects on the growth of promastigotes, an extracellular form of the *leishmania* parasite.

The researchers have published two papers on their work and have others forthcoming from these results. They also presented their findings at conferences of the American Society of Tropical Medicine and Hygiene and the African Society of Bioinformatics and Computational Biology.

During the project, two undergraduate students from an engineering school were trained for six months each to complete their degree in statistics and data analysis. Dr. Harigua also mentored two scientists, including one who completed and defended her doctoral work and one who submitted her first research proposal as a PI. Dr. Harigua also received an additional $83,000 grant alongside one of her mentees and others at the Institut Pasteur de Tunis for future work.

PUBLICATIONS

Emna Harigua-Souiai, Rafeh Oualha, Oussama Souiai, Ines Abdeljaoued-Tej, and Ikram Guizani. 2022. Applied machine learning toward drug discovery enhancement: leishmaniases as a case study. *Bioinformatics and Biology Insights* 16: 1-10. https://doi.org/10.1177/11779322221090349

Emna Harigua-Souiai, Mohamed Mahmoud Heinhane, Yosser Zina Abdelkrim, Oussama Souiai, Ines Abdeljaoued-Tej, and Ikram Guizani. 2021. Deep learning algorithms achieved satisfactory predictions when trained on a novel collection of anticoronavirus molecules. *Frontiers in Genetics* 12-2021. https://doi.org/10.3389/fgene.2021.744170

TUNISIA – PROJECT SG1-007: POC CL DIAGNOSIS: HANDHELD FAST PCR ASSAYS AND LATERAL FLOW DETECTION FOR LEISHMANIA PARASITES DETECTION AND IDENTIFICATION

PI: Insaf Ben Hadj Ali Insaf, Institut Pasteur de Tunis
Dates: September 2019 – August 2021

PROJECT OVERVIEW

Early and accurate detection of infectious diseases is a key step not only for surveillance, epidemiology, and control but also, notably, for timely disease diagnosis, patient management, and follow-up. In recent decades, several diagnostic tests satisfying these criteria were developed to identify major human pathogens such as human immunodeficiency virus (HIV), tuberculosis (TB), and malaria, as these diseases received much more attention compared to neglected tropical diseases such as leishmaniases. Leishmaniases are a group of vector-born parasitic diseases with a wide range of clinical manifestations, some of which are fatal if left untreated. More than one million cutaneous leishmaniases (CL) cases are annually reported, with 80% of those occurring in the Middle East and North Africa (MENA) region. In addition, the primary drugs employed for CL treatment are toxic, and their efficiency may depend on parasite species/strains. CL diagnosis is also complicated, as it is routinely performed via microscopy direct examination, a time-consuming technique that requires trained personnel and cannot identify particular parasites.

This PEER project aimed to identify novel CL molecular diagnosis assays that satisfy criteria for timely patient management and disease control and equip areas with low resources and poor laboratory infrastructure with equitable access to high-quality patient diagnosis and management. This project also supported the scientific training and mentoring of several female researchers under the guidance of the PI Dr. Ali, leading to completed research and degrees, as well as enhanced future research goals.

FINAL SUMMARY OF PROJECT ACTIVITIES

This PEER Women's Mentorship seed grant arose out of the PI Dr. Ali's work as a part of PEER project 5-518, during which she and her colleagues identified five promising targets to use in fast PCR assays for leishmaniases. All targets included sequence information covering different strains of the species of interest. Within these targets, they designed four primer pairs targeting the *L. major /L. Tropica* group of species and two targeting the *L. infantum /L. tropica* group of species. Five markers gave specific profiles (mt22F1R1, mt22F2R2, mt30F/R, it20F1/R1, and it20F2/R2) as expected and were therefore selected for the fast and ultrafast PCR assays development. The researchers set up and processed several types of PCR assays with different types and processing times, including simplex fast PCR, fast duplex PCR, simplex ultra-fast PCR, and duplex ultra-fast PCR. They tested the detection limit of various *Leishmania* strains and the impact of human DNA on the assays. Among their findings was the ultra-fast duplex PCR showed consistent, stable, and reproducible results.

This follow-on seed grant project supported the continuing research and mentoring of several female scientists, including a doctoral student, a biology student, and an engineering student. As part of the research team, they worked with the PI on strategy and methodology of the study and received training on molecular biology techniques, as well as bioinformatic analyses. The PI also established a mentoring program where she met individually and in monthly group meetings with young scientists. The meetings included discussions of their short- and long-term scientific and educational goals, as well as identifying goals in technical skills development, leadership skills improvement, personal branding, work-life balance, and career development.

The PEER team also held a workshop on technologies based on Palm PCR and lateral flow PCR attended by parasitologists, lab technicians, and students. The PI also received an additional grant to continue her work.

PUBLICATION

Insaf Bel Hadj Ali, Yusr Saadi-Ben Aoun, Zeineb Hammami, Oumayma Rhouma, Ahmed Sahbi Chakroun, and Ikram Guizani. 2023. Handheld ultra-fast duplex polymerase chain reaction assays and lateral flow detection and identification of *Leishmania* parasites for cutaneous leishmaniases diagnosis. *Pathogens* 12(11): 1292. https://doi.org/10.3390/pathogens12111292

WEST BANK-GAZA - PROJECT 2-347: RAINWATER HARVESTING ANALYSIS USING WATER HARVESTING EVALUATION TOOL (WHEAT)

PI: Issam A. Al-Khatib, Birzeit University
U.S. Partners: Defne S. Apul, University of Toledo, and Steve Burian, University of Utah (Funded by the National Science Foundation)
Dates: December 2013 – June 2017

PROJECT OVERVIEW

Rapid population growth and political issues associated with control over Palestinian water and land resources have exacerbated problems of water supply and management. Many Palestinian localities in the West Bank suffer from shortages of domestic and agricultural water mainly during the summer months, when the water shortage makes everything difficult. Water scarcity can be considered as a major constraint for economic and social development and sustainability of the domestic and agricultural sector in the West Bank. Rainwater harvesting systems (RWH) can play an important role in creating a realistic and sustainable environment in the future. Their use in drinking, domestic, and agricultural sectors not only compensates for the shortage of water but also reduces the chances of severe floods causing widespread damage.

The aim of this project was to analyze the different aspects of rainwater harvesting through the development of a Water Harvesting Evaluation Tool (WHEAT), which is a new and extensible sustainability modeling and analysis framework. The data, models, results, and developed relations produced in all tasks (i.e., assessment of socioeconomic and water-related topics at household and community scale and hydrological assessment within the community boundaries and adjacent watersheds) were integrated in WHEAT. This tool was then applied to assess the impact of any intervention on the water sector in the target community, including water, economy, and social impacts.

FINAL SUMMARY OF PROJECT ACTIVITIES

The project was successfully completed in June 2017. It developed the Water Harvesting Evaluation Tool (WHEAT) and manual in Arabic, which have been utilized in multiple courses at Palestinian universities, as well as guidelines for rainwater harvesting at the household level. A total of 6,000 copies have been printed and around 4,000 copies have been distributed to different Palestinian individuals, ministries, institutions, NGOs, schools, university students, women's associations, etc. Additionally, four Master's students graduated thanks to support from this project, and the team developed and submitted six manuscripts for publication.

A solid understanding of competitiveness and importance of investing in the rainwater harvesting (RWH) and sanitation sector as a means to enhance livelihoods and business opportunities in rural areas was successfully achieved among both local residents and policy makers in the study area and other Palestinian areas, as most of actions, including the 14 training workshops (almost 1000 people trained) conducted, the development of the guidelines for rainwater harvesting at the household level, and the Palestinian Conference on Rainwater Harvesting and Management activities, were implemented with participation and involvement of policy makers from different levels. The guidelines were adopted by the policy makers at Ministry of Local Government, the Ministry of Education and Higher Education, Palestinian Water Authority and the Environment Quality Authority.

The understanding of local authorities of the importance of efficient and sustainable RWH reportedly increased, as many of them participated in all activity actions. This is anticipated to contribute to the reduction of water and sanitation related diseases among residents in the target area. The implemented training workshops will have an impact on building, locality and storm water infrastructure design and analysis. The results of this activity are anticipated to give the population the incentive to harvest rainwater based on the scientific bases. The results of this activity were of interest to the Palestinian Water Authority, Ministry of Local Government, municipalities, local councils, and hydrology professionals in the West Bank, as they were involved in the different stages of activity implementation. The government is currently considering tax exemptions for those who establish rainwater cisterns.

PUBLICATIONS

Issam A. Al-Khatib, Hamzeh Al Zabadi, and Ghassan Saffarini. 2017. Radon in harvested rainwater at the household level, Palestine. Journal of Environmental Radioactivity 169–170: 192-196. https://doi.org/10.1016/j.jenvrad.2017.01.014

I. Celik, L.M. Tamimi, I.A. Al-Khatib, et al. 2017. Management of rainwater harvesting and its impact on the health of people in the Middle East: case study from Yatta town, Palestine. Environ Monit Assess 189: 271. https://doi.org/10.1007/s10661-017-5970-y

CERVICAL CANCER

MALAWI

Malawi - Project CCSPT1: Accelerating the Introduction of a Human Papillomavirus Screen-and-Treat Strategy In the Republic Of Malawi

U.S. Lead: Dr. Jennifer Tang, University of North Carolina at Chapel Hill
Malawi Lead: Dr. Luis Gadama, The University of Malawi College of Medicine
Implementing Partners: Management Sciences for Health, University of Washington, University of Malawi Polytechnic

MOZAMBIQUE

Mozambique - Project CCSPT 2: Evaluating Innovative Technologies and Approaches to Addressing Cervical Cancer in the Republic Of Mozambique

U.S. Lead: Dr. Kathleen Schmeler, The University Of Texas Md Anderson Cancer Center
Mozambique Lead: Dr. Cesaltina Ferreira Lorenzoni, Universidade Eduardo Mondlane
Implementing Partners: Population Services International, Rice University, Albert Einstein College of Medicine, International Gynecologic Cancer Society, and the Clinton Health Access Initiative

MALAWI

MALAWI - PROJECT CCSPT1: ACCELERATING THE INTRODUCTION OF A HUMAN PAPILLOMAVIRUS SCREEN-AND-TREAT STRATEGY IN THE REPUBLIC OF MALAWI

U.S. Lead: Dr. Jennifer Tang, University of North Carolina at Chapel Hill
Malawi Lead: Dr. Luis Gadama, the University of Malawi College of Medicine
Implementing Partners: Management Sciences for Health, University of Washington, University of Malawi Polytechnic
Dates: March 2019 - September 2023

Cervical cancer is largely preventable through cervical cancer screening and preventive therapy (CCSPT). However, resource-limited countries such as Malawi have had challenges with implementing routine cervical cancer screening (CCS) and timely preventive therapy. The currently used primary screening strategy (visual inspection with acetic acid, or VIA) requires a time-consuming pelvic examination, which is challenging to offer on a large scale because of limited clinic space at health facilities and limited numbers of health providers. Timely preventive treatment of precancerous cervical lesions has also been difficult to achieve because cryotherapy, the previously used ablative treatment, requires expensive and heavy refrigerant gas cylinders that are difficult to fill and replace.

To respond to these needs, UNC developed a cluster randomized trial that integrated a novel cervical cancer screen-and-treat algorithm into voluntary family planning (VFP) services via two different models. Model 1 involved (1) cervico-vaginal self-sampling for high-risk HPV (hr-HPV) while waiting for appointments at the VFP clinic or other clinics, (2) same-day VIA for those women found to be hr-HPV-positive by rapid GeneXpert HPV testing, and (3) same-day thermocoagulation treatment for HPV-positive women who are eligible for ablative therapy by VIA. Model 2 offered women the same services as in Model 1, but they were given the option to perform cervico-vaginal self-sampling in the community, via Heath Surveillance Assistants (HSAs) who brought their HPV sample to the clinic and notified them to return to the clinic for VIA and possible same-day thermocoagulation if their hr-HPV test was positive.

The study's Broad Objective was to compare the effectiveness and budget impact of these two models for averting potential cervical cancer cases and evaluate the implementation and acceptability of the models in multiple different health care facility settings. The Specific Objectives were:

• Objective 1: To compare the proportion of eligible women who receive CCS and VFP services in the catchment areas of health facilities assigned to the two models.

• Objective 2: To assess the acceptability, appropriateness, and feasibility of the two models among key stakeholders, including service providers and clients, during the early, midline, and final implementation phases of the project.

• Objective 3: To estimate the cost and budget impact of each model compared to the standard-of-care (VIA and cryotherapy), using information collected for the previous objectives.

The PEER CCSPT study built upon previous research performed by the team's investigators in Malawi that had found that thermocoagulation and GeneXpert HPV testing was acceptable and feasible in the study's setting. It was a collaboration between investigators at the University of North Carolina at Chapel Hill (UNC), UNC Project-Malawi, Kamuzu University of Health Sciences (KUHeS, formerly the University of Malawi College of Medicine), Management Sciences for Health (MSH), the Centre for Health, Agriculture, Development Research and Consulting (CHAD), and the University of Washington (UW). The team also worked closely with members of the Malawi Ministry of Health (MOH) and the District Health Management Teams (DHMTs) of Lilongwe and Zomba Districts to guide study implementation and any resulting policy decisions regarding acceleration of an HPV-based cervical cancer screen-and-treat strategy in Malawi.

STAKEHOLDER ENGAGEMENT

The PEER CCSPT Malawi project organized a launch meeting in April 2019, which was attended by 61 stakeholders, including representatives from the Malawi MOH, USAID, and NAS. Likewise, the project held a final dissemination meeting with the same stakeholders in April 2022. As the project took place in Lilongwe and Zomba districts, their District Health Management Teams (DHMTs) and other non-governmental organizations (NGOs) operating in the country were consulted on site selection. Site selection and randomization was completed in Summer 2019. Zomba Central Hospital and Bwaila Hospital were later dropped from randomization since those sites did not have Health Surveillance Assistants (HSAs) that performed community work and thus were not eligible to be randomized to Model 2. Both sites were assigned to Model 1.

The PEER CCSPT Malawi project engaged stakeholders through the creation of the Local Advisory Board (LAB), which included representatives from the Malawi MOH, NGOs, and civil society groups. The initial LAB meeting was held in June 2019, and subsequent meetings were held on a quarterly basis. For a complete list of LAB meetings, refer to Section 3: Stakeholder Events.

In 2019, the team developed a communications strategy and worked with the MOH to develop information, education, and communication (IEC) materials on HPV self-sampling and cervical cancer. In early 2020, the team began pre-implementation community sensitization meetings that included local governmental, traditional, and religious leaders from the communities surrounding the health facilities participating in the project; however, these were put on hold in March 2020 due to restrictions put on non-essential research during the beginning of the COVID-19 pandemic. The project held two meetings with representatives from the health facilities—one in Lilongwe and one in Zomba—in late July 2020 after the restrictions on non-essential research were eased to re-engage the facilities on the project and prepare for launch or, in some cases, re-launch. Additional community and facility sensitization meetings were conducted in Summer 2021 to improve uptake of services.

In late 2020, the PEER CCSPT Malawi began a series of Quarterly Review Meetings with the participating health facilities. These meetings were a venue for sharing facility experiences, discussing successes, challenges, and solutions, and recognizing exceptional contributions made to the project.

Project team members were also active on the Malawi National Cervical Cancer Programme (CECAP) Steering Committee. A team representative delivered updates on the project and solicited feedback from the MOH during those meetings. The MOH signaled its interest in project results throughout this engagement.

PROCUREMENT AND FACILITY PREPAREDNESS

During site selection, the PEER CCSPT Malawi team identified supply, equipment, and rehabilitation needs at the health facilities. The team organized facility rehabilitation and equipment procurement, starting in August 2019. Facility rehabilitation included installing air conditioners, burglar bars, and power back-ups; purchasing tables, chairs, and lockable cabinets; and renovating labs so that they could be air-conditioned. Major procurements by UNC included thermocoagulators, data collection tablets, specimen bags, wet mount tubes, cervicovaginal brushes for self-sampling, MobileODT colposcopes, GeneXpert machines, HPV cartridges, PreservCyt solution vials, and power back-up systems. The project installed solar power back-up systems at each facility, which were connected to uninterrupted power supply (UPS) batteries. The UPS were originally purchased from PhD Powerhouse, but since they did not automatically switch from solar to main electricity as originally intended and kept breaking down, they were originally switched out to locally supplied UPS for better sustainability.

Throughout the life of the project, the project team procured pharmaceutical and office consumables for each health facility as an incentive for participating in the study. Frequently requested items included vinegar, stethoscopes, specula, forceps, blood pressure modules, thermometers, examination couches, boots, and cloth for uniforms.

UNC approved the transfer of ownership of the GeneXpert machines from UNC to the health facilities at which they were installed in March 2023.

It is important to note that while non-essential research was put on hold during the initial stage of the COVID-19 pandemic, the health facilities participating in the project continued to provide services according to the facilities' prior standard-of-care (mostly VIA for screening), although some continued to use thermocoagulation (rather than cryotherapy) for treatment. Project-specific activities were permitted to restart in August 2020 after restrictions were eased.

Throughout the implementation period, the Clinical Mentors routinely visited each facility to provide mentorship and supportive supervision as well as to collect data. The Clinical Mentors were integral in maintain service uptake. Whenever screening numbers seemed to decrease, they worked with the facilities to identify and solve issues. The Clinical Mentors also conducted community sensitization to enhance uptake.

RESEARCH

There were several research components of the PEER CCSPT Malawi project, including the Endline Household Survey, facility-level analyses, implementation evaluations, and Time & Motion studies. UNC, UNC Project-Malawi, and KUHeS collaborated to execute the Endline Household Survey. The purpose of the Endline Household Survey was to gather data for the study's primary objective, to compare the proportion of eligible women who receive CCS and VFP services in the catchment areas of health facilities assigned to the two models. This survey asked questions about basic demographic information, reproductive health information, HIV status, distance to the nearest health facility, prior VFP use, VFP use during project implementation, prior CCSPT services received, and any CCSPT services received during project implementation. The team made preparations in September and October 2021, then implemented the survey in the targeted villages in October, November, and

December 2021. The team collected surveys from 8,010 women for its target sample size of 8,000. The results of the Endline Household Survey were published in *Cancers* in May 2023.

KUHeS led the implementation evaluations. Data from the Client IDIs, Client Exit Surveys, Manager and Coordinator IDIs, Provider and HSA focus groups (FGs), and AFA Tool were used for analyses pertaining to the project's second objective, to assess the acceptability, appropriateness, and feasibility of the two models among key stakeholders, including service providers and clients. Additionally, KUHeS and UNC conducted Time & Motion studies in October-November 2019 and July-August 2021. The data collected through the Time & Motion studies, as well as the Workload Assessment Tool, Client Exit Surveys, and Observation Checklists were used for the costing analysis, the project's third objective, to estimate the cost and budget impact of each model compared to the standard-of-care (VIA and cryotherapy). Several manuscripts related to these analyses were in process at the time of the final report in the fall of 2023, including manuscripts on the decision/costing analysis, health-related quality-of-life among Malawian women with cervical cancer or lesions, results from the client IDIs, and results from the implementation evaluations. Additionally, two manuscripts on facility-level analyses were under development, one manuscript examining changes in Couple Years of Protection and another manuscript looking at uptake of cervical cancer screening across sites.

PUBLICATION

J.H. Tang, F. Lee, M.B. Chagomerana, K. Ghambi, P. Mhango, L. Msowoya, T. Mkochi, I. Magongwa, E. Mhango, J. Mbendera, et al. 2023. Results from Two HPV-Based Cervical Cancer Screening-Family Planning Integration Models in Malawi: A Cluster Randomized Trial. Cancers 2023, 15, 2797. https://doi.org/10.3390/cancers15102797

MOZAMBIQUE

MOZAMBIQUE - PROJECT CCSPT 2: EVALUATING INNOVATIVE TECHNOLOGIES AND APPROACHES TO ADDRESSING CERVICAL CANCER IN THE REPUBLIC OF MOZAMBIQUE

U.S. Lead: Dr. Kathleen Schmeler, The University of Texas MD Anderson Cancer Center

Mozambique Lead: Dr. Cesaltina Ferreira Lorenzoni, Universidade Eduardo Mondlane

Implementing Partners: Population Services International, Rice University, Albert Einstein College of Medicine, International Gynecologic Cancer Society, and the Clinton Health Access Initiative

Dates: May 2019 - September 2023

To evaluate new strategies for cervical cancer screening using human papillomavirus (HPV) testing, and treatment of pre-invasive disease using thermal ablation, the MD Anderson team performed the **MULHER** Study, a prospective trial of **M**ozambican women **U**ndergoing cervica**L** cancer screening with **H**PV testing in conjunction with family planning s**ER**vices followed by thermal ablation for those testing positive. Cervical cancer prevention services were integrated with voluntary family planning services, as appropriate, to increase access to both services.

In summary, the MULHER study enrolled 9,014 women in Maputo City, Maputo Province and Gaza Province, Mozambique between January 2020 and January 2023 despite pauses in enrollment and care delivery due to the COVID-19 pandemic. The median age was 37 years (range; 30-49) and 4,122 women (45.7%) were living with HIV (WLWH). Over 97% of participants chose self-collection over provider collection of cervicovaginal samples. The HPV positivity rate was 31.1% overall and 39.5% among WLWH. Of the 2,805 HPV-positive patients, 2,588 (92.3%) returned for all steps of their diagnostic work-up and treatment, including ablation (n=2,383, 92.1%), LEEP (n=169, 6.5%), and cold knife conization (n=5, 0.2%). Thirty-one patients (1.2%) were diagnosed with cancer and referred to gynecologic oncology. The researchers concluded that it is feasible to perform cervical cancer screening with primary HPV testing and follow up in low-resource settings. Self-collection of samples was preferred, and the majority of screen-positive patients completed all steps of their diagnostic work-up and treatment. The team's findings provide important information for further implementation and scale-up of cervical cancer screening and treatment services as part of the World Health Organization (WHO) global strategy for the elimination of cervical cancer. The collaborative team from MD Anderson, Rice University and Universidade Eduardo Mondlane/Mozambique Ministry of Health has received subsequent funding as described below to continue this work in Mozambique.

- MD Anderson provided initial and follow-up hands-on training for the clinical teams on how to perform collection of HPV samples, visual inspection with acetic acid, colposcopy, cervical biopsy, thermal ablation and LEEP. These trainings were supplemented with regular virtual training to ensure safe and efficient patient care and compliance with the clinical protocol.

- The MD Anderson REDCap (Research Electronic Data Capture) specialist provided support to the entire PEER team to ensure data was entered regularly and was of good quality.
- Three gynecologists (two in Maputo, one in Xai Xai) served as the referral physicians for women needing additional evaluation and treatment, including excision or evaluation/treatment for cancer.
- Weekly virtual meetings were conducted throughout the life of the project and included all members of the research and clinical teams. The Malawi PEER Cervical Cancer team met with the MD Anderson researchers virtually approximately every quarter.
- Over the course of this grant period, the researchers participated in several meetings with the Ministry of Health and CDC regarding updates and changes to the national cervical cancer screening program and strategies to improve cervical cancer screening and treatment of women with pre-invasive disease. The Ministry held several meetings regarding evaluation and approval of thermal ablation as a treatment modality, as appropriate, for women with ablation eligible pre-invasive disease. MD Anderson and the PSI team provided technical support for this process, and thermal ablation has been approved by the Ministry as the preferred treatment modality. In addition, there were several workshops and meetings to discuss transition to HPV testing, and to design management/treatment algorithms for cervical cancer screening with HPV testing. MD Anderson has been closely involved in the development of these algorithms.
- The researchers continue to support the Ministry in reviewing cervical cancer screening guidelines and guidelines to treat women with pre-invasive cervical disease. They also continue to provide ongoing training in cervical cancer prevention and treatment of women with pre-invasive cervical disease for nurses and gynecologists in Mozambique through in-person and virtual workshops and regular, monthly ECHO (Extension for Community Healthcare Outcomes) sessions.

PUBLICATIONS

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REPORT FROM SUBAWARDEE IMPLEMENTING PARTNER POPULATION SERVICES INTERNATIONAL

Site Establishment: In January 2020, fixed sites were established at two clinics in Maputo, and two clinics in Gaza in December 2020. PSI/Mozambique piloted the weekly transport of HPV samples and results between Gaza health units and the laboratory based at APOPO, in Maputo, which was chosen as the laboratory partner given the lack of adequate laboratory facilities in Gaza. To reduce the waiting time for the results to reach Gaza, an electronic folder was created where the results were published on a weekly basis, which reduced the turnaround time for sample results from 7 to 4 days. Patient files were encrypted, downloaded, supported, and protected on a cloud-based server to ensure patient confidentiality and improve security and disaster recovery. Only the PEER Coordinator, the Clinical Officer of the Project and the APOPO Data Officer had access to the files.

The launch of mobile sites was originally scheduled for January 2021, but these activities were postponed due to COVID-19. A total of 6 mobile sites were launched over the course of the project. Four sites were launched in Maputo in May 2021, and 2 sites were launched in Gaza in December 2021. Satellite facilities were established in Maputo at Xipamanine Health Center and Zimpeto Health Center (May 2021) and June 1 Health Center and Health Center May 1 (June 2021). In December 2021, two more health units (Chissano Health Center and Malehice Health Center) were set up as mobile brigades in Gaza.

Initially, the program aimed to screen a total of 14,600 women for HPV in Maputo and Gaza; however, the project targets were adjusted downward due to multiple delays caused by the COVID-19 pandemic and by pauses due to the lack of key consumables (e.g., stockouts of Thinprep solution in May 2021). As of December 2022, a total of 9,083 women were screened in the program.

Capacity Building of Health Facility Staff: Over the life of the project, the MD Anderson Cancer (MDA) team based at the University of Texas provided regular virtual training on topics related to cervical cancer for PSI clinical staff and collaborators from UEM via Zoom and quality assurance activities were conducted virtually due to COVID-19. Virtual training sessions were offered for clinical staff to strengthen knowledge and skills to provide high-quality treatment services using thermal ablation, and to improve patient referral capacity for specialized gynecology and voluntary family planning (vFP) services.

There were a total of 95 weekly virtual training courses and 31 monthly cervical cancer prevention ECHO (Extension for Community Healthcare Outcomes) sessions offered over the course of the project. In addition to virtual ECHO sessions, the PEER Project Coordinator, Quality of Care Manager and PSI clinical tutors facilitated on-site and practical training for counseling and preventive therapy and offered quality guidance during follow-up technical support visits. Weekly meetings were established by PEER's technical team (i.e., 4 PEER nurses, 3 PSI clinical tutors, PSI quality manager, PSI clinical officer and PEER project coordinator). In addition to PSI staff, 2 MoH PEER project coordinators and gynecologists attended weekly meetings to support the project in referral hospitals. Monthly ECHO training in cervical cancer prevention included PEER nurses, as well as nurses and doctors from all provinces of Mozambique, facilitated by local and Brazilian specialists. Please see below in Section 3 for more details on trainings conducted over the course of the project.

Service Delivery: Integrated HPV screening activities and voluntary vFP services under the PEER project began in January 2020 and continued until December 2022 with a notable expansion of services to the 6 satellite health facilities. Each of these locations provided the following user services: (a) counseling on all available FP methods; b) discussion of the side effects of each available FP method; c) personalized advice based on the method chosen by the client; and d) HPV and HIV screening (for women who come to the health unit with unknown HIV status). See Section 10 of the report for details on the program indicators outlined in the MEL plan.

Meetings and Coordination: Throughout the life of the project, PSI staff participated in weekly meetings organized by the MDA team, along with consortium members. Additionally, PSI staff led weekly internal coordination meetings with project personnel to discuss progress and challenges related to the provision of services and activities. The PSI team met weekly with the APOPO Laboratory team to coordinate the flow of samples and results to/from Gaza and the entry of data into the REDCap database. Every month, PEER's field intervention team held meetings to discuss issues related to improving the quality of services provided by the PEER team. PSI has also had regular coordination meetings with Universidade Eduardo Mondlane (UEM), and UEM team members travelled to Gaza to conduct site visits in March 2022.

Data Collection/M&E Activities: PSI developed PEER's data collection forms for screening and treatment activities. These forms include: 1) an eligibility and consent form to enroll patients in the study; 2) an admission form to collect patient data; and 3) a daily record of samples collected and sent to the laboratory. A form was also developed and used to determine wealth quintile. The PEER project forms were complemented by health facility records used by the MoH and the laboratory results generated by APOPO via the GeneXpert database. Both MDA and PSI used the REDCap database to enter individual admission forms; a second data base was developed to collect information on patients who were not eligible for ablation and were referred to gynecology for evaluation of excisional procedures (LEEP) or biopsy. PSI/Mozambique conducted in-depth interviews (IDIs) with patients who received CCS&PT and vFP services to develop, test and refine key messages and promotional strategies among women eligible for CCS&PT. A total of 4 key messages were tested, shown below:

i. *"Cervical cancer is caused by a common virus called HPV. Cervical cancer can be prevented through regular HPV testing";*
ii. *"HPV screening is easy, fast and okay. You can ask a nurse to do it, or you can do it yourself";*
iii. *"If your test is positive for HPV, it is easy to treat. Early HPV treatment can help prevent cervical cancer, so it is important to seek out your nurse for immediate treatment"; and*
iv. *"Common symptoms of cervical cancer include pain during intercourse, or bleeding between the period or during and/or after intercourse. If you experience any of these symptoms, you should seek help immediately."*

The messages were evaluated with clients for their clarity and relevance. Clients were asked provide feedback on how the messages could be improved. Based on client insights, the team refined messages for use in health information products and flyers in Portuguese and Changana.

More than 97% of women chose to self-sample for HPV. To measure service acceptability and overall user satisfaction regarding self-sampling for HPV, PSI conducted two rounds of quantitative client exit surveys with a total of 504 clients. The first round was conducted in December 2020 and the second in March 2021. The vast majority of clients (>80%) across the two study sites were comfortable collecting vaginal HPV samples, although roughly 5% of clients across Maputo and Gaza found the self-collection process "very difficult." Strategies should be developed to ensure all women are comfortable, understand the procedure and feel confident in their ability to collect self-samples.

Additionally, a qualitative survey was conducted with the aim of testing the integrated CCS&PT and voluntary FP service delivery models to assess whether integrated service delivery can optimize the uptake and health impact of both services.

UPTAKE OF CCS&PT SERVICES

A total of 9456 women were enrolled in PEER. 373 women were excluded based on eligibility criteria. 9083 participants were screened for HPV. At final analysis, 69 participants were excluded due to being outside of the 30-49 yrs age range. The final analysis here is based on 9014 HPV tests. In total, there were 9,014 eligible women tested for HPV under PEER: 2,035 screened in 2020; 3,900 screened in 2021; and 3,079 screened in 2022. Of the 9,014 women screened, a total of 2,805 women (31.1%) were positive for HPV. PSI teams treated a total of 2,309 (82.3%) HPV+ women, of whom 2,165 (93.8%) were treated using thermal ablation and 144 (6.2%) using cryotherapy. These women were treated by PEER nurses. Some women were treated with cryotherapy because the thermal ablation probes were faulty, and others came for follow up on days when thermal ablation was not available.

A total of 369 women were referred for specialized treatment care. Please note that 127 (4.5%) HPV+ women were not treated in the project, some because they were unreachable, others because they preferred not to adhere to the treatment and others because they needed permission from their husbands.

PEER-REVIEWED PUBLICATIONS AND PROCEEDINGS

In March 2021, PSI submitted an abstract for 2022 International Conference on Family Planning to the integrated services track and vFP and reproductive health cancers sub-track. The abstract was accepted for oral flash and poster presentation and was presented by Marcos Chissano in November of 2022 in Pattaya, Thailand at the International Conference on Family Planning. In November of 2022, PSI Mozambique, together with MD Anderson and the PEER Malawi team submitted a pre-formed panel to FIGO to discuss accomplishments, challenges, lessons learned, and recommendations for future implementation and scale across PEER teams and partners. The FIGO conference is scheduled for October 2023 and notification of panel acceptance will be in the spring of 2023. At the time of the final report in the fall of 2023, PSI was developing two manuscripts for intended publication, one with a focus on self-sampling from both the provider and client perspective and one focused on the findings from the integration of CCS&PT into existing VFP programs.

LIBERIA

Liberia: University of Massachusetts Medical School (UMass)
PI: Olga Valdman (Original Pi: Patricia McQuilkin)
Other Team Members: Steven Hatch, Stuart Levitz, Ann Moormann, Sanjay Ram, Olga Valdman

Liberia: Vanderbilt University Medical Center (VUMC)
PI: Troy Moon
Other Team Members: Marie Martin, Bonnie Miller, Amy Chomsky, Sapna Gangaputra, Jessica Howard

Liberia: Yale School of Medicine (Yale)
PI: Onyema Ogbuagu
Other Team Members: Lydia Aoun-Barakat, Laura Crawford, Sheela Shenoi

Liberia: Sim, Sim/Liberia, Elwa Hospital (ELWA)
PI: Rick Sacra
Other Team Members: David Okiror

Liberia: University of Liberia College of Health Sciences/A.M. Dogliotti Medical School
PI: Bernice Dahn

LIBERIA: UNIVERSITY OF MASSACHUSETTS MEDICAL SCHOOL (UMASS)

PI: Olga Valdman (Original Pi: Patricia McQuilkin)

Other Team Members: Steven Hatch, Stuart Levitz, Ann Moormann, Sanjay Ram, Olga Valdman

Dates: June 2018 - August 2023

Focus Areas: Clinical Research Training, Family Medicine, Infectious Diseases

Since 2018, the collaboration between multiple partners from the U.S. and Liberian sides on the PEER/Liberia grant has accomplished most of the goals set from the beginning, at times even going above and beyond. The involvement of the University of Massachusetts (UMass) team focused predominantly on Family Medicine and the collaboration with ELWA hospital in Liberia. Additionally, together with their Liberian colleagues they developed a robust research training course, supported pilot research projects, and developed and implemented an infectious disease teaching curriculum. Specifically, the following accomplishments should be noted relative to the three objectives in the work plan:

Objective 1: Strengthening medical training and building specialty and subspecialty medical capacity in Liberia

During the five years of the project, UMass helped ELWA and the Liberian College of Physicians and Surgeons (LCPS) to develop a robust Family Medicine training program. Here are some activities undertaken:

- Developed a three-year curriculum in line with West African College of Physicians (WACP) standards.
- Created policy and procedures for residency administration, including a three-year template for rotation schedules, recruitment, admission process, orientation, disciplinary actions, promotion, and approaches to working with challenging learners.
- Supported preparation of residents for WACP exams, of whom 23 sat for the WACP primary exams and 20 passed those exams during the course of the grant. Additionally, one Family Medicine (FM) graduate passed the WACP membership exam. Locally, in training and graduation exams were developed utilizing both the WACP format, Liberian priorities, and Objective Structured Clinical Examination (OSCE) testing.
- Conducted extensive work on the evaluation front, including development of rotation evaluations, faculty and resident feedback forms, on-the-fly professionalism evaluations, and semi-annual evaluations providing residents with comprehensive formative and summative feedback and support for improvement. E-formats of these evaluations were also developed to facilitate efficiency, completion, and data tracking.
- Developed specialty rotations with curriculum and structure for Otorhinolaryngology (ENT), Ophthalmology, Family Medicine, Community Medicine, and Radiology. At the time of initiation of this work, there were no ophthalmology or ENT faculty in Liberia. Therefore, such faculty were recruited from the Ghana College of Physicians and sponsored to come and train FM residents

twice a year while also developing local capacity for these specialties; now the rotation can be run in-country, no longer requiring overseas faculty travel.

- Created other specialty training as per work plan, including HIV medicine through UMass HIV fellows developing and delivering an HIV management curriculum, as well as a longitudinal Behavioral Health curriculum developed and delivered by the director of behavioral health education at UMass Chan Medical School, Dr. Liz Dykhouse.
- Placed three UMass Global Health fellows in Liberia for a combined total of seven months providing bed-side teaching, aiding curricular development, introducing teaching modalities, and delivering lectures.
- Organized several faculty retreats bringing faculty from J.J. Dossen and ELWA hospital together with residents to collaborate, reflect, and plan for upcoming years.
- Delivered more than 200 hours of didactic lectures remotely and posted the recorded videos at https://libraryguides.umassmed.edu/c.php?g=499787&p=7779362 with open access to build sustainable education material access.
- Although the team was unable to develop a focused family medicine rotation for the medical students due to the timing of the A.M. Dogliotti School of Medicine (AMD) curriculum reform and new curriculum roll-out, they were able to send residents and fellows to physician-as-teacher trainings and develop a team structure where students and especially interns in the ELWA and J.J. Dossen hospitals work closely with FM residents and fellows who provide clinical and evidence-based teaching.

Through these activities, the team achieved their stated project objectives. Family Medicine has become one of the most sought-after specialties, attracting the highest number of medical students applying each year. Thanks to PEER support, the UMass researchers have recruited and supported four Family Medicine faculty as well as Ob/Gyn faculty; additionally, several graduates of training activities under the project are serving in junior faculty/mentorship roles at ELWA and other hospitals across the country. The number of Liberian physicians trained in family medicine increased from 7 to 22, with 13 more candidates in the training process as of the fall of 2023. ELWA received a five-year accreditation from WACP in 2020 and LCPS in 2022 for both residency and fellowship training (the first fellowship in Liberia to be accredited by LCPS). The first LCPS fellow in Family Medicine is slated to graduate in 2024 and will become a faculty member, while others will be starting their fellowship in the next year. Through the participation of the UMass team in the AMD curriculum reform, they were able to ensure that family medicine is formally incorporated as a stand-alone rotation in the medical school curriculum for the first time in history of medical training in Liberia; the rotation is set to begin in the 2024-2025 academic year.

Postgraduate medical education in Family Medicine in Liberia has improved dramatically; the chair of LCPS named Family Medicine as the strongest residency in Liberia. Family Medicine is now contributing to the pool of Liberian specialists, with four graduates per year. Although there are no exact data on improved patient outcomes in terms of reduced morbidity and mortality in Liberia, observations of the situation indicate that the physician staffing levels at the ELWA, J.J. Dossen, and several other hospitals where FM graduates have been placed have improved dramatically. It can be reasonably expected that the presence of highly trained medical doctors, especially in rural areas where commonly there might only be nurses and para-professionals available, is expected to translate to improved morbidity and mortality.

<u>Objective 2: Improve the ability of Liberia to conduct clinical research</u>

In this objective UMass took leadership not only through Family Medicine but across PEER/Liberia initiatives. The original PI for the UMass team, Dr. Patricia McQuilkin, led the development of PEER/Liberia research training. She developed several iterations of research training courses with lectures given by Liberian and U.S. faculty across more than five institutions. In years 1 and 2, several in-person research workshops were held with close to 100 participants joining at least some lectures and 23 completing the full training series. As COVID broke out in 2020, the training was adapted to a virtual platform and became a longitudinal series of 13 two-hour sessions delivered online and recorded. A total of 60 trainees took part in the online training and 72 more listened to the recordings later on. In year 3, the training was pivoted to a train-the-trainer model focusing on training 15 teaching apprentices (TAs) and supporting local faculty in taking over the course, which has now (as of 2023) been integrated into the new Master of Public Health program and the University of Liberia training curriculum. The TAs trained were engaged in the latest supplemental funding year (2022-2023) by Family Medicine to assist with the research training course that took place in December 2022 for FM fellows and faculty, as well as supporting ongoing research development. Family Medicine developed monthly journal clubs for residents, as well as research-in-progress meetings for faculty and senior residents supported by Liberian research experts. By the end of the grant in the fall of 2023, the previously trained TAs had become the key faculty in Family Medicine research training, as well as other courses provided by the University of Liberia.

In addition to developing a comprehensive curriculum, building the workforce, and transferring ownership of the training to local partners, the UMass PEER team launched a pilot project grants program that funded eight research projects supported and mentored by the PEER research team. Dr. Andrews has completed and published her project. Drs. Ireland, Ekyinabah, and Oguni have completed their projects and have used the results to pursue fellowship status in the West African College of Physicians. Drs. Gorpudolo, Gbalon, and Sanoe have completed data collection and were working on data analysis. Dr. Barclay completed collecting data and was working on analysis.

<u>Objective 3: Develop an outpatient residency continuity clinic to care for Ebola survivors and the broader population</u>

Through the PEER grant initiatives, Family Medicine established a continuity clinic at ELWA Hospital for the first time in the country. Family Medicine residents were assigned patients to follow on an inpatient and outpatient basis, including Ebola survivors. A staff member dedicated to scheduling and coordinating appointments was hired and given a phone that patients were able to call to set up appointments. Unfortunately, during Covid this effort was significantly disrupted and has taken time to rebuild. However, the residents who were involved in the pilot have seen the value and impact of continuity and are eager to pursue it in other settings in which they are working and leading now. Additionally, ELWA had a cohort of Ebola survivors who were monitored and connected to specialty care, including ophthalmology at the L.V. Prasad Eye Institute.

In addition, Advanced Life Support Obstetrics (ALSO) training, which was initially started in April 2022 and continued in June 2023, has been a tremendous success. In April 2022, Dr. Olga Valdman and senior UMass FM resident Dr. Rebecca Gwaltney organized three distinct courses on ALSO in accordance with American Academy of Family Physicians standards and protocols. A total of 17 people were trained as providers and 9 as faculty, and 5 others audited the course. All participants reflected on the rigor and impact the training had on their skills to provide safe maternity care. Mannequins and equipment were donated to ELWA to continue performing such trainings all year round. In 2023, the UMass team engaged the local faculty on the ground, especially Dr. Susan Kimono, director of the Ob/Gyn department at ELWA, as well as faculty responsible for obstetrics training of FM residents, in preparing for the course, updating course materials, and delivering the bulk of the content with UMass support. Two more instructors were trained in 2023 as well. For the three-day provider course this year, 13 Family Medicine residents, one general practitioner, and 5 midwives participated. Although 3 individuals had to re-take the final exam, they were able to do it successfully on their second attempt, joining the other 16 who passed the course initially. Because the course had been offered the previous year, it was decided that residents who had taken it previously would have to take it again. All 7 of them unanimously agreed that taking it for the second time fully solidified their skills and improved their comfort level in managing obstetrical emergencies. They were even able to apply skills to several cases that presented on the ward, and several reported doing vacuum-assisted deliveries successfully for patients who previously would have been taken for cesarean sections.

During the course of the entire PEER grant, in addition to trainings mentioned above the UMass team also implemented Basic Life Support (BLS) training with the help of UMass/ Family Health Center of Worcester Global Health fellow Dr. Duy Nguyen, who traveled to ELWA in 2021 to conduct BLS training and provide mannequins and materials for ongoing learning.

Another capacity building highlight of the project was the visit of key Liberian partner Dr. David Okiror to the United States in the spring of 2023 to present at the Society of Teachers of Family Medicine annual conference with Dr. Rick Sacra of SIM/ELWA and Dr. Olga Valdman of UMass, after which he spent one week visiting the UMass Family Medicine Department. The bilateral exchange of ideas and practices and the collaboration that has developed between two sister Family Medicine training programs have been powerful and will continue to bear fruit for the trainees for both programs.

In summing up the impacts of this five-year effort, PI Dr. Olga Valdman notes that despite any challenges and ups and downs, this investment has been transformational to the health system and to specialty training in Liberia: “Although we know that this grant was an anomaly for PEER, which traditionally funds and supports research initiatives, we want to applaud USAID for investing in medical education at the specialty level. Family Physicians trained through this grant both as clinicians and researchers will now be leaders across the country leading primary care teams and setting up standards and processes, and the impact of this investment will have many ripple effects to come.”

LIBERIA: VANDERBILT UNIVERSITY MEDICAL CENTER (VUMC)

PI: Troy Moon

Other Team Members: Marie Martin, Bonnie Miller, Amy Chomsky, Sapna Gangaputra, Jessica Howard

Dates: June 2018 - May 2022

Focus Areas: Clinical Research Training, Curriculum Development, Faculty Development Program, Ophthalmology

The Vanderbilt University Medical Center (VUMC)-led component of PEER/Liberia aimed to promote institutional and administrative capacity building to strengthen the A.M. Dogliotti School of Medicine (AMD) and Liberian College of Physicians and Surgeons (LCPS) to become accredited, sustainable, and robust local institutions. Following are the key results and impacts achieved on main objectives of the project:

Objective 1: Strengthen Medical Training and Build Subspecialty Medical Capacity in Liberia

- 49 faculty members and teaching apprentices participated in the Faculty Development Program, enhancing teaching skills.
- AMD's medical school curriculum was reformed, resulting in a new seven-year, integrated, and competency-based curriculum launched in 2021.
- The Faculty Mentorship Training Program was implemented to strengthen faculty mentorship in Liberia.
- The Residents as Teachers and Leaders (RATL™) Program was introduced to improve clinical teaching skills.
- Camp xSEL, a science camp for high school students, was launched to support the science education pipeline in Liberia.
- Ophthalmology subspecialty development in Liberia was supported, with training, remote mentorship, and access to online resources.

Objective 2: Improve Ability of Liberia to Conduct Research

- A four-part research capacity building workshop series was held for clinical residents, faculty, and medical students, covering research methodologies and ethics.
- Research projects on various health topics were developed, including pediatric influenza and RSV surveillance, cryptococcal meningitis, and family planning in Liberia.
- A COVID Webinar was conducted for clinical faculty, residents, and medical students to address research during the pandemic.
- A needs assessment of IRB functioning was conducted, and educational workshops on research ethics were organized for different IRBs in Monrovia.
- Collaboration with USAID's BRIDGE-U funding mechanism resulted in projects building on expertise and collaborations fostered through PEER Liberia.

In summary, the overall project impacts may be summarized as follows:

- Medical training capacity in Liberia was expanded through curriculum reforms, faculty development, and mentorship programs.
- Research capacity in Liberia was strengthened, with increased knowledge and skills in research methodologies and ethics.
- Collaborations and networks among Liberian institutions and U.S. academic partners were fostered, enhancing coordination and knowledge sharing.
- Sustainable developments were achieved in medical training and research institutions in Liberia, setting the foundation for continued growth and progress.

Vanderbilt University and its partners actively contributed to the growth of medical education and research in Liberia, with a focus on building local capacity and fostering collaborations that will continue to benefit the country's healthcare and research landscape in the future.

LIBERIA: YALE SCHOOL OF MEDICINE (YALE)

PI: Onyema Ogbuagu

Other Team Members: Lydia Aoun-Barakat, Laura Crawford, Sheela Shenoi

Dates: July 2018 - August 2021

Focus Areas: Clinical Research Training, Infectious Diseases

The original goal of the PEER award to Yale was to establish an infectious disease (ID) fellowship program at the John F. Kennedy Medical Center. This was then modified to coordinate West African College of Physicians (WACP)-recognized ID fellowship training at an institution in West Africa for two eligible Liberian physicians. Only one eligible candidate was identified, and at the time of the final report in November 2021, Joyce Bartekwa was completing the training she began in 2019 at Jos University Teaching Hospital in Nigeria and was board eligible (scheduled to sit for her fellowship exam in April 2022). The Yale team offered mentoring and one-on-one ID support Residents and junior faculty to nurture interest in ID-related research issues. This has included preceptorships in inpatient and outpatient settings (the infectious diseases and HIV clinics) as well as creation of a repository of ID lectures and other resources for the entire Medicine department.

Numerous challenges were encountered during implementation of this project. Dr. Ogbuago reports that he and his colleagues pulled back for a wider view of the medical education pipeline, and these modified expectations revealed the ill-prepared status of the Residents in JFK's Department of Medicine Residency Program regarding passing the WACP Membership exams at the end of residency, which would then allow further regionally recognized specialty training. Support was provided to Residents for the virtual (and mandatory) workshops prior to the twice-a-year WACP membership examinations. The most impact was from the hiring of four senior faculty MD specialists (in Gastroenterology, Cardiology, Pathology, and Nephrology) to each spend 12 weeks at JFKMC providing didactic and hands-on training, as well as specialized attention to the skills and responses sought by WACP examiners. This positioned a class of six residents to be eligible for and hopefully perform well in the forthcoming WACP membership exams in April 2022.

Part of the difficulties encountered on the project may have been due to the high standard set by the Yale team for the residency program and the physicians it produces. WACP is the recognized bar that has been set for JFKMC's Department of Medicine residents. The Department's training program has been accredited by WACP to provide post-graduate training, and most of the physicians recruited from the sub-region to teach are WACP Fellows. Despite the challenges, of the 22 trainees with the Yale team worked, 20 had passed their WACP primary exam by the end of the project, five had obtained WACP membership, which signals the completion of residency, and two have further achieved WACP Fellowship status in General Internal Medicine. The local Liberia College of Physicians and Surgeons (LCPS) offers a less rigorous examination which does not carry much weight outside of Liberia; all 22 have their LCPS primary certification, and 19 have their LCPS membership certification.

Yale joins several other PEER/Liberia partners in collaborating on the USAID program Bringing Research to Impact for Development, Global Engagement, and Utilization (BRIDGE-U): Liberia, which runs from 2021 through 2026.

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LIBERIA: SIM, SIM/LIBERIA, ELWA HOSPITAL (ELWA)

PI: Rick Sacra

Other Team Members: David Okiror

Dates: December 2018 - August 2023

Focus Areas: Family Medicine, Faculty Development Program

According to project PI Dr. Rick Sacra, the impact of this project has been nothing short of monumental. Family Medicine, a field that was virtually unknown in Liberia ten years ago, is now common knowledge at all levels of healthcare administration, including the Ministry of Health, the Liberia College of Physicians and Surgeons (LCPS), County Health Teams, and District Hospitals. Even though residency training only began in July 2017, by August 2023 there were 15 graduates from the membership program recognized by LCPS, serving as medical directors of hospitals and health centers, county health officers, and junior faculty within the Family Medicine Residency (FMR) Program. Furthermore, a new rotation in Family Medicine is slated to begin for final year Medical Students in 2024/2025 according to the revised A. M. Dogliotti (AMD) College of Medicine Curriculum. The USAID PEER/Liberia Partnership program can be especially proud that this funding catalyzed the development of a new primary care specialty in Liberia even during the COVID-19 pandemic, which could have easily derailed a project like this. Family Medicine will contribute to a shift toward more holistic and cost-effective care nationwide, in collaboration with all the other specialties that have faculties within LCPS.

Following are summaries of the activities undertaken by the SIM/ELWA team under each of their three objectives, with explanations for those which proved impractical or were reworked during the course of the grant.

Objective 1: Strengthen medical training and build subspecialty medical capacity in Liberia through hospital-based residency training, medical student teaching, faculty development, subspecialty care training to family physician trainees, and behavioral health training

Under Objective 1, the first activity was to create a structured curriculum for FMR which aligns with the West African College of Physicians (WACP) curriculum. This has been accomplished as we follow the WACP, which itself has revised its curriculum several times. The ELWA Hospital Family Medicine Faculty received full five-year accreditation from WACP in 2020. A new 2023 WACP curriculum includes online core knowledge modules and is being implemented starting with the 2023 class of residents, with the residents being trained by fellows of the West African College and LCPS. Rotation plans have been developed and documented with the partnership of UMass FMR collaborators. Much needed updates to LCPS policies and procedures and their adoption for Family Medicine were accomplished through the intense involvement of Family Medicine faculty in rewriting the LCPS Residency Policies and Procedures document in 2019/2020 and orienting all residents to this document. Feedback about training, rotations, and faculty from both faculty and residents was been solicited through detailed questionnaires both periodically (in association with residency retreats held in 2019 and 2021) and after each rotation, with this feedback helping drive decisions about rotation content and faculty assignments. The recruitment of core Family Medicine faculty was a key goal under this objective. The program chair's salary was initially funded by core USAID PEER funds, but those costs have now transitioned to partial funding by another long-term partner, African Mission Healthcare, for sustainability. Supplemental funds were used to bring in two additional core faculty, one of whom continues to develop the Part 2 Fellowship program/curriculum. Under the project's "Core Faculty" theme, SIM/ELWA deployed UMass Global Health Fellows to work in Liberia. The COVID pandemic interrupted this process, but even so, three UMass Global Health Fellows served 6-8 week stints in Liberia alongside UMass FM Residents (supported by UMass funds), who taught and coordinated Journal Clubs, clinical rounds, CPR training, and ALSO (Advanced Life Support in Obstetrics) training. The UMass team (Dr. Valdman and Maria Barluenga) was instrumental in assisting ELWA to organize schedules for clinical instruction, lectures, coordinating the mix of remote and in-person didactic sessions with the academic coordinator. The graduates who remained on as Junior Faculty, Dr. Igwilo and Dr. Korha, have been mentored and developed in their teaching and administrative skills.

The second theme under objective 1, which involved medical student teaching, was delayed by the constraints of working with the A.M. Dogliotti College of Medicine and their curriculum review system. However, SIM/ELWA joined in crafting the new curriculum, which is gradually being implemented. A complementary set of Family Medicine didactics and clinical teaching was put into the final year curriculum, to be implemented in 2024/25, with focus on gerontology, lifestyle medicine, travel medicine, and palliative care. For the third theme, Faculty Development, the initial plan to use the "Training of Tomorrow" course was scrapped after in depth consultation with both UMass partners and Fellows within the WACP. It became clear that only WACP-approved training would be accepted in this context. After consultation with WACP fellows/faculties, Dr. Sacra and his team revised these plans and used the "Doctors As Educators" course, as well as sending their faculty and senior residents to the faculty development seminars provided by other USAID PEER partners in collaboration with LCPS. Subspecialty Care Training was the focus of the fourth theme, and the team recruited faculty and provided subspecialty-based training in HIV/viral hepatitis care (by UMass fellows), Obstetrics (by an OB/GYN specialist funded by USAID), ENT (by a specialist from Ghana who made six one-month visits to teach intensive rotations to two residents at a time), Ophthalmology, Mental Health, Microbiology, and Pathology. Pediatrics was provided by another resource. This allowed the SIM/ELWA team to provide the full range of subspecialty training required by the WACP Family Medicine curriculum. Many of these didactic sessions are now in UMass Family Medicine databank. For the fifth theme, Behavioral Health (BH) Training, Dr. Liz Dykhouse from UMass provided interactive remote didactic sessions to residents, providing a full range of BH resources, including the trainees' self-assessments of their own reactions to patients and to the traumas and stresses of physician practice, as well as a full range of BH tools for patients with a wide range of mental health issues.

Objective 2: Improve the ability of Liberia to conduct clinical research
An initial set of four research trainings was conducted in 2019, funded by PEER (carried out by UMass in collaboration with other partners and JFK departments), each running four half-days. A second set of trainings was carried out in 2020, in online/zoom format due to COVID-19. This led to a set of eight pilot projects being approved, including one led by a family physician resident. These research projects continue in various states of completion as of August 2023. Thanks to supplemental funds provided by PEER/Liberia, the team organized a research training in December 2022, based at ELWA Hospital and conducted by Dr. Trish McQuilkin (UMass Pediatrics) in collaboration with three local faculty from the Liberia College of Health Sciences (LCHS). Participants included one part-2 senior resident, four FMR graduates, and five Family Medicine faculty members. A follow-on mentoring scheme was put in place to allow ongoing pursuit of research opportunities through an agreement with one of the local Liberian faculty through the fall of 2024. Research outputs include presentations at various Scientific Sessions by Family Physicians, including "ELWA Hospital Primary Care Intervention to Manage COVID-19 during the First Peak of the Epidemic from April 2020 to August 2020 in Monrovia, Liberia.

Outcomes and Lessons Learned" by Dr. David Okiror and 14 others, presented at the recent LCPS Annual General and Scientific Meeting. Research is probably the area where Liberia has the largest gaps and needs before developing state-of-the-art outputs, but this grant has done a lot to introduce trainees to research fundamentals.

Objective 3: Increase access to specialty care for Ebola survivors and the broader population

By the time funding was received in December 2018, the Ebola epidemic had faded to the back of peoples' minds. There were still a few Ebola survivors attending the ELWA Hospital Continuity Clinic at the beginning of the project, and they were folded into the ongoing efforts to improve access to high-quality Family Medicine care at ELWA. Family Medicine's emphasis on developing curriculum, a quality improvement mindset, and training time in the outpatient setting should go a long way toward improving preventive and chronic disease care in Liberia in the long run.

LIBERIA: UNIVERSITY OF LIBERIA COLLEGE OF HEALTH SCIENCES/A.M. DOGLIOTTI MEDICAL SCHOOL

PI: Bernice Dahn

Dates: June 2020 - October 2023

Focus Areas: Clinical Research Training, Curriculum Development, Faculty Development Program, Infrastructure Improvements

The PEER Liberia activity was designed to provide sub awards to the university to help strengthen administrative management through overhead costs. To resolve this issue, while the third-party arrangement was in place, a financial assessment was done in 2019 to determine gaps that needed to be addressed to allow the university to receive a subaward from the National Academies. The findings showed the following: (1) there were no audit reports available; (2) no accounting software in place; (3) no standard operating procedure to outline the process for financial controls; (4) no dedicated financial management personnel; and (5) no dedicated account for the college to set aside grants for project implementation. The recommendation was that PEER should provide technical support to strengthen the capacity of the university to receive a subaward. In the meantime, funds to support activities at the university were administered through other organizations.

Based on the above, the results below were obtained:

1. Teaching Apprentice Program: The Teaching Apprentice Program with support from USAID/PEER/NAS was developed to identify and recruit the ULCHS Medical School future preclinical faculty to replacing foreign faculty. To achieve this, the secured funding from PEER/NAS supported abroad graduate program for 14 (3 females and 11 males) Liberian Teaching Apprentices at the University of Ghana specifically in the Biomedical Sciences. By the time the project ended, six of them in Cohort 1 had successfully completed their studies and returned home to join the ULCHS faculty while the remaining eight returned home at the end of December 2023.

2. Faculty Development Training: 61 faculty members (21 females and 40 males) of three cohorts at the ULCHS and the main University of Liberia were impacted by the faculty development training implemented in collaboration with Vanderbilt University. The primary goal of the training was improving change management, excellent classroom teaching skills, research utilization, and advancing the capacity building of medical education through effective leadership in education, assessment, and evaluation. The faculty involved in these trainings were all from preclinical and clinical (with backgrounds in internal medicine, pediatrics, surgery, psychiatry, and clinical pathology), including faculty from the departments of Chemistry, Physics, and Biology from the main University of Liberia. The training also looked at mentorship training for two cohorts of faculty and the Resident as Teachers and Leaders (RATL) training. The RATL is a blended program consisting of web-based self-learning modules and interactive hands on learning.

3. The new revised ULCHS curriculum with support from PEER Grant (implemented in collaboration with U.S. partners on the program)

4. The establishment of the ULCHS Grant Management Office, which by the time of the final report on the project was managing $11 million in new grants awarded to the university for a wide range of new activities

5. Procurement of Laboratory equipment and reagents for the ULCHS Medical School laboratory

6. Refurbishment and purchase of laboratory equipment and reagents for the University of Liberia Science College (Physics, Chemistry, and Biological Science).

7. Procurement of two vehicles to facilitate transportation service to commute faculty and students between the JFK Hospital and medical school campuses.