LASER PULSE

Long-term Assistance and Services for Research (LASER) Partners for University-Led Solutions Engine (PULSE)

SECONDARY DATA ANALYSIS OF POVERTY, FOOD, AND NUTRITION SECURITY IN MADAGASCAR

SUPPLEMENT TO AGREEMENT NO. AID-7200AA18CA00009

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PROJECT BACKGROUND

This report presents the results of the Secondary Data Analysis (SDA) completed under the USAID/BHA/TPQ/SPADe Madagascar RFSA Activity Design project. The research undertaken in this project will inform the design of the FY24 Resilience and Food Security Activity (RFSA) in Madagascar, which will serve the needs of rural Malagasy communities affected by chronic nutrition and food insecurity. This project is supported through a buy-in from USAID/BHA/TPQ/SPADe into the Long-term Assistance and Services for Research (LASER) project currently in place between USAID/DDI/ITR/R and Purdue University under a cooperative agreement # 7200AA18C00009. This project has been executed by Abt Associates under a sub-contract with Purdue University.

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ABOUT LASER PULSE

LASER (Long-term Assistance and SErvices for Research) PULSE (Partners for University-Led Solutions Engine) is a $70M program funded through USAID's Innovation, Technology, and Research Hub, which delivers research-driven solutions to field-sourced development challenges in USAID partner countries.

A consortium led by Purdue University, with core partners Catholic Relief Services, Indiana University, Makerere University, and the University of Notre Dame, implements the LASER PULSE program through a growing network of 3,500+ researchers and development practitioners in 86 countries.

LASER PULSE collaborates with USAID missions, bureaus, and independent offices, and other local stakeholders to identify research needs for critical development challenges, and funds and strengthens the capacity of researcher-practitioner teams to co-design solutions that translate into policy and practice.

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EXECUTIVE SUMMARY

OBJECTIVES AND PURPOSE OF THE SDA

Madagascar has significant and ongoing humanitarian caseloads due to recurrent shocks, such as conflict, droughts, and economic crises. The situation is particularly challenging in the Southern and Southeastern parts of the country, where the population suffers acute poverty and food insecurity conditions exacerbated by frequent extreme weather events and economic shocks. The USAID Bureau for Humanitarian Assistance (BHA) seeks to build resilience among households and communities vulnerable to recurrent shocks, thereby also reducing the need for ongoing and future food and nutrition security humanitarian assistance in the region.

The purpose of the Secondary Data Analysis (SDA) is to use secondary data to inform the targeting and design strategy for multi-year resilience food and nutrition security programming in Madagascar which will serve the needs of rural Malagasy communities. The analysis will contribute to the BHA and USAID goals of improving the quality and impact of food security programming, saving lives, and reducing the need for humanitarian assistance. The analysis focuses on four regions (Androy, Anosy, Atsimo Andrefana, and Atsimo Atsinanana), and is representative at the regional level.

BRIEF METHODOLOGY

Through this secondary data analysis of the Madagascar Resilience Food Security Activities (RFSA) Activity Design engagement, we aim to understand the correlates of poverty, food insecurity and malnutrition among affected households and children in Madagascar (i.e., the target population). We consider the target population to be households living in the bottom wealth quintile, children living with stunting, and children living below the minimum acceptable diet threshold. The four research questions (RQ) of the SDA are to understand:

1) The demographic and socio-economic characteristics of the target population.
2) How demographic and other characteristics of the target population vary geographically across each of the targeted regions.
3) How demographic and other characteristics of the target population compare to those of households and individuals not in the target population; and
4) Which household characteristics are significantly associated with the outcomes that define the target population, i.e., high levels of poverty, low levels of food access and diet diversity, high levels of food insecurity, and chronic malnutrition.

To address these questions, we employed a range of methods, including descriptive statistics (RQ1 above), geospatial analysis techniques (RQ2), econometric analysis (RQ3), and machine learning (RQ4). Our primary data set is the 2021 Demographic and Health Survey (DHS) for Madagascar.

KEY FINDINGS

The table below summarizes the key findings from the analysis, as well as the potential implications for BHA and implementing organizations as they design the program activities and targeting strategies for the next round of RFSA programming in Madagascar.

Key Findings	Program Design Implications
Variation across the four regions is notable, particularly for results related to poverty.	Successful program design will be customized to each region as much as possible. For example, household targeting tools should be region-specific, though when there is data to support it, sub-region heterogeneity should be considered.
Socioeconomic variables such as dwelling characteristics and asset ownership are critical for predicting poverty status of a household.	Targeting tools should focus on the socioeconomic characteristics that were most salient in this analysis, including roof type, mobile phone ownership, and cooking fuel. Household employment in agriculture, zebu ownership, and improved water source showed sub-regional variation. Programs could be targeted to specific geographic areas based on these factors. It would also be worthwhile for program implementers to track changes in socioeconomic factors during the course of the RFSA implementation.
Results were far more robust for poverty outcomes than food security outcomes, likely due to sample size limitations on child-level data.	The results related to child stunting and Minimum Acceptable Diet (MAD) should be treated with caution due to sample size limitations. It would be difficult to develop a household targeting strategy to identify households at risk of food insecurity based on these findings alone. The results for poverty outcomes are strong and should be helpful inputs to developing a targeting tool that selects households most likely to be living in poverty. This aligns well with USAID's planned graduation approach.
Education of the household head, as well as sanitation characteristics, appear to be strongly associated with households living in poverty.	USAID might consider incorporating activities related to coaching and mentoring adults with low levels of educational attainment. Coaching is a common foundational component of programs that use a graduation approach and could include activities focused on life skills, mentoring to run a business, behavior change coaching related to Water, Sanitation, and Hygiene (WASH), and education about maternal and child health. These activities could be included within this RFSA or as part of the other activities in the Mission portfolio, given the connection with poverty.

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ACRONYMS

BHA	Bureau for Humanitarian Assistance
CI	Confidence Interval
DDI	Bureau for Development, Democracy, and Innovation
DHS	Demographic and Health Surveys
DRMS	Desk Review and Market Study
GHI	Global Hunger Index
GIS	Geographic Information System
GPS	Global Positioning System
HR	Household Recode
IQR	Interquartile Range
ITR/R	Innovation, Technology and Research Hub Research Division
IR	Individual Recode
KR	Children's Recode
LASER	Long-Term Assistance and Services for Research
LBR	Local Bivariate Regression
MAD	Minimum Acceptable Diet
MR	Men's Recode
PEA	Political Economy Analysis
OCHA	Office for the Coordination of Humanitarian Affairs
PI	Principal Investigator
PR	Household Member Recode
PULSE	Partners for University-Led Solutions Engine
RFSA	Resilience Food Security Activities
SPADe	Strategic Planning and Activity Design
SDA	Secondary Data Analysis
SFS	Sequential Forward Selection
TPQ	Office of Technical and Program Quality
USAID	United States Agency for International Development
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

1. INTRODUCTION TO SECONDARY DATA ANALYSIS

1.1. BRIEF COUNTRY CONTEXT

Madagascar has significant and ongoing humanitarian caseloads due to recurrent shocks, such as conflict, droughts, and economic crises. When coupled with underlying or chronic drivers of food and nutrition insecurity, like poverty, lack of drinking water, and poor feeding practices, Madagascar requires significant humanitarian assistance.

Extreme weather events and economic shocks have particularly affected the regions of Androy, Anosy, Atsimo Andrefana, and Atsimo Atsinanana (termed the Southern region for this document). The Southern region recorded the lowest rainfall levels in 40 years, resulting in a prolonged drought from 2018 to 2022. Sandstorms, lack of irrigation infrastructure and livestock watering, and pest infestations further impacted agriculture and caused decline in rice, maize, sweet potatoes, and cassava production (Narvaez & Eberle, 2021). Cyclones Emnati and Batsirai devastated parts of Atsimo Atsinanana region in 2022. The 2020 COVID-19 pandemic was a shock to the local economy in addition to a global health crisis.

This had devastating effects on harvests and livelihoods. These environmental aspects, combined with a lack of livelihood diversification, ongoing poverty, small land holdings, insecurity driven by frequent cattle thefts, and recurring political crises have driven the population of southern Madagascar to acute food insecurity conditions (Narvaez & Eberle, 2021). According to the Global Hunger Index (GHI), Madagascar ranks third in countries experiencing the most hunger with nearly half the population (48.5%) being undernourished from 2019-2021[1]. This has been steadily increasing since 2010 when undernourishment was 28.3% (Grebmer et al. 2021).

1.2. SDA PURPOSE AND AUDIENCE

The USAID Bureau for Humanitarian Assistance (BHA) seeks to reduce the need for ongoing and future food and nutrition security humanitarian assistance in Madagascar and build resilience among households and communities vulnerable to recurrent shocks. All the analytical products are intended to be posted publicly so the results can be used to better inform the understanding of food and nutrition security, poverty, and resilience. The analysis focuses on four regions (Androy, Anosy, Atsimo Andrefana, and Atsimo Atsinanana), and is representative at the regional level. More broadly, the analysis will contribute to the BHA and USAID goals of improving the quality and impact of food security programming, saving lives, and reducing the need for humanitarian assistance.

The purpose of the Secondary Data Analysis (SDA) is to use secondary data to inform the targeting and design strategy for multi-year resilience food and nutrition security programming

[1] A note on terminology: undernutrition is a sub-group of malnutrition. We use malnutrition for its wider meaning throughout the document. https://www.who.int/news-room/fact-sheets/detail/malnutrition

in Madagascar, which will serve the needs of rural Malagasy communities. This study will provide BHA design teams and potential implementing partners with the information needed to inform critical program design decisions and develop contextually specific and evidence-based programming. This information also has the potential to influence the work of USAID's Bureau of Resilience, Environment, and Food Security and the USAID Mission in Madagascar as secondary stakeholders.

1.3. RESEARCH QUESTIONS

This analysis will address the following four research questions determined by the BHA team:

1) What are the demographic and other characteristics of households and individuals with (1) high levels of poverty and (2) low levels of food access and dietary diversity for each of the targeted provinces?
2) How do the demographic and other characteristics of households and individuals with high levels of poverty, low levels of food access, high food insecurity, and high levels of chronic malnutrition vary geographically across each of the targeted provinces?
3) How do the demographic and other characteristics of households and individuals (as described in question 1) with high levels of poverty, low levels of food access, high food insecurity, and high levels of chronic malnutrition for each of the targeted provinces compare to household and individuals for those indicators that are not target populations (by quintile or that are above -2 z score for chronic malnutrition)?
4) Based on results of statistical inference modeling (e.g., OLS, logistic, multivariate, etc.), what characteristics are significantly associated with high levels of poverty, low levels of food access, high food insecurity, and high levels of chronic malnutrition in each of the targeted provinces? What additional insights can these results provide, beyond the current state of the literature and beyond the specific research questions provided above, to better understand the associations between potential predictors (characteristics) and the outcomes (key indicators)?

1.4. LITERATURE REVIEW

The research team, in its selection of variables for analysis from the Demographic and Health Surveys (DHS) dataset, collected background information from a thorough review of relevant literature. This literature focused on the topics of poverty and malnutrition along with their associated socio-demographic and socio-economic correlates. The research team also incorporated several sources that used similar methods to those planned in this SDA or answered similar research questions.

Studies from regions analogous to Madagascar in general geographic location and ranking in the Human Development Index, like the Democratic Republic of the Congo, showed

that living in poverty was associated with a low educational background, electricity access, and asset ownership (LASER PULSE, 2023). Similarly, research from Zimbabwe highlights associations between poverty incidence and factors such as education, sanitation, asset ownership, and the gender of the household head (Viceisza et al. 2020). These studies from diverse geographies echo our research objectives and analytical approach.

Building on this, the issue of malnutrition, especially in Madagascar, is pressing. Studies report that schoolchildren, aged between 5-14, show high rates of stunting and being underweight (Aiga et al. 2019). The older children, particularly those from larger households, are more susceptible to malnutrition. Such patterns are reiterated in studies from Ifanadiana, Madagascar, emphasizing socio-demographic factors – particularly child age, birth size, and maternal/paternal height - as primary correlates of stunting and malnutrition (McCuskee et al, 2018). In addition to socio-demographic and socioeconomic factors, child health characteristics, including infection, and maternal characteristics such as occupation and dietary patterns were also found to be risk factors for stunting (Rabaoarisoa et al. 2017).

Studies have shown that dietary diversity among children in Madagascar is associated with sanitation, health, wealth status, and maternal education and birth type (Farris et al. 2019; Aheto, 2020). These studies suggest that targeting maternal health outcomes and socio-economic factors in child nutrition and health policies can have a positive impact on child nutrition. These comprehensive insights, spanning poverty, malnutrition, and socio-demographic intricacies, provide an informative background for our study. By leveraging existing literature, we aim to build upon these discussions, enhancing our understanding of these outcomes at play in Madagascar with the findings we will put forward in this report.

2. METHODOLOGY

2.1. DATA MANAGEMENT

2.1.A.DATA SOURCES

For the SDA, the primary data source was the 2021 Demographic and Health Surveys (DHS) dataset for Madagascar. The DHS program conducts representative household surveys in different countries, providing comprehensive data on an assortment of topics including fertility, health, nutrition, and more. Specifically, we pulled data from the Household Recode (HR) and Household Member Recode (PR), the Individual Recode for women (IR), the Children's Recode (KR), and, for GIS purposes, the Men's Recode (MR). We systematically integrated these datasets by referencing the Guide to DHS statistics provided by USAID, to construct our comprehensive analysis datasets, allowing for a holistic understanding of our research topics across different demographic groups and the outcome variables of interest.

The GIS team obtained the following geospatial data from the DHS Program: the GPS coordinates for the DHS clusters, interpolated indicator data and geospatial contextual layers. Additional contextual geospatial data such as administrative boundaries, roads and populated

places were obtained from authoritative sources such as the United Nations Office for the Coordination of Humanitarian Affairs' (OCHA) Humanitarian Data Exchange. High resolution population models were obtained from the WorldPop program. The research team assessed all data acquired for currency, accuracy, and provenance to ensure the quality of the data. The layers were then cleaned, processed to ensure proper spatial alignment, and put in an ArcGIS geodatabase.

2.1.B. DATA CLEANING

During the data cleaning phase, the study team utilized the guide to DHS Statistics to determine the inclusion and construction of essential variables for the analysis datasets. Utilizing Stata, we began with preliminary checks to gauge the scope of the Madagascar DHS dataset in terms of its observations and breadth. We cleaned the data by conducting a series of checks which included creating summary tables for our variables of interest to check that they existed within the provided data set. We also checked the number of observations, and if there were inherent outliers that needed to be excluded prior to analysis.

We conducted the outlier analysis for several variables according to univariate outlier detection methods in recent literature (Filzmoser et al. 2016). The variables included number of zebus owned, number of poultry owned, and amount of agricultural land owned. To identify upper outliers for each of these variables, we first calculated the interquartile range (IQR). Using the IQR, we then determined the median value for each variable and established an upper boundary. This boundary was set at the respective median plus a factor of three times the IQR divided by 1.35. Any data points exceeding this upper boundary for each respective variable were considered as upper outliers.

To ensure the robustness of our subsequent analyses and mitigate the impact of these outliers, we replaced the outlier values with the calculated upper boundary value for each variable. This method allows us to retain the observations in our analysis while reducing the potential influence of extreme outlier values. We then created clean datasets at the level of households, household members, children, women, and men. To streamline our analysis and enhance computational efficiency, we retained only indispensable variables. This meticulous filtering yielded a dataset that was both comprehensive and optimized for our analysis needs.

2.1.C. VARIABLE CONSTRUCTION

Prior to variable construction, we prepared a mapping that detailed all pertinent variables within our three pivotal outcome variables: poverty, malnutrition, and dietary diversity. This mapping not only identified each variable but also pinpointed its source file, tracing it back to one of the five core DHS data levels. For instance, within the poverty outcome, we derived variables such as household size, asset ownership, and primary source of drinking water from the HR dataset. Similarly, for the child stunting outcome, we pulled the data for child age, height, and weight from the KR dataset. Then to maintain the integrity and accuracy of our variable construction, we outlined our Stata variable construction code to reflect the statistical equations in the DHS Guide to Statistics. We then merged the different cleaned

datasets to create three analysis syntax files, one for each of our outcome variables: Household Poverty, Child Stunting, and Child Minimum Acceptable Diet.

We defined many of the variables based on ranges of the cleaned variables to create the bins to be used in the analysis. For example, the head of household age was categorized into "19 or younger", "20-34", "35-49", and "50 plus."

2.2. KEY VARIABLES

2.2.A.POVERTY

The poverty variable focuses on the economic well-being of households in Madagascar. The primary measure for poverty was the household's position in the wealth index. The wealth index was calculated according to a standardized DHS approach and was included in the raw DHS data sets used by the research team. This standardized DHS approach uses a common statistical method of principal components analysis to apply weights to a set of indicators, including household consumer durables, assets, and dwelling characteristics to generate an index of the overall household living standard (Rutstein and Johnson, 2004). The wealth index is a relative measure of poverty, as each household is ranked based on how its wealth score compares to the wealth scores of other households in the 2021 DHS for Madagascar. This differs from an absolute poverty measure, such as comparing household expenditures to a fixed poverty line. We utilize the wealth index for this study given that no recent absolute poverty measures are available for Madagascar and the fact that it is commonly used in health-related analysis. For clarity, we note that the wealth index is used to divide the survey population into five equal groups (quintiles), ranked from poorest to wealthiest. The cut lines for the quintiles of the wealth index are based on the distribution of household members, not households as used in our analysis.

2.2.B. FOOD INSECURITY AND MALNUTRITION

Our primary indicators for food insecurity and malnutrition focus on the nutritional well-being of children, particularly child stunting, and child Minimum Acceptable Diet (MAD). The research team calculated these indicators using child-level data from the DHS. Child stunting reflects chronic malnutrition. Moderately or severely stunted is defined as the proportion of children aged 0-59 months (children under 6 years old) whose height-for-age is two standard deviations or below the World Health Organization (WHO) Child Growth Standards median. MAD measures dietary diversity and meal frequency for children aged 6-23 months. It reflects the quality and quantity of the child's diet and is indicative of the adequacy of the child's micronutrient intake.[2]

[2] The definition of minimum acceptable diet is complicated. It depends on both minimum dietary diversity and minimum meal frequency, defined separately for breast-fed and non-breastfed children. Further details can be found in the Guide to DHS Statistics DHS-7 (dhsprogram.com/Data/Guide-to-DHS-Statistics/index.cfm).

2.2.C. SOCIO-DEMOGRAPHIC AND SOCIOECONOMIC CORRELATES

To provide context and depth to our main variables of interest, the research team also analyzed several socio-demographic and socioeconomic correlates. We examined the number and composition of household members, which offers insights into household dynamics and potential strain on resources. We also considered the highest level of education attained by the household head as those factors were found to be associated with poverty, stunting, and diet diversity across the studies discussed in Section 1.4. Other key variables include housing and location factors such as type of residence, main floor material, source of drinking water, type of toilet facility, and the main source of energy for cooking, all of which shed light on the living conditions and environment of households. Additionally, asset ownership variables, such as ownership of durable assets, land, and livestock or other animals, paint a broader picture of a household's economic status. For a minimally acceptable diet, we also have indicators from the same data set on the occupation and literacy of the child's mother, as well as child health variables related to acute respiratory infection and diarrhea.

2.3. DESCRIPTIVE ANALYSIS

The descriptive analysis was designed to understand how demographic and other characteristics of households and individuals in the study's target population (households with high levels of poverty, children with stunting, and children without MAD) varied compared to those not in the target population. Our primary method of analysis was to see how certain characteristics, like the gender of the household head, were associated with our outcome variables.

For RQ1 we calculated weighted proportions (with associated 95% confidence intervals) of households or children in our target populations within different socio-demographic and socio-economic subgroups. For RQ3, we used a simple bivariate regression model to measure whether a household or child was more or less likely to belong to a certain subgroup if it was in the target population compared to those not in the target population. Annex D provides more details on our methodology for RQ3.

A statistically significant relationship between an outcome variable and a subgroup variable helps us understand which demographic factors are more strongly correlated with living in poverty, child stunting, and child diets. While significance does not imply that these factors are underlying drivers of the outcomes, they may inform which household characteristics may be used to identify households that may benefit from RFSA activities. Our initial review of the DHS dataset determined that sample sizes were generally too small to be statistically valid at the level of specific districts. Therefore, the analysis used the regional level for poverty within the four regions of interest (Androy, Anosy, Atsimo Andrefana, and Atsimo Atsinanana). For childhood diet and stunting, the regional level analysis also had small samples, which led us to conduct an additional analysis in which we pooled the four regions together.

Our analysis focused on three dependent binary variables, poverty as defined in the example, child stunting, and minimum acceptable diet. Through the regressions, we compared

all three outcome variables across all four regions of interest against various categorical indicators like head of household age, level of education, and gender along with home characteristics, possessions, and demographics. The minimal acceptable diet analysis also investigated relationships with maternal indicators like her literacy, occupation and child health status like diarrhea and acute respiratory infection, as these were available in the same data set.

2.4. GEOSPATIAL ANALYSIS

The geospatial analysis was tailored to explore a subset of the second research question, how the demographic and other characteristics of households and individuals with high levels of poverty, low levels of food access, high food insecurity, and high levels of chronic malnutrition vary geographically across and within each target region. After the data curation effort described above, a review of different geospatial analysis approaches was explored. Techniques explored included Moran's I, Optimized Hot Spot analysis, cluster/outlier analysis among others. After consultation with the USAID and LASER Pulse team, the Local Bivariate Regression (LBR) was selected due to its ability to convey relationships between variables within a spatial context. The analysis used the ArcGIS LBR tool. Time constraints limited the analysis to household poverty, however the other components of Research Question 2, high food insecurity and high levels of chronic malnutrition, could also be the subject of LBR analysis. Variables used in the analysis were identified in partnership with USAID to align with the graduation approach and the analysis assessed the relationship between these variables and household poverty at the DHS cluster level.

Poverty can be a challenging phenomenon to capture. The DHS surveys have created a derived variable "Wealth Index" to serve as a proxy for poverty. The proportion of the cluster's households in the lowest wealth quintiles was determined and used in the LBR calculations as the dependent variable.

LBR differs from the traditional regression approaches in that it considers the cluster in the context of nearby clusters. LBR captures local variations that may not be evident in non-spatial regression. LBR uses measures of entropy to determine whether there is a statistically significant relationship between two variables and whether that relationship varies over space. Results from LBR classify relationships as either being positive, negative, or inconclusive. Positive relationships mean that as one variable (for example, stunting) changes, the dependent variable (for example, poverty rate) changes in the same direction. When there is a negative relationship between the two variables it indicates that the two variables move in opposite directions to each other. For instance, when stunting rises, the poverty rate falls and vice versa.

To do the calculation, the tool defines a "local area" for each cluster and then calculates the relationship between the two variables. Local area can be defined using either distance or a specific number of clusters. For this analysis, LBR was calculated using the 30 nearest clusters. Thirty clusters is the minimum number of clusters necessary to calculate LBR and it provides a balance between having a sufficient number of clusters to define a local area but not so large that it causes distant clusters to affect the result.

LBR was calculated at the DHS cluster level using DHS Program provided GPS coordinates for the clusters. Because the geospatial analysis relied on DHS Cluster locations, the results are only representative of the enumeration area around that cluster and are not representative for the district or region as a whole. However, unlike the regionally representative data from the full survey, cluster-level data makes it possible to observe intra-regional heterogeneity in a way that would not be possible at only the regional level. Revealing such heterogeneity is valuable because it can uncover pockets of high or low values that would be missed at a regional level. Knowing where these areas lie can ensure that programs are able to target their activities to the areas with the greatest need.

2.5. ECONOMETRIC AND MACHINE LEARNING ANALYSIS

The econometric and machine learning analysis explored the fourth research question. To determine a set of indicators that are strongly associated with the outcomes of interest (poverty, food insecurity, and malnutrition), we used a feature selection machine learning algorithm that iteratively selects indicators from the larger pool of DHS indicators described in Section 2.2. Machine learning provides the flexibility to adjust the parameters of the model to select indicators that maximize predictive accuracy. In other words, it allows us to select indicators that are highly correlated with poverty, food insecurity and malnutrition, and robust to changes in model parameters.

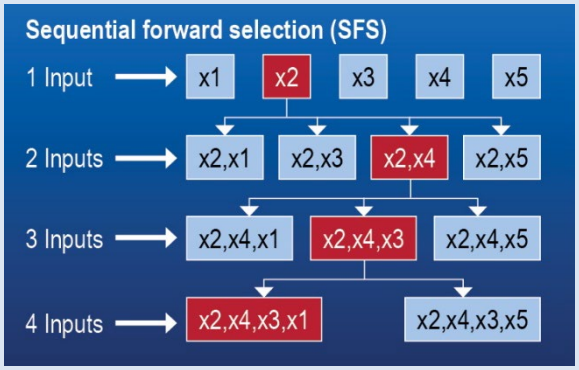

Figure 1: Sequential Forward Selection (SFS)

Source: Feature Selection for Pattern Recognition, J.S. Roger Jang, National Taiwan University
PPT - Feature Selection for Pattern Recognition PowerPoint Presentation - ID:5568648 (slideserve.com)

The mechanics of how the machine learning model identifies variables are explained in the annex. As a general overview of the machine learning method, the variables or "features" being selected by the model are simply variables from the DHS dataset. We employed a logistical regression model with a machine learning algorithm known as Sequential Forward Selection (SFS) to help us identify the most informative features from our data that impact the determination of our outcomes. SFS iteratively builds the model by selecting the most significant variables one at a time, progressively adding more based on their contributions to the model's performance. The performance of the model is measured by an accuracy score.

This analysis, like the descriptive and regression analyses for RQ1 and RQ3, identifies correlations between a given outcome variable and household demographic and socioeconomic variables by exploring how they vary together in the household level data. For example, for the poverty outcome, these correlations are derived from the SFS algorithm applied to a logistic regression model where poverty status is the dependent variable and household demographic,

and socioeconomic variables are the independent variables. Likewise, for child stunting and MAD respectively, separate logistic regressions include child and maternal characteristics as the independent variables.

These quantitative results complement the primarily qualitative Desk Review and Market Study (DRMS) and Political Economy Analysis (PEA) studies, which provide context about the lived reality of households in our four focal regions. For example, and as a preview of the results, the machine learning analysis shows that living in poverty is strongly, negatively associated with whether a household head had completed any level of education in three out of four regions. The DRMS provides additional context into how low levels of education are a barrier for the uptake of improved agricultural practices, leading to reduced yields and increased vulnerability to shocks and stresses. The econometric and machine learning analysis shows that ownership of a mobile phone is highly correlated with living in poverty in all four regions. The finding on mobile phone ownership is an important one, due to the potential for financial inclusion through mobile money. Focus group discussions reveal that mobile phones are often shared between several households (for example, members of a savings group); therefore, ownership could be considered a criterion towards "graduation from poverty."

2.6. LIMITATIONS

We should note a number of limitations to the analysis presented in this document:

1. This analysis does not identify causal relationships. A statistically significant relationship between any given outcome variable and a subgroup variable (which could be a socio-economic or socio-demographic subgroup) does not imply that belonging to a certain subgroup causes that outcome. Our analysis cannot claim, for example, that owning a house with a thatch or leaf roof results in poverty, even if the relationship is statistically significant. Statistical significance implies that an association is highly likely to exist, but it is not necessarily a driver of poverty, child stunting or MAD.
2. Given that we measure multiple comparisons there is also a chance that a small number of results are deemed statistically significant when there is no association. This is known as a false positive and will occur a small fraction of the time. Since we use a 95% confidence interval, it can be expected that about 5 out of every 100 relationships tested might produce a false positive. Since distinguishing between true positives and false positives is not straightforward, this potential for misinterpretation should be acknowledged as a limitation in our findings.
3. Our analysis uses a relative measure of poverty, in that, it considers a household as living in poverty if they rank in the bottom 20th percentile of the wealth quintile. Absolute measures of poverty that use consumption measures were not available in the 2021 DHS data. This may be problematic because the absolute poverty rate in

Madagascar was high in 2012[3] and a series of weather and health crises worsened living conditions in recent years. Our analysis will not be able to identify households who may be in need of assistance if they have a higher wealth index than 20% of the population.

4. There is an imperfect overlap between the area of analysis for this report (regional level) and RFSA target area (specific districts within these regions). This discrepancy is starkest in the Atsimo Andrefana region, in which USAID has targeted one district (Ampanihy Ouest) for the RFSA, but the results for this secondary data analysis provide averages across all nine districts in this region.
5. The 2021 DHS data used for Research Questions 1, 3, and 4 are representative at the regional level, but not lower. We cannot therefore examine the twelve districts in the RFSA target specifically but use the regions in which they exist as proxies. We anticipate that the geospatial analysis in RQ2, and the tandem DRMS and PEA studies, will fill in some evidence gaps related to district-level or cluster-level heterogeneity.
6. The 2021 DHS data offer relatively small sample sizes at the regional level for child-level outcomes. This is particularly true for studying MAD, which is asked only of the youngest child between 6 and 23 months in the household. There are 758 children in this age range in the four regions under study.
7. Finally, we acknowledge that the socio-economic and health situation in Madagascar has experienced volatility – e.g., COVID-19, drought, political dynamics -- since the DHS data were collected in 2021. Results from this study should be interpreted in conjunction with the findings of the sister DRMS and PEA studies for Madagascar.

[3] According to the World Bank County Profile for Madagascar, the poverty headcount ratio at $2.15 a day (2017 PPP) was 80.7% in 2012.

3. RESULTS

This section of the report is divided into two main sections. First, we discuss the results related to the poverty outcome measure, and then we turn to child stunting and child MAD as our main measures of food security and nutrition. Within each of these two main sections, we discuss the results of each research question in order, starting with the descriptive analysis, then moving on to geospatial analysis, comparisons between groups, and finally the results from the machine learning analysis.

3.1. POVERTY

The poverty results highlight many factors associated with poverty. Households with household heads with no education are more likely to be living in poverty than households with some education. Likewise, households who do not own a mobile phone are more likely to be living in poverty than those who do own a phone. Poor sanitation and dwelling conditions are also associated with a higher rate of living in poverty compared to households with improved dwelling conditions. The following sections detail the descriptive, geospatial, regression and machine learning results for the poverty analysis.

3.1.A. DESCRIPTIVE

First, we present the results for the descriptive analysis, in which we describe the characteristics that are common among households living in poverty.

Household-level results

The rate of households living in poverty, according to the lowest quintile of the wealth index, is relatively high in all four of the target regions. For Androy, Anosy, and Atsimo Andrefana, the poverty rate is narrowly bounded between 39 and 47 percent of households (Figure 2, below). The rate of households living in poverty is higher in Atsimo Atsinanana, at 66 percent. This compares to a poverty rate of 19 percent among households in Madagascar as a whole using the same wealth index. Please note that the overall rate is not 20 percent because the cut lines for the quintiles of the wealth index are based on the distribution of household members, not households as used in our analysis.

What is a confidence interval?

The gray bands on top of the bars in Figure 2 represent the 95% confidence intervals (CI). The CI tells us how precise the poverty rate estimate is. A smaller confidence interval implies more precision. For example, the confidence interval for Androy is between 35% and 54%. In other words, the true poverty rate will fall within this range 95% of the time if we were to repeatedly sample households.

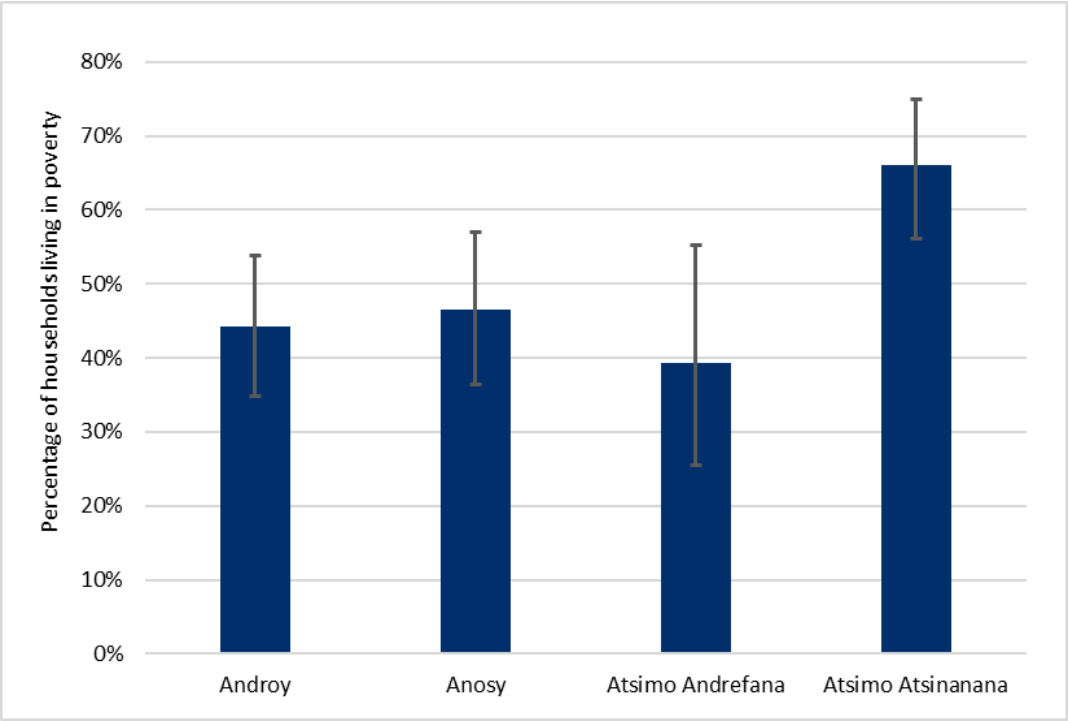

Figure 2: Poverty Rates by Region

Source: 2021 Demographic and Health Surveys (DHS)

We next examine the rate of poverty disaggregated by numerous factors that may be correlated with poverty in these four regions. These indicators fall into two general domains: socio-demographic and socio-economic characteristics as referenced in Section 2.2. Full results for all available indicators in these domains are included in Annex A. We discuss in the text the most noteworthy of the results.

Relationship between Poverty and Socio-demographic and Health Characteristics

For socio-demographic factors, a key relationship is between poverty and the gender of the household head. Based on the data for our four regions, there is no statistically significant difference between female-headed and male-headed households (Figure 3).

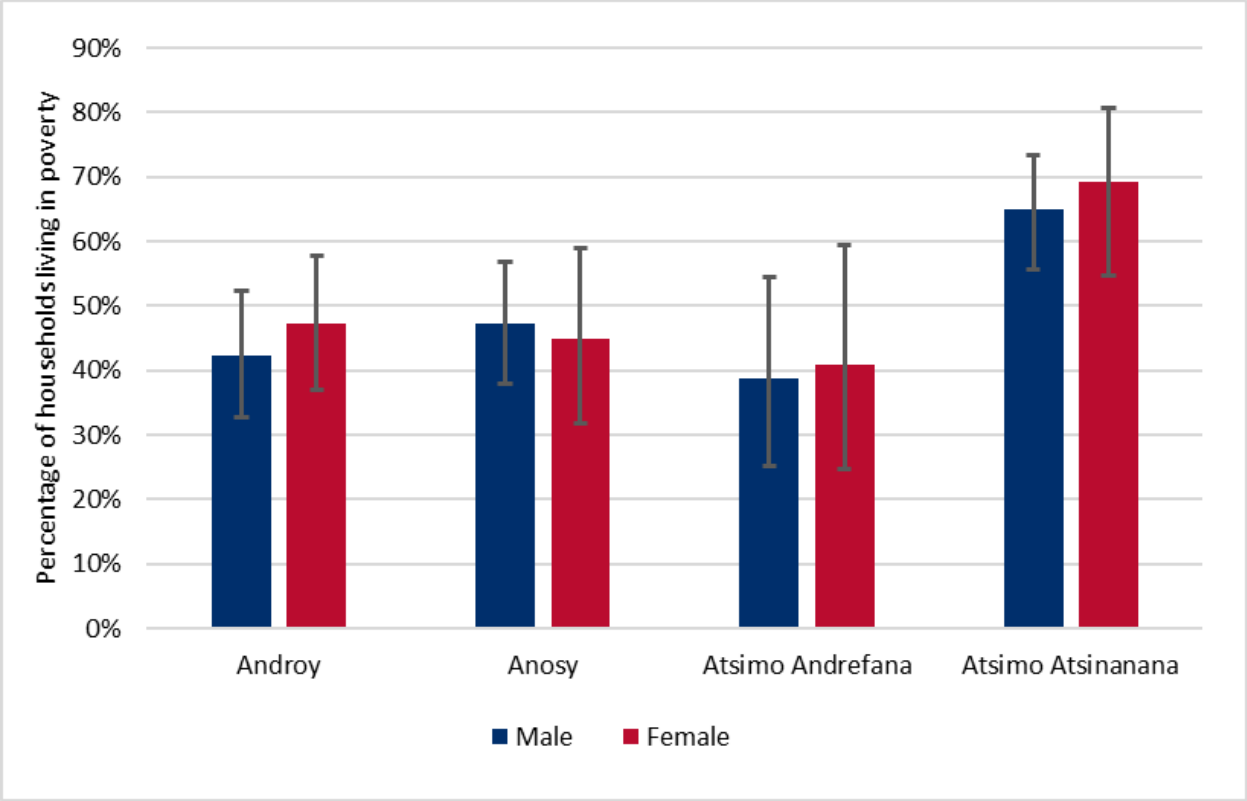

Figure 3: Poverty Rates by Region and Gender of Household Head

Source: 2021 Demographic and Health Surveys (DHS)

For multiple indicators related to household composition and age distribution, there is no clear pattern concerning households living in poverty. For example, an indicator commonly used in the poverty literature is the number of members in the household, with larger households generally more likely to live in poverty than smaller households. As Figure 4 indicates, this does not appear to be the case across the four regions, as there is no clear pattern in the relationship between household size and poverty rates. Descriptive statistics tell a similar story for the number of children under five in the household and the number of dependents: there is no clear relationship with poverty rates.

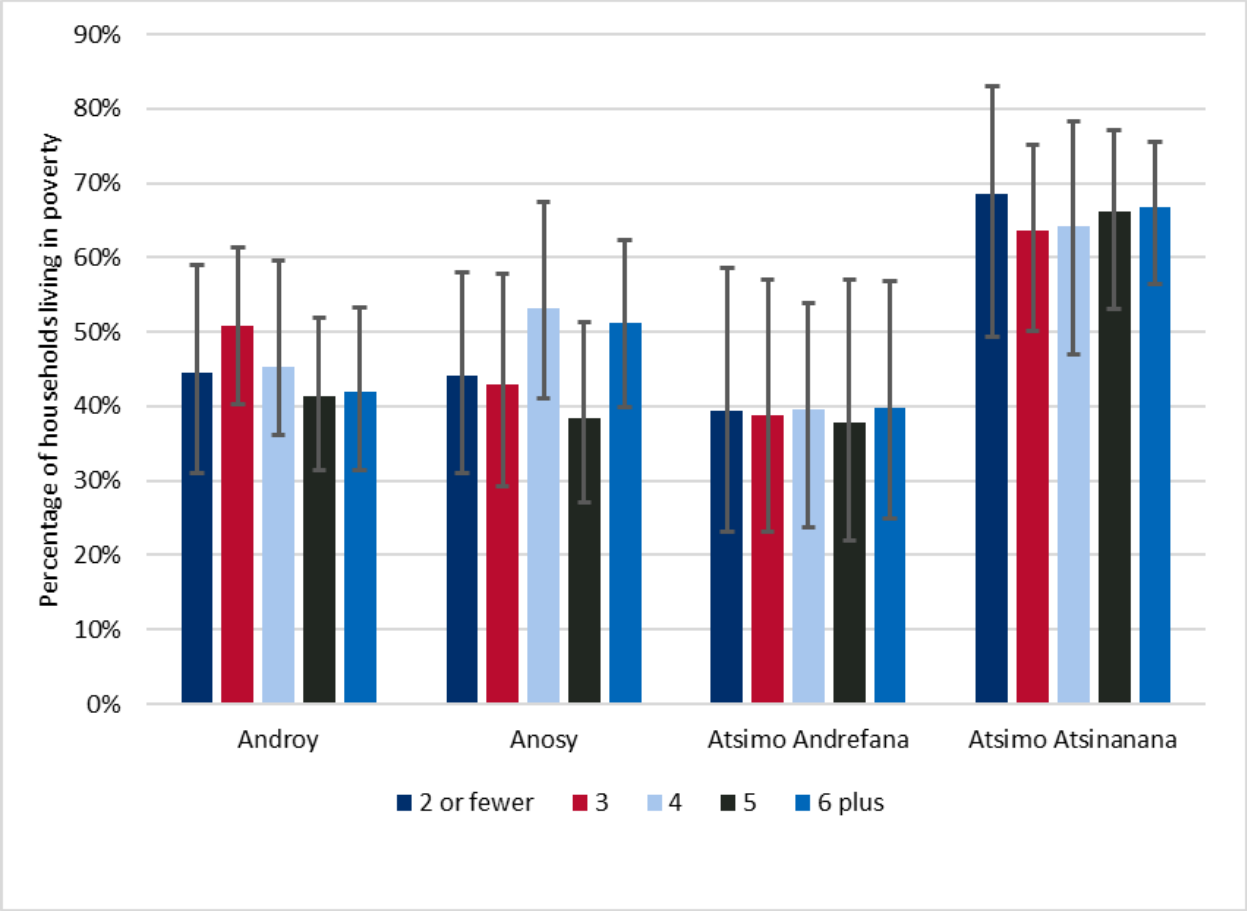

Figure 4: Poverty Rates by Region and Size of the Household

Source: 2021 Demographic and Health Surveys (DHS)

Relationship between Poverty and Socioeconomic Characteristics

We also examine multiple indicators related to socio-economic characteristics. One socio-economic factor often connected to poverty is the level of household education; households with a household head with completed primary or higher education are less likely to be living in poverty than those with a household head with no education. We examine the level of poverty according to the level of education of the household head, as grouped into three categories: no education, incomplete primary, and completed primary or higher (Figure 5). A clear pattern emerges across all four regions. Households whose head has no education suffer higher rates of poverty than those whose head has completed primary education or higher. In Atsimo Andrefana, we can also distinguish a difference in poverty rates between households whose head has no education and those whose head has incomplete primary education.

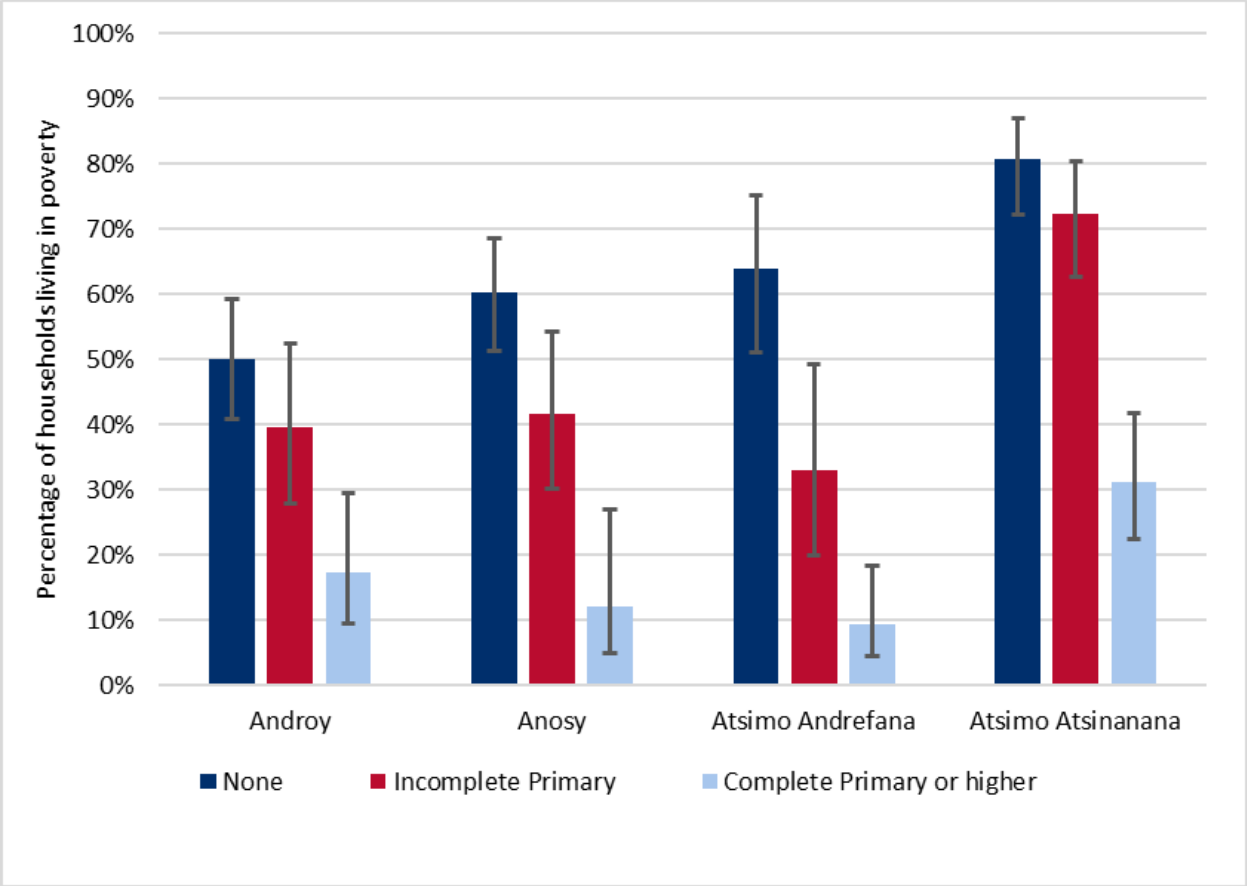

Figure 5: Poverty Rates by Region and Household Head Education

Source: 2021 Demographic and Health Surveys (DHS)

Dwelling characteristics are another set of indicators that may be correlated with households living in poverty. One such indicator is whether the households have an improved water source or use an unimproved/surface water source. As Figure 6 illustrates, across three of the four regions (except in Atsimo Andrefana), households living in a dwelling with an unimproved water source are more likely to be living in poverty than households living in a dwelling with an improved water source.

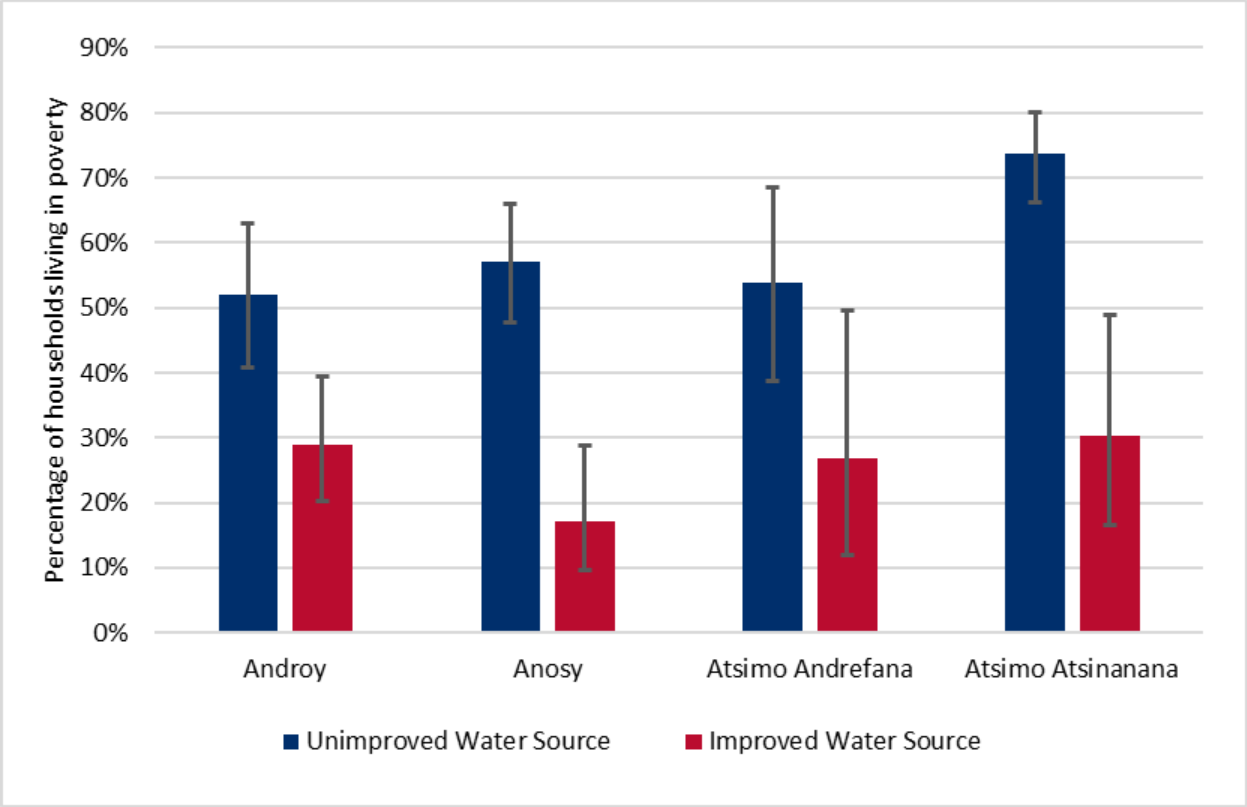

Figure 6: Poverty Rates by Region and Type of Water Source

Source: 2021 Demographic and Health Surveys (DHS)

A similar pattern is evident for toilet facilities (Figure 7). Across three of the four regions (except in Anosy), the poverty rate is higher among those households who practice open defecation than households with an improved toilet.

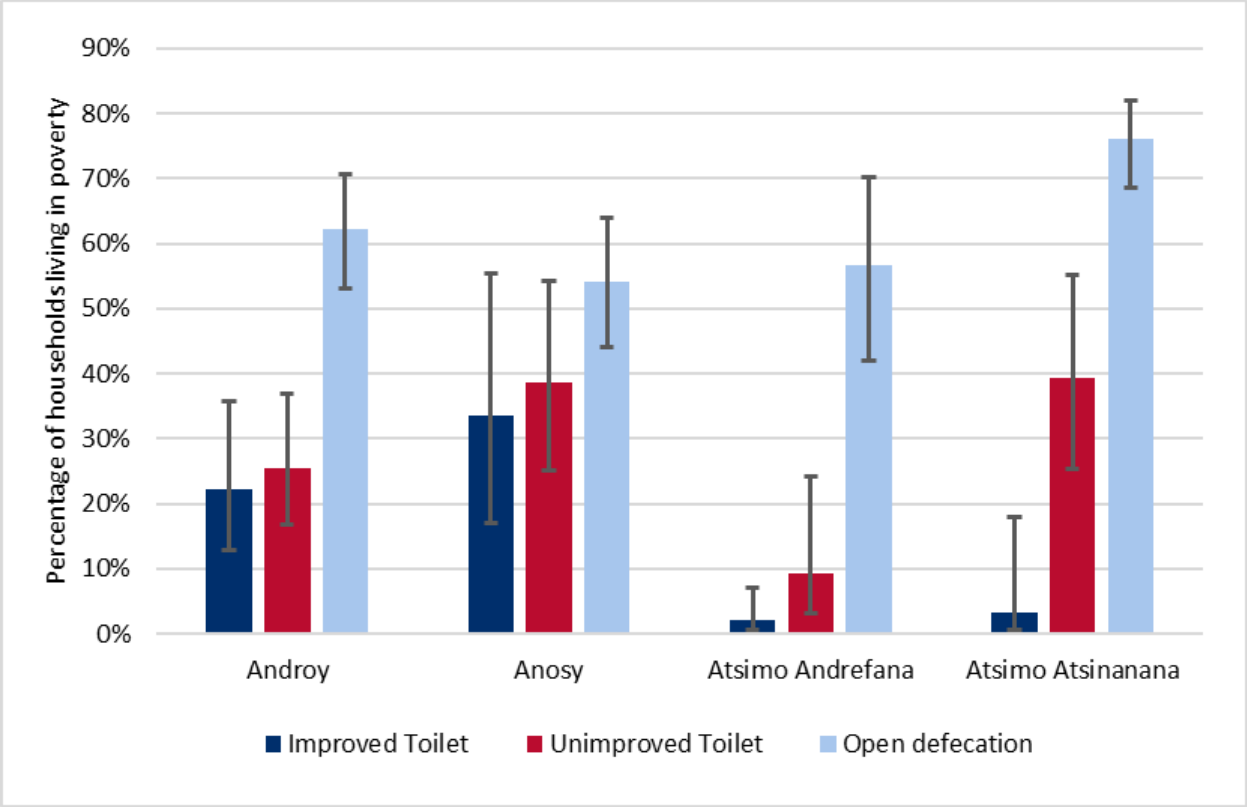

Figure 7: Poverty Rates by Region and Toilet Facility Type

Source: 2021 Demographic and Health Surveys (DHS)

Another common delineation in poverty analysis is comparing households that live in urban and rural locations, with urban locations typically having lower poverty rates. For three of the four regions, there is not a statistically significant difference in poverty rates between rural and urban areas. Only in Atsimo Atsinanana, households in rural areas are more likely to live in poverty than those in urban locations (Figure 8).

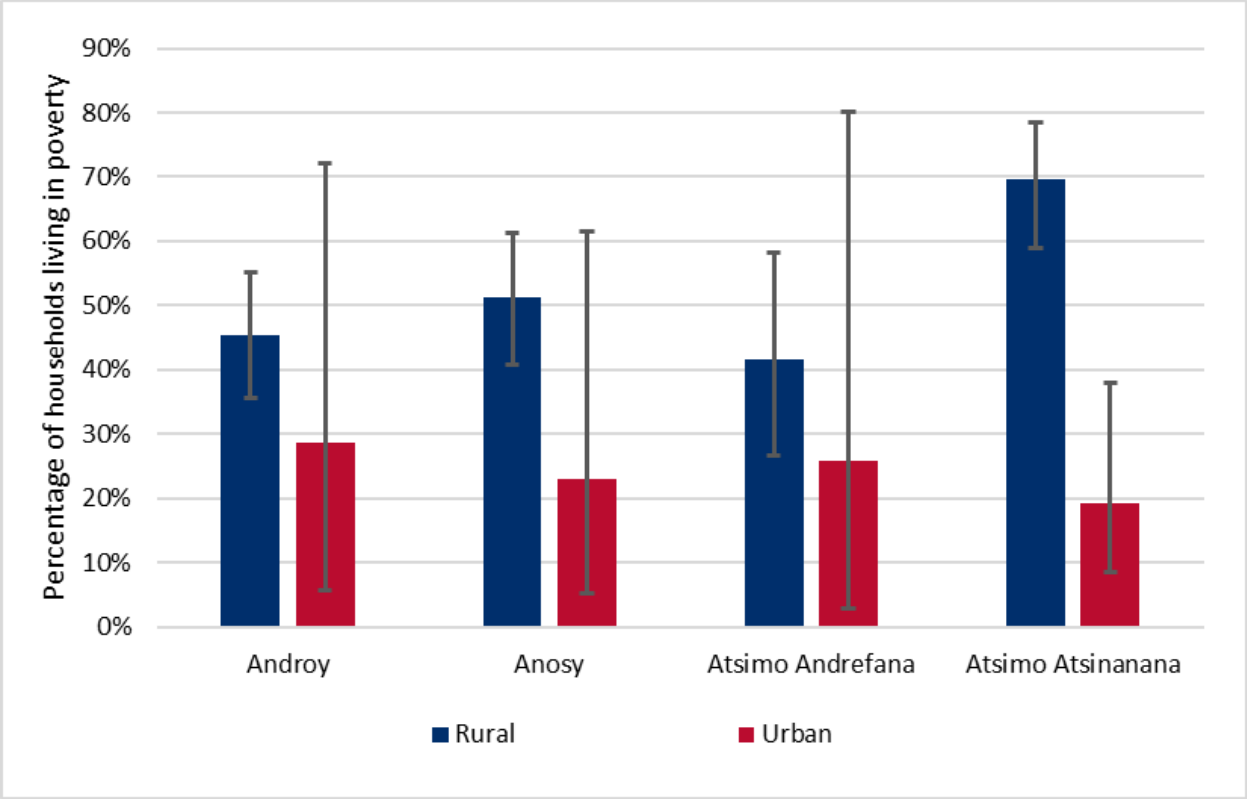

Figure 8: Poverty Rates by Region and Urban/Rural Location

Source: 2021 Demographic and Health Surveys (DHS)

Geospatial mapping

Results of local bivariate regression analysis show associations between poverty rates and several of the DHS indicators in multiple geographic clusters. Local bivariate analysis measures the relationship between two variables by measuring their correlation within the cluster and neighboring clusters. Indicators with statistically significant associations are women's employment in agriculture, men's employment in agriculture, zebu ownership, and Water, Sanitation, and Hygiene (WASH) characteristics. For other indicators, there are no statistically significant associations with poverty at the cluster level. Indicators analyzed with no significant bi-variate association with poverty rates at the cluster levels include:

- Woman solely or jointly with partner made decisions to not use family planning.
- Woman solely or jointly with partner made decisions to use family planning.
- Woman solely or jointly with partner made decisions related to health, purchases or visits.
- Share of children with wasting
- Number of children under 5
- Age of household head
- Share of children achieving minimum dietary diversity

- Household size
- Share of men who do not work
- Share of men whose occupation is sales
- Share of men whose occupation is unskilled labor
- Share of women whose occupation is unskilled labor
- Number of poultry owned

Working in agriculture, for women and men, is associated with living in poverty in several clusters. Specifically, as the share of households living in poverty increases in clusters so does the share of women and men employed in agriculture. The green plus symbols in Figure 9 show the clusters with this relationship.

For women's employment in agriculture, there is at least one cluster with this positive relationship in almost all districts, with the exception of Bekily, Beloha and Tsihombe in Androy. These results suggest that in most areas (with the exception of the three districts of Androy), targeting RFSA interventions towards households where women are working in agriculture could assist in reaching households living in poverty.

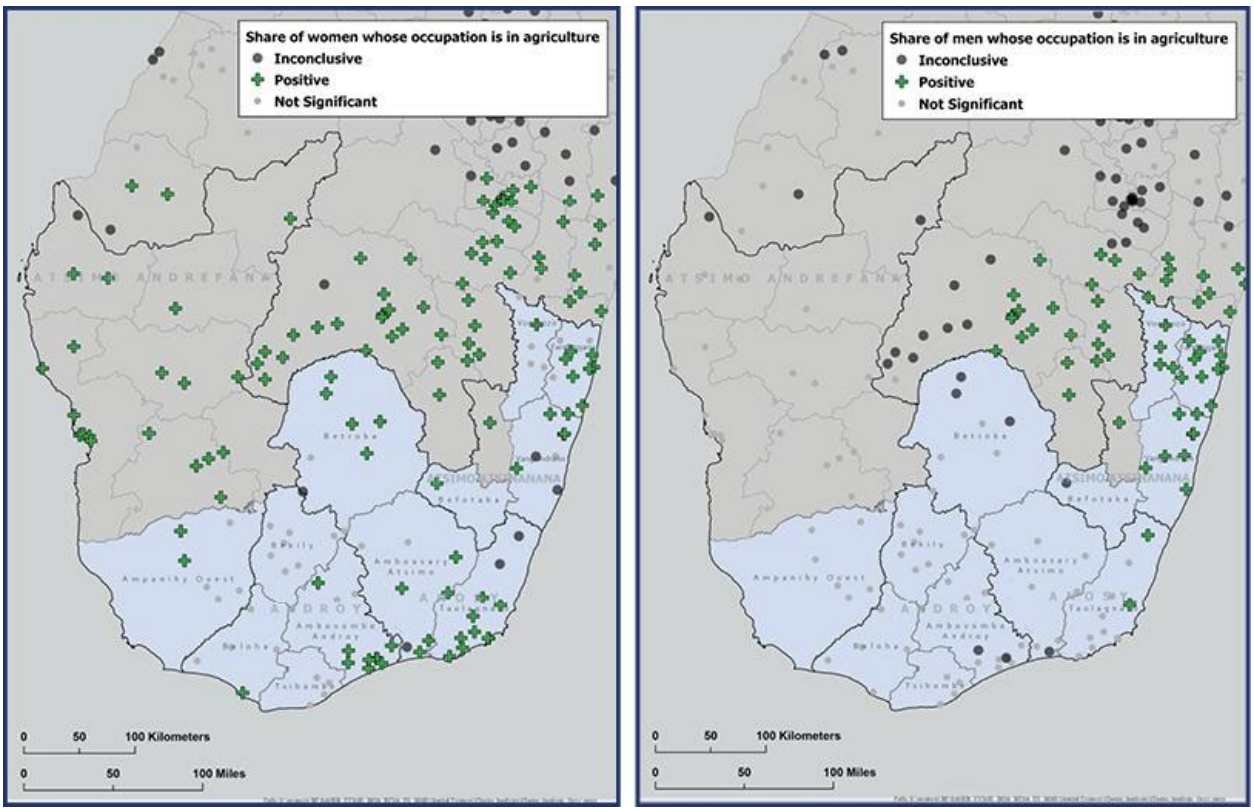

Figure 9: LBR Results for Share of Women and Men Whose Occupation is in Agriculture and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

For men working in agriculture, a positive relationship was found with poverty as well, although in fewer clusters. As the share of men working in agriculture increases, the poverty rate increases in all districts in Atsimo Atsinanana and in one cluster in Taolagnaro. As with the results for women, targeting interventions towards households with men working in agriculture could also be a strong criterion, albeit in a more limited geographic area.

Ownership of zebus is associated with living in poverty in certain areas within our four study regions (Annex E-2). As the share of zebu ownership increases in these areas, the rate of poverty increases. This relationship is present in clusters in central Betroka, Vangaindrano, and Taolagnaro districts.

The remaining variables have negative relationships with poverty (red negative signs in the map). This means as the value for that variable increases in clusters, the share of households living in poverty decreases. For example, as the proportion of non-working women increases in clusters, the proportion of households in poverty decreases. In Amboasary Atsimo, Taolagnaro and Betroka, targeting interventions towards households with non-working women is not likely to be a strong criterion for poverty and could in fact be counterproductive.

There are two WASH indicators associated with household poverty: households with improved water (Annex E-4) and households that handwash with soap (Annex E-1). In Atsimo Atsinanana and central Betroka, Vangaindrano, and Taolagnaro districts, as the proportion of households with an improved water source increases in clusters, the proportion of households in poverty decreases. For handwashing, as the proportion of households with handwashing facilities increases in clusters in Atsimo Atsinanana and Betroka, the proportion of households in poverty decreases.

Finally, in certain clusters, as the proportion of women working in sales increases, the proportion of households in poverty falls (Annex E-6). In parts of Farafangana, Vondrozo and Taolagnaro districts, targeting interventions towards households in which women are working in sales could be counterproductive in the northernmost areas of Atsimo Atsinanana.

It is important to remember with LBR that strengths and relationships between variables may be different from the results of more traditional regression and correlation. This is due to LBR's consideration of neighboring clusters and the finer geographic scale for this analysis. The process of aggregating from DHS cluster to regional level can obscure inter-regional variation. The more granular picture of relationships presented by the LBR analysis can be helpful during the process of trying to target interventions at a sub-regional level.

3.1.B. COMPARISON ACROSS GROUPS AND LOCATIONS

In this section, we examine the bivariate relationships between living in poverty and socio-demographic and socio-economic characteristics of households. In other words, do those households living in poverty differ on these characteristics from households that are not living in poverty? How do these differences vary across the four study regions? The sign of coefficients presented in the tables indicate whether a characteristic is positively or negatively

associated with living in poverty and the stars indicate whether the difference in the characteristics between those groups is significant (* is p<0.10, ** is p<0.05, and *** is p<0.01).

Household-level results

For female headship, Table 1 indicates that there is no statistically significant difference in the likelihood of living in poverty compared to male-headed households. Therefore, these results should not be considered as having a strong correlation with living in poverty.

We do not see a clear association between the likelihood of living in poverty and the age of the household head, with no statistically significant differences found in three of four regions. In Anosy only, a younger household head is associated with a lower likelihood of living in poverty (see textbox). The situation is similar for household size, with no statistically significant relationship with living in poverty, aside from Androy, where smaller households are more likely to live in poverty. In terms of household composition, we see some statistically significant differences, particularly for the dependency ratio (the ratio of household members under 15 or above 65 years of age to household members between the ages of 15 to 64). The results suggest that households living in poverty have a higher proportion of dependent members than households not living in poverty.

How is statistical significance measured?

The stars on the coefficients in Table 1 represent the estimates' level of statistical significance:

*Significant at the 0.1 level
**Significant at the 0.05 level
***Significant at the 0.01 level

If the p-value (p) is greater than 0.1, we state that no statistically significant relationship was detected.

How should the sign of the coefficients be interpreted?

The negative coefficient for age of head in Anosy implies that the head of a household living in poverty, on average, is 3.6 years younger than the head of a household not living in poverty. This result is statistically significant at the 0.01 level.

Table 1: Poverty based on Socio-Demographic Characteristics by Region

	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Head is female	0.05	-0.02	0.02	0.04
Age of head	-1.69	-3.43**	-1.07	-0.65
Household size	-0.57***	0.22	-0.21	-0.46
Number of children under five	0.03	0.26***	0.48***	0.09
Number of dependent members	-0.21	0.46***	0.55**	0.06
Dependency ratio	0.18*	0.36***	0.65***	0.29***

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

Differences in socio-economic characteristics between households that are and are not living in poverty are more prominent than socio-demographic characteristics. A selection of

these results is found in Table 2, below. Households in poverty in the target four regions of Madagascar are significantly more likely than households not living in poverty to have household heads with no education. For water and sanitation indicators, households living in poverty are less likely to have an improved water source and more likely to be practicing open defecation than households not living in poverty. Households living in poverty are also likely to differ from those not living in poverty according to other dwelling characteristics: less likely to have electricity in their dwelling, cook with charcoal, or have an additional room for sleeping. Households in poverty are more likely to have a thatch or leaf roof. Phone ownership is also less common among households in poverty.

Table 2: Poverty based on Socio-Economic Characteristics by Region

	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Head no education	0.17***	0.31***	0.48***	0.26***
Improved Water Source	-0.21***	-0.31***	-0.28**	-0.28***
Toilet: open defecation	0.38***	0.17**	0.48***	0.34***
Roof of thatch or leaf	0.45***	0.47***	0.55***	0.34***
Dwelling has electricity	-0.05***	-0.19**	-0.37***	-0.24***
Main cook fuel is charcoal	-0.12***	-0.20***	-0.52***	-0.25***
Number of rooms for sleeping	-0.24***	-0.25***	-0.68***	-0.46***
Owns mobile phone	-0.29***	-0.39***	-0.51***	-0.48***
Location is urban	-0.04	-0.15	-0.08	-0.14***

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

Next, we examine whether ownership of agricultural assets differs between households living in poverty and those that are not living in poverty. In Atsimo Atsinanana, households in poverty own less agricultural land than households not in poverty. Households in poverty are also less likely to own any livestock than households not in poverty in three of the four regions. Ownership of poultry is associated with reduced likelihood of poverty in two of the four regions, compared to not owning poultry. This result is in line with findings from the Desk Review and Market Study, where chickens in particular are noted to be an indicator of resilience. Households living in poverty are also less likely than households not living in poverty to own sheep and ducks in some of the regions.

Table 3: Poverty based on Agricultural Assets by Region

	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Owns agricultural land	0.03	0.06	0.20**	0.05
Hectares of agric. land	-0.01	-0.13	-0.09	-0.24**
Owns animal cart	-0.15***	-0.06*	-0.03	-0.01**
Owns livestock	-0.08**	-0.12*	-0.12**	-0.03
Owns goats	-0.05	0.02	-0.02	-0.00
Owns sheep	-0.06**	-0.06**	0.03	-0.00
Owns poultry	-0.03	-0.12**	-0.09**	-0.02
Owns zebus	-0.11***	-0.08	-0.00	-0.09
Owns ducks	-0.01	-0.04**	-0.09***	-0.04
Own pigs	0.00	-0.03*	-0.09***	-0.05

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

3.1.C. IDENTIFYING KEY CORRELATES OF POVERTY

As referenced in the methodology section, we employed a logistical regression model combined with the Sequential Forward Selection (SFS) to pinpoint the most influential features impacting our key outcome of poverty. Performance evaluation was achieved using a confusion matrix (a table that displays the distribution of correctly or incorrectly classified predictions) and an accuracy score (indicating the combined accuracy of prediction). This analysis provides us with an overview of the strongest predictors associated with higher levels of poverty.

We executed the selection process for the poverty outcome first on the pooled dataset combining all four regions together, and then specifically for each of the four regions of interest. In our analysis, we consistently selected ten key variables for the overall poverty assessment, as well as for each individual region. Throughout all poverty predictions, including the regional ones, we used centerfold values of 5, 10, and 20, and presented the variables that yielded the most accurate results in terms of correctly predicting a household's poverty status.

What are the selected indicators?

Tables 4 – 6 show the variables selected by the machine learning SFS procedure. A check means that the variable was one of the ten most highly correlated variables with poverty status in that region.

In our analysis of all four regions combined, a core set of variables consistently emerged as influential across different regions, underscoring their general significance in assessing poverty in Madagascar. For socio-demographic variables, one variable – the number of dependent household members – was identified in the pooled data and in two of the regions separately (Table 4).

Table 4: Selected Socio-Demographic Features by Region

Socio-Demographic Variables	Overall	Anosy	Androy	Atsimo Andrefana	Atismo Atsinanana
Number of Dependent Members	✓	✓	✓		
Female head of household					✓
Number of children under 5				✓	

***Source**: 2021 Demographic and Health Surveys (DHS)*

For socio-economic variables, the identified, shared variables include a metal roof and ownership of a mobile phone, both of which were influential across all four regions (Table 5).

Table 5: Selected Socio-Economic Features Associated with Poverty by Region

Socio-Economic Variables	Overall	Anosy	Androy	Atsimo Andrefana	Atismo Atsinanana
Ownership of a mobile phone	✓	✓	✓	✓	✓
Roof of metal	✓	✓	✓	✓	✓
Roof of thatch or leaf	✓	✓	✓	✓	
Floor of cement	✓	✓	✓	✓	
Main cooking fuel as charcoal	✓	✓	✓	✓	
Ownership of a radio	✓		✓		✓
Improved Water Source	✓		✓		✓
Toilet: open defecation	✓		✓	✓	
Household head no education				✓	✓
Household head primary education		✓			✓
Main cooking fuel as wood				✓	✓
Ownership of a bicycle	✓	✓			
Household head incomplete secondary education 1		✓			
Household head incomplete secondary education 2				✓	
Location is urban		✓	✓		

***Source**: 2021 Demographic and Health Surveys (DHS)*

Finally, Atsimo Atsinanana was the only region where agricultural assets emerged as prevalent variables (Table 6). While each region presented its unique set of influential variables, the prevalence of shared variables underlines their overarching impact on poverty assessment in all of Madagascar.

Table 6: Selected Agricultural Asset Features Associated with Poverty by Region

Agricultural Asset Variables	Overall	Anosy	Androy	Atsimo Andrefana	Atismo Atsinanana
Ownership of pigs					✓
Number of owned poultry					✓

***Source**: 2021 Demographic and Health Surveys (DHS)*

For all regions, a crossfold value (see Annex F) of 20 yielded the highest accuracy scores, which ranged from 79% in Anosy to 89% in Atsimo Andrefana. Having a high accuracy rate not only validates our methodological approach but also strengthens the evidence suggesting that these identified factors have a crucial role in determining poverty levels in Madagascar.

What is an accuracy score?

The accuracy score is a measure of how well the model predicts the individual poverty status of a household. For example, an accuracy score of 79% means that the model correctly predicted the poverty status for 79% of households in the Anosy test sample.

3.2. FOOD INSECURITY AND MALNUTRITION

In this section, we will follow a similar pattern to discuss results related to the outcomes of analysis related to food security and malnutrition. Based on the variables available in the DHS dataset, the key selected variables are child stunting and children meeting MAD thresholds. First, we will discuss the descriptive results, followed by the comparisons between groups, and finishing with the machine learning analysis. Overall, the results for these outcomes demonstrate fewer relationships with statistical significance and therefore less conclusive than the earlier analysis focused on poverty due to sample size limitations in the DHS dataset.

3.2.A. DESCRIPTIVE

First, we will present the results for the descriptive analysis, in which we describe the characteristics that are common among children experiencing stunting and children who meet MAD thresholds.

Child level results

As mentioned above in Section 2.2, we examine two key outcome variables at the child level: stunting and MAD.

Children Experiencing Stunting

We discuss descriptive stunting results in the four target regions in Madagascar first. For three (Androy, Anosy, and Atsimo Atsinanana) out of the four regions, the rate of children with stunting falls in a narrow band from 46 to 48 percent. Atsimo Andrefana has a much lower level of stunting compared to other regions, at 30 percent. Compared to the previous DHS in 2009,

the rate of stunting has decreased in three of the four regions (by more than 10 percentage points) but has increased slightly (two percentage points) in Atsimo Atsinanana (Institut National de la Statistique, 2010).

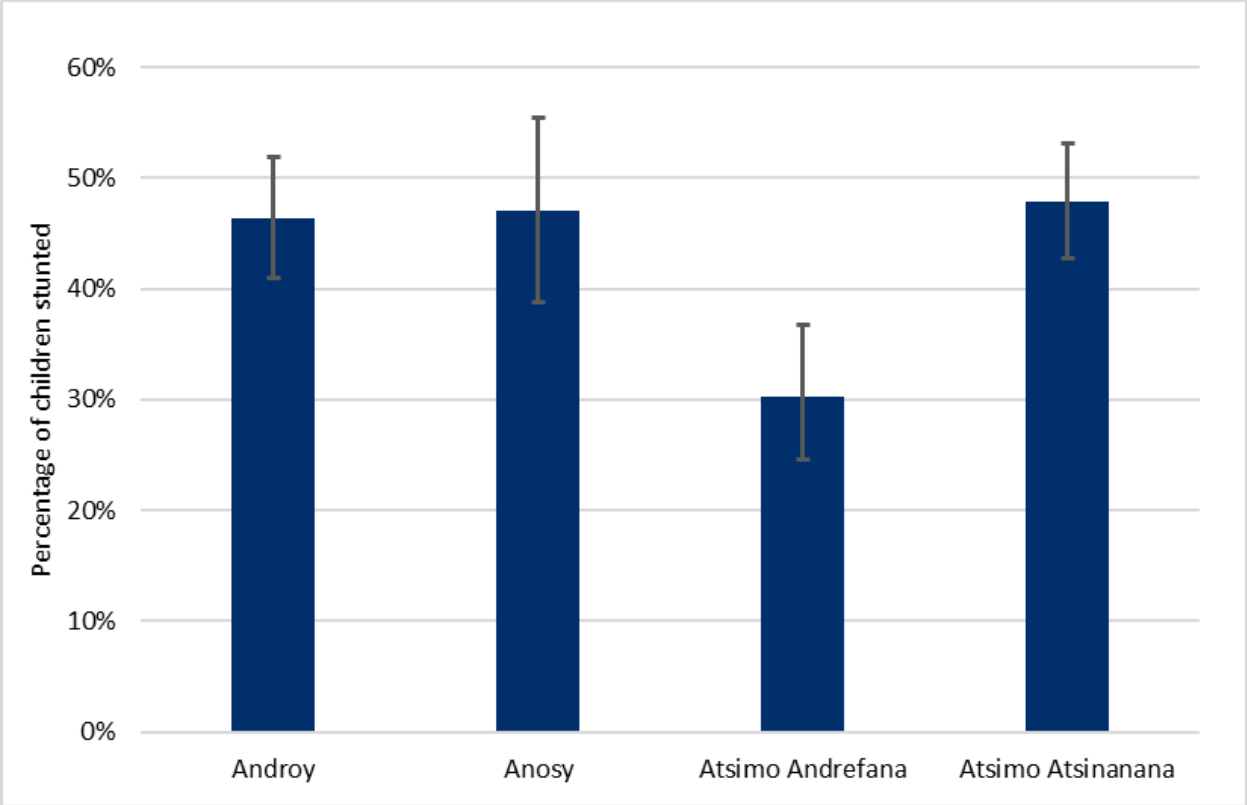

Figure 10: Child Stunting by Region

Source: 2021 Demographic and Health Surveys (DHS)

Relationship between stunting and socio-demographic factors

Next, we examine stunting by socio-demographic factors, starting with the gender of the household head. Based on Figure 11, there is no clear pattern between children affected by stunting and female headship across the four regions. We find no statistically significant differences between female- and male-headed households.

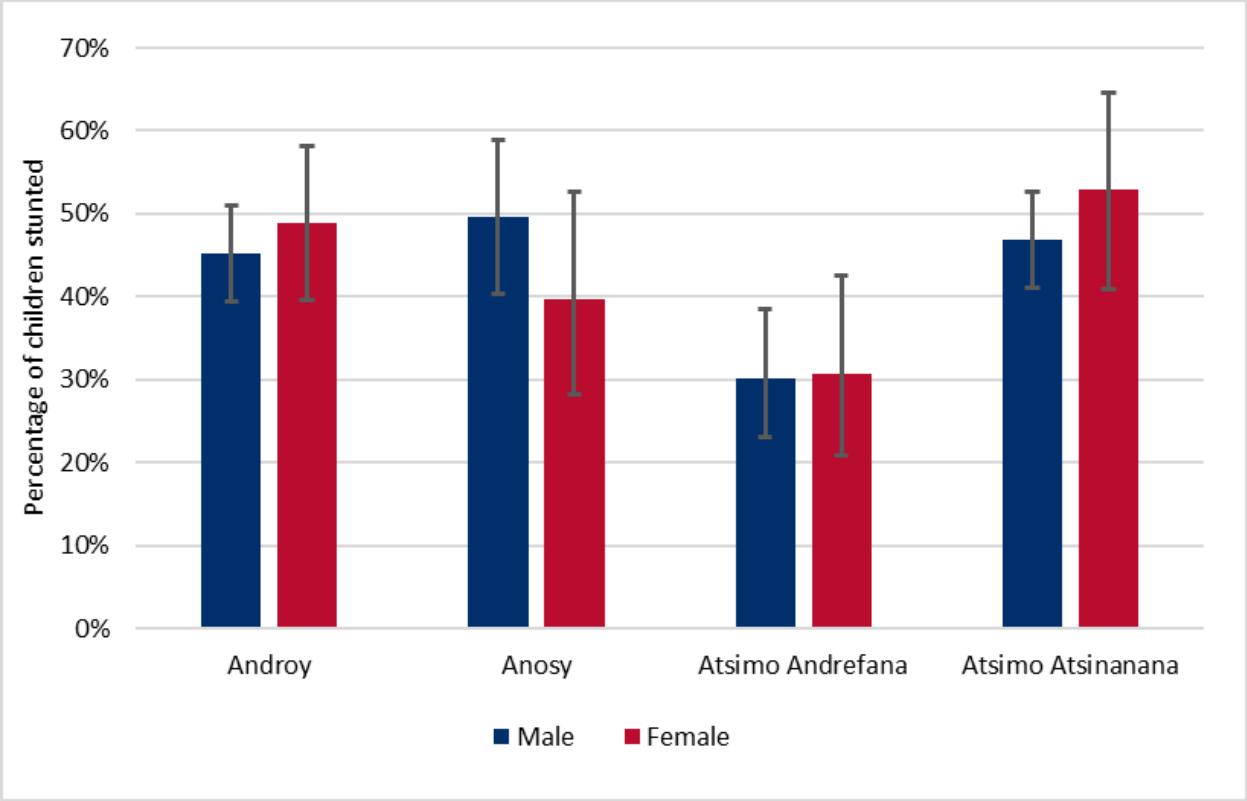

Figure 11: Child Stunting by Region and Gender of Household Head

Source: 2021 Demographic and Health Surveys (DHS)

As with the descriptive results for poverty discussed above Figure 13, there are no clear patterns concerning children living with stunting and multiple indicators related to household composition and age distribution (household size, age of household head, number of children under 5, and number of dependents). For example, in the below graph, there is no consistent relationship between the size of the household and rates of child stunting across the four regions (Figure 14).

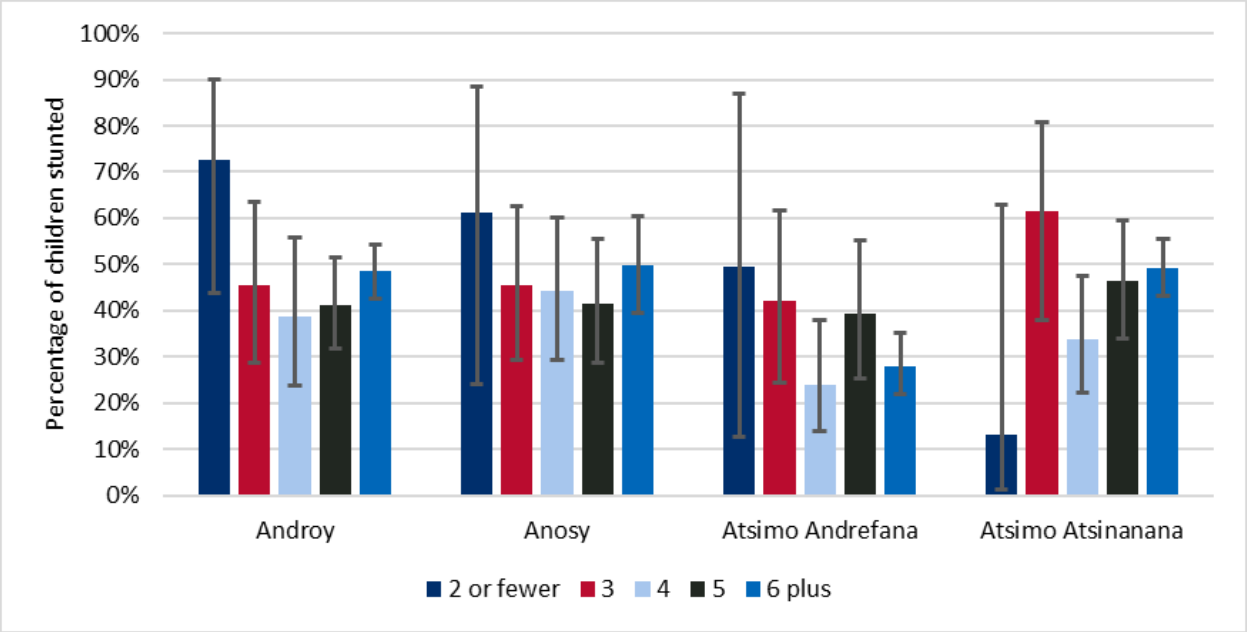

Figure 12: Child Stunting by Region and Size of Household

***Source**: 2021 Demographic and Health Surveys (DHS)*

Relationship between stunting and socioeconomic characteristics

We turn now to socioeconomic characteristics of households with children who are living with stunting. Unlike the descriptive results for households living in poverty, we do not see a consistent relationship between the level of a household head's education and child stunting.

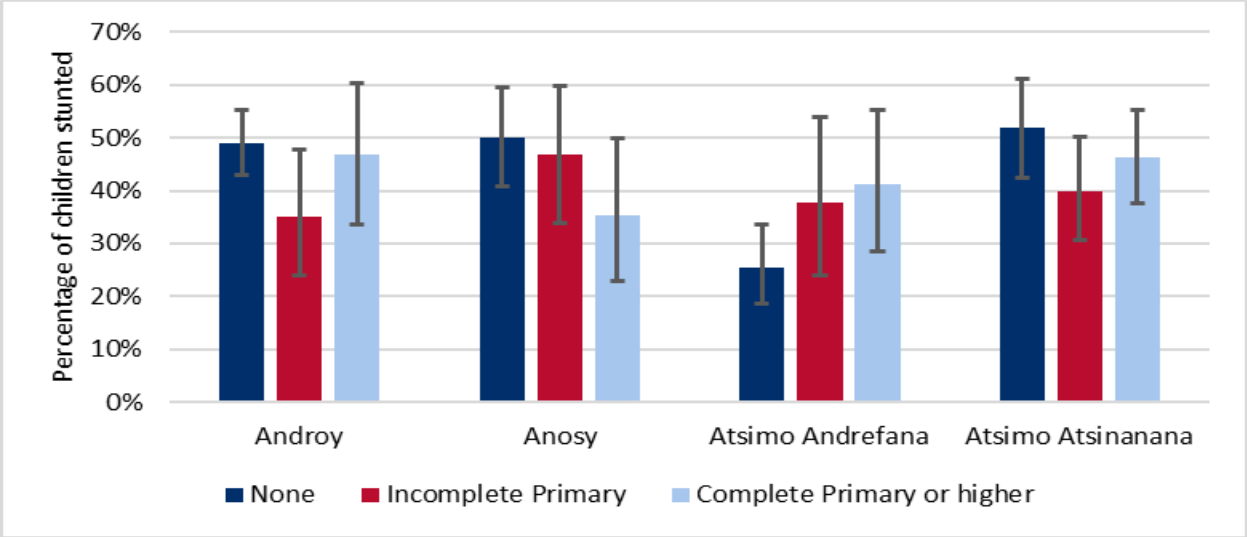

Figure 13: Child Stunting by Region and Household Head Education

***Source**: 2021 Demographic and Health Surveys (DHS)*

In terms of dwelling characteristics, we can detect no statistically significant differences in the rate of stunting between households with an improved water and those with an unimproved water source in any of the four regions (Figure 14). The results are the same for toilet facilities. In terms of rural or urban locations, no pattern is clearly visible, with half of the regions having higher rates of stunting in urban versus rural regions.

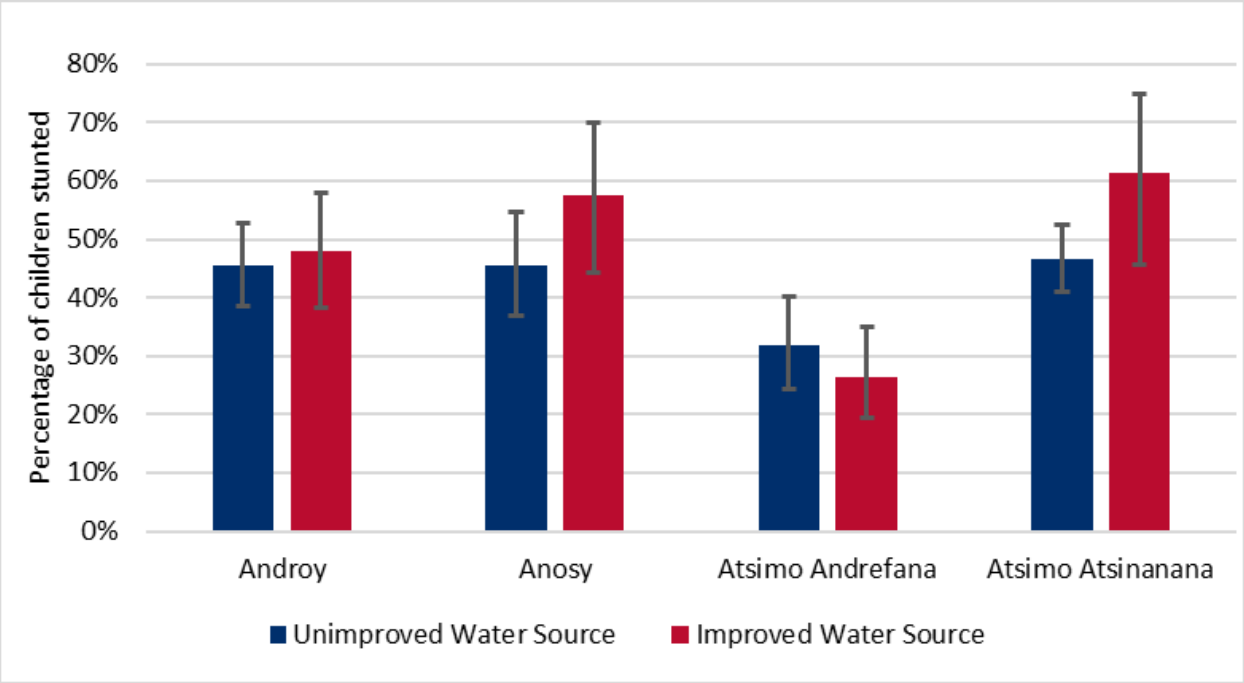

Figure 14: Child Stunting by Region and Type of Water Source

Source: 2021 Demographic and Health Surveys (DHS)

Children that Meet MAD Threshold

The second child-level nutrition outcome relates to food access and dietary diversity, using MAD as the key outcome indicator. Unlike the other outcome indicators – poverty and child stunting –higher levels of children meeting MAD thresholds are a positive development indicator, whereas the opposite is true for high rates of poverty and child stunting. We see that very few children aged 6 to 23 months in the four target regions of Madagascar are meeting MAD thresholds, ranging from 3 percent in Androy to 10 percent in Atsimo Atsinanana (Figure 15). The confidence intervals around these estimates are wide and therefore there is no statistically significant difference in the levels of children meeting MAD thresholds between the four study regions.

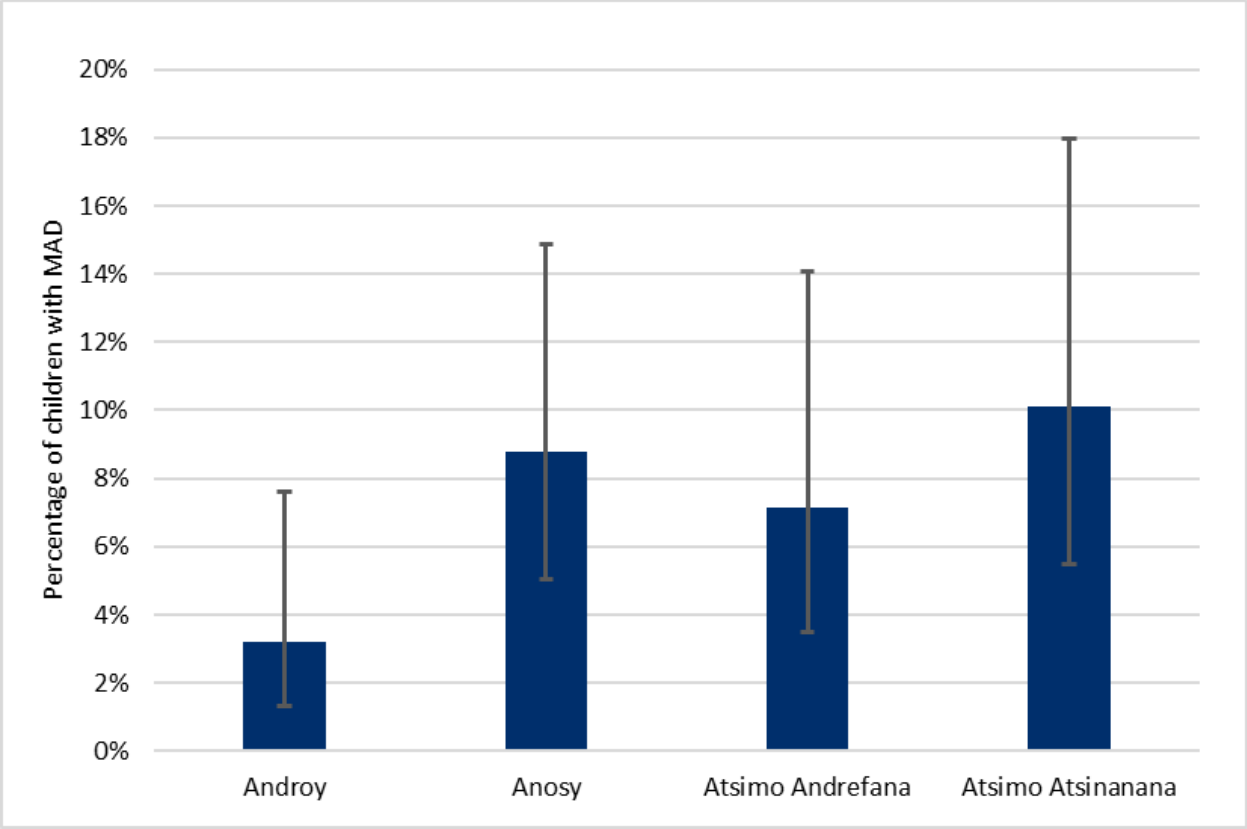

Figure 15: Child MAD by Region

Source: 2021 Demographic and Health Surveys (DHS)

Relationship between MAD and socio-demographic factors

For socio-demographic factors, we will start with the relationship between children living with MAD and the gender of the household head (Figure 16). As with the results for children living with stunting, there are no statistically significant differences between children from female- and male-headed households.

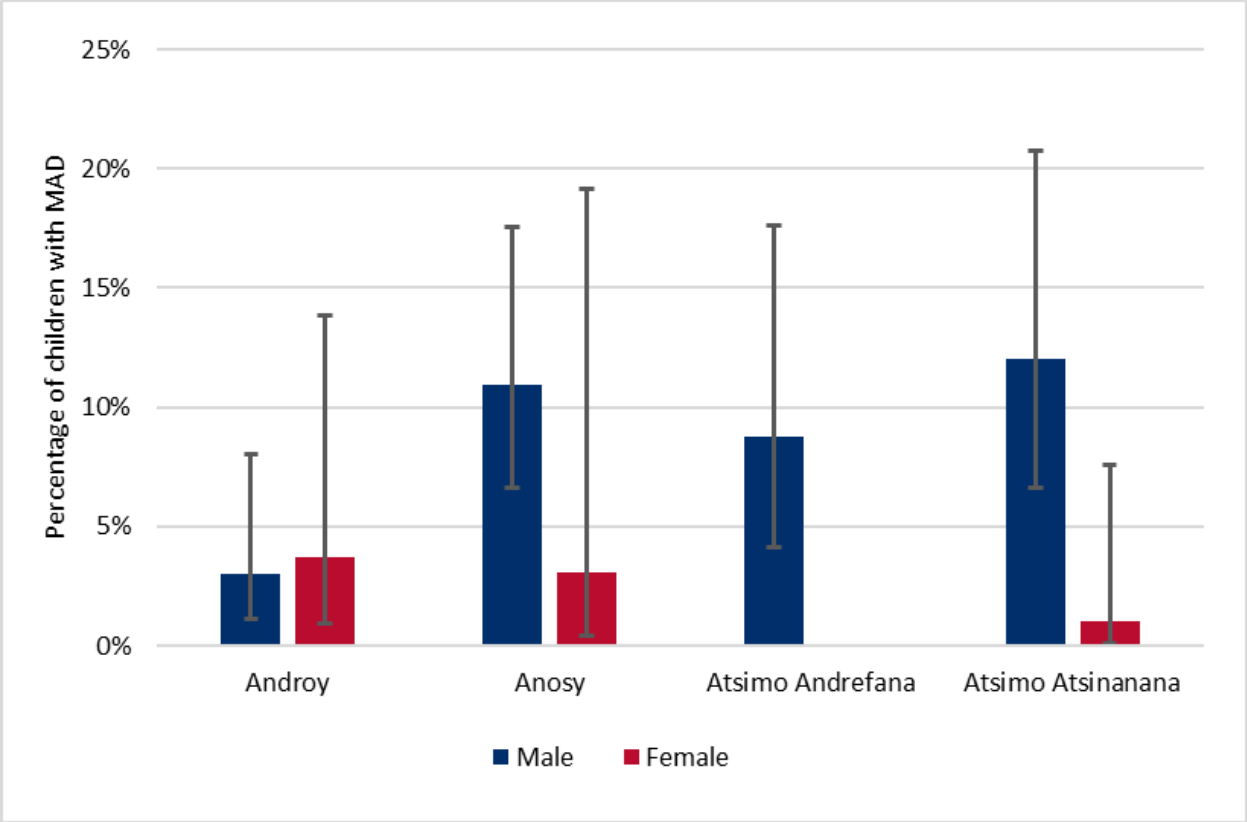

Figure 16: Child MAD by Region and Gender of the Household Head

***Source**: 2021 Demographic and Health Surveys (DHS)*

Another socio-demographic factor is the age of the household head. We can see from Figure 17 that there are no statistically significant differences between age groups of the household head (34 or younger, to 35-49 years of age, to 50 and above) in the proportion of children meeting MAD thresholds. The wide confidence intervals are due in part to small sample sizes for certain categories, particularly for the 50-year-old and older group (as little as thirteen cases for Anosy in that age group).

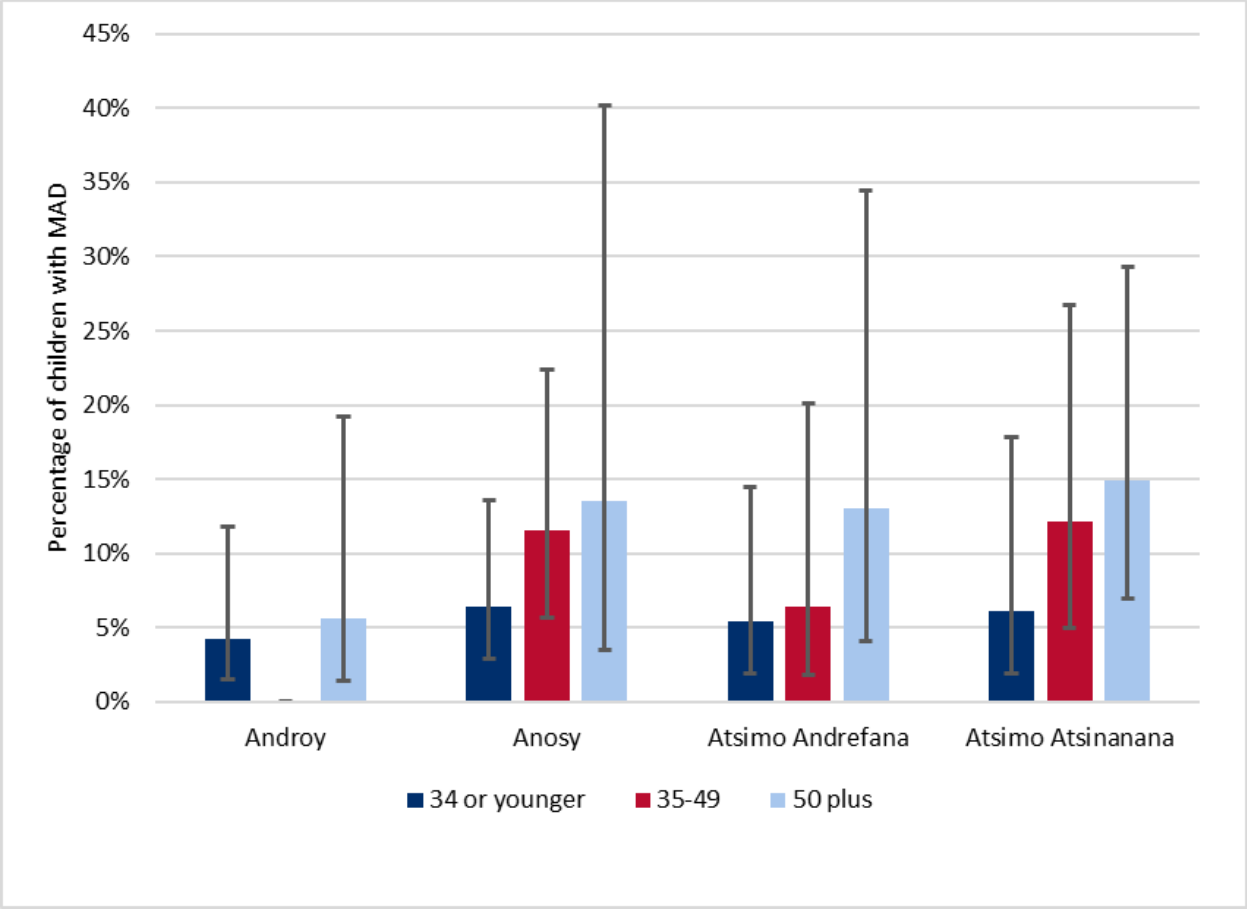

Figure 17: Child MAD by Region and Age of the Household Head

Source: 2021 Demographic and Health Surveys (DHS)

Relationship between MAD and socioeconomic indicators

A socioeconomic indicator that is unique in looking at MAD is the literacy of the mother. Unlike the poverty and stunting outcome measures, the MAD data is collected in the DHS women's questionnaire. Therefore, there are a few additional variables available for analysis. Figure 18 indicates no statistically significant difference in the likelihood of a child reaching the MAD threshold when the child's mother is literate (able to read parts or all of a sentence).

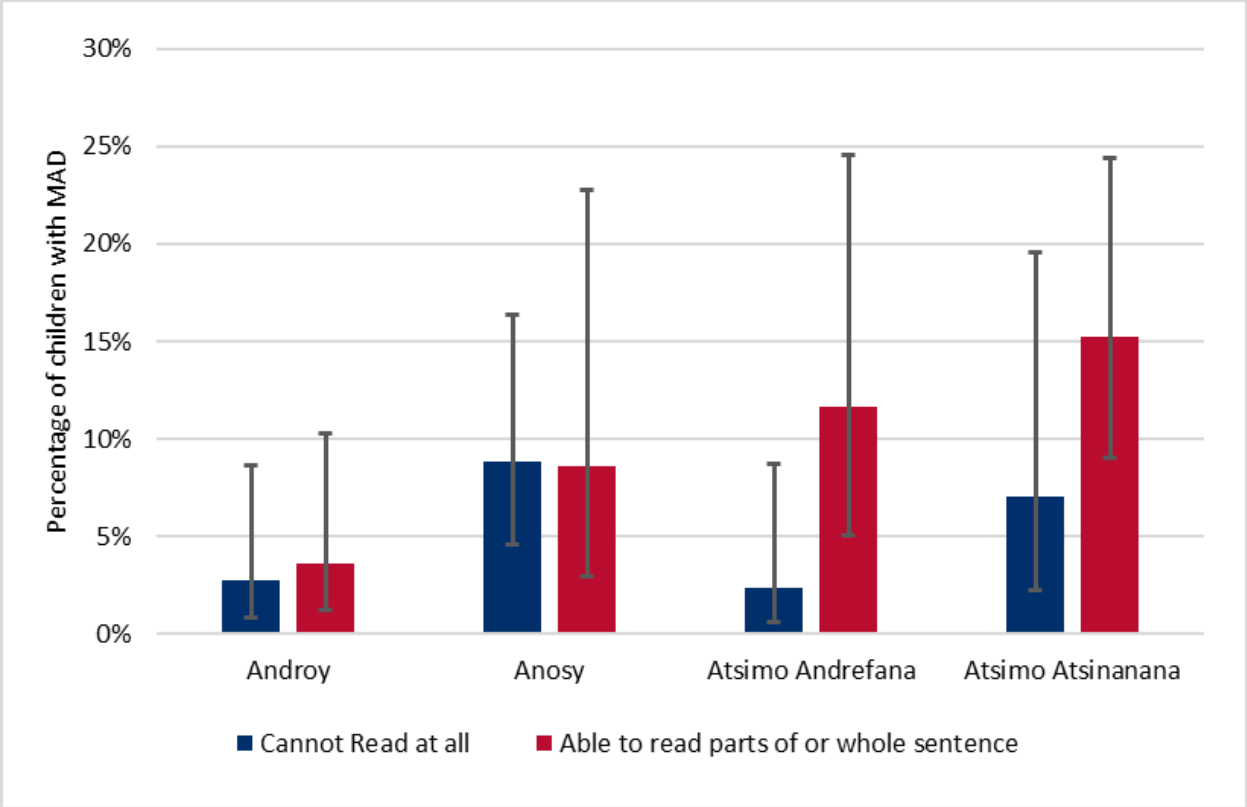

Figure 18: Child MAD by Region and Mother's Literacy

Source: 2021 Demographic and Health Surveys (DHS)

In terms of dwelling characteristics, we examine water sources for the household. We find no statistically significant difference in any of the regions (Figure 19).

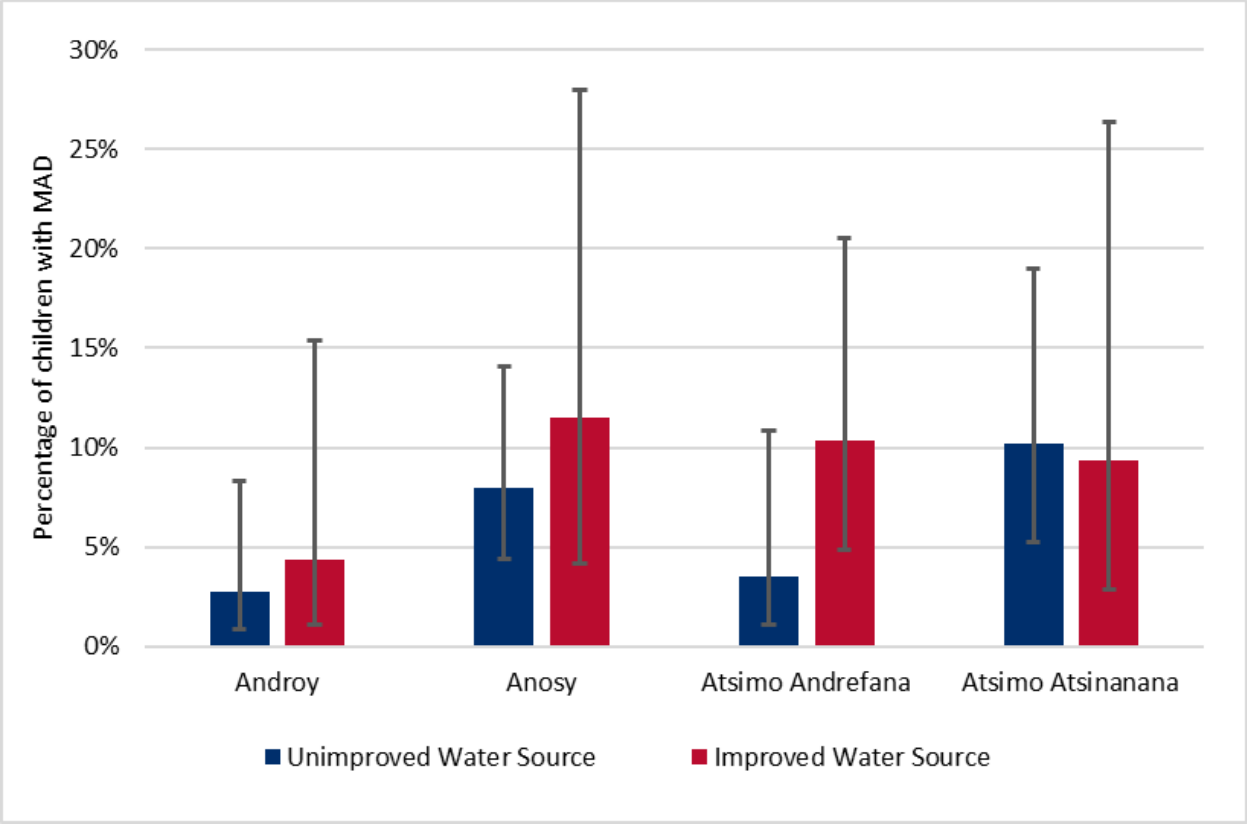

Figure 19: Child MAD by Region and Type of Water Source

Source: 2021 Demographic and Health Surveys (DHS)

3.2.B. COMPARISON ACROSS GROUPS AND LOCATIONS

In this section, we first compare children who are experiencing stunting with those who are not to identify some of the key factors that set this group apart. We then complete a similar analysis to compare characteristics among children who are and are not able to meet MAD thresholds.

Child level results

Children Experiencing Stunting

In terms of the key outcome of child stunting, we see few differences in socio-demographic characteristics between children living with stunting and those living without it. When we pooled data across all four regions, none of the indicators have a statistically significant relationship. This includes the likelihood of having a female head, an older household head, and belonging to a larger household. At the regional level, the only indicator with a statistically significant difference in more than one region is the dependency ratio, with children with stunting more likely to belong to households with a higher dependency ratio than children without stunting in Androy and Anosy.

Table 7: Child Stunting Based on Socio-Demographic Characteristics by Region

Demographics	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Female head	0.01	0.03	-0.08	0.00	0.04
Head age	-0.34	0.51	-0.83	0.11	-0.43
Household size	-0.07	0.06	0.05	-0.41	0.13
Number of children U5	-0.06	-0.02	0.02	-0.19**	-0.02
Dependency ratio	0.12	0.38**	0.25*	-0.30	0.02

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

For socio-economic characteristics and stunting, we see weak bi-variate associations. Pooled results indicate statistically significant differences for electricity and ownership of radios between children with stunting and those that do not have stunting. For regions, none of the indicators have statistically significant results in more than one region.

Table 8: Child Stunting Based on Socio-Economic Characteristics by Region

Socioeconomic	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Head no education	0.02	0.07	0.07	-0.15**	0.07
Improved Water Source	0.01	0.02	0.05	-0.05	0.04
Toilet: open defecation	0.00	0.03	-0.05	0.07*	0.07
Roof of thatch or leaf	-0.03	0.02	-0.13	-0.04	0.03
Dwelling has electricity	-0.03**	-0.00	-0.03	0.01	-0.06**
Main cook fuel is charcoal	-0.03*	-0.04	-0.03*	0.00	-0.02
Number of rooms for sleeping	-0.04	-0.01	-0.05	-0.04	-0.00
Owns mobile phone	-0.02	-0.04	-0.02	0.12**	-0.06
Owns radio	-0.05**	-0.00	-0.04	-0.03	-0.14**
Location is urban	0.01	-0.04	0.07	0.04	-0.01*

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

We also note an inconsistent direction of relationships and statistical significance in the association between children living with stunting and household ownership of agricultural assets. Pooled results find no statistically significant differences in agricultural assets. At the regional level, children with stunting are less likely than children who do not have stunting to belong to households owning an animal cart in Anosy and Atsimo Andrefana. This relationship

also holds for sheep ownership in Anosy and Atsimo Atsinanana, but in Androy children with stunting are more likely to live in households that own sheep than children without stunting.

Table 9: Child Stunting Based on Agricultural Assets by Region

Assets	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Owns agricultural land	0.00	0.01	-0.08	0.02	-0.03
Owns animal cart	-0.03	0.05	-0.09**	-0.09*	0.01
Owns livestock	-0.05	-0.06	0.00	-0.15**	-0.02
Owns goats	-0.03	0.03	-0.05	-0.09	-0.00
Owns sheep	-0.02	0.07**	-0.10**	-0.05	-0.02*
Owns poultry	-0.03	-0.07	0.03	-0.09	-0.04
Owns zebus	0.01	0.09*	-0.05	-0.11**	0.04
Owns ducks	-0.01	0.01	-0.03	0.04	-0.02
Own pigs	0.01	-0.00	0.10*	0.02	-0.07

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

Children that Meet MAD Threshold

For a minimum acceptable diet, pooled results indicate that children reaching MAD thresholds are less likely to have a female head and more likely to have an older head of the household than children not meeting the MAD threshold. At the regional level, children reaching the MAD threshold are less likely to belong to a household with a female head in three of the regions, excepting Androy. Children reaching the MAD threshold are more likely to have an older head of the household in Atsimo Atsinanana, but no statistically significant difference is found in the other three regions. Household composition indicators related to household size and dependency ratio do not have statistically significant differences between children meeting the MAD threshold and those who do not. The number of children under five is associated with falling below the MAD threshold in Androy, but not statistically significant in other regions.

Table 10: Child MAD Based on Socio-Demographic Characteristics by Region

Demographics	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Female head	-0.17***	0.04	-0.20**	-0.20***	-0.17***
Head age	3.90*	3.52	2.32	2.52	7.27*
Household size	0.33	-1.28*	0.33	0.67	0.69
Number of children under 5 years	-0.12	-0.34*	-0.07	-0.05	-0.03
Dependency ratio	-0.11	0.28	-0.52***	0.15	-0.14

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

In terms of socio-economic indicators, we can see from pooled results that children meeting the MAD threshold are less likely (when examining each indicator individually) to have a mother working in agriculture, practice open defecation, or belong to a household using a cooking fuel other than charcoal than children not meeting the MAD threshold. For regions, there is a statistically significant difference in the household head having an incomplete primary education in the regions of Androy and Atsimo Atsinanana between the two groups of children. Children meeting the MAD threshold are less likely to have mothers working in agriculture in Androy or in unskilled labor in Androy and Atsimo Atsinanana (Annex Table B-3). Children meeting MAD thresholds live in households that are less likely to practice open defecation in Androy and Atsimo Atsinanana, and more likely to use charcoal for cooking in Androy and Atsimo Andrefana than children below the MAD threshold.

Table 11: Child MAD Based on Socio-Economic Characteristics by Region

Socioeconomic	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Head no education	-0.13	-0.06	-0.12	-0.26*	0.11
Head has incomplete primary education	-0.04	-0.22***	0.01	0.06	-0.24*
Mother's occupation is agriculture	-0.26***	0.55***	0.00	-0.02	0.06
Toilet: open defecation	-0.21**	-0.27*	-0.08	-0.29	-0.28**
Main cook fuel is charcoal	0.28***	0.42**	0.18	0.33**	0.23
Number of rooms for sleeping	0.25	-0.07	0.17	0.00	0.76**
Owns radio	0.13*	0.17	0.11	-0.02	0.31***

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

For agricultural asset indicators, with pooled data, none of the coefficients are statistically significant. At the regional level, there are only a few statistically significant differences between children meeting the MAD threshold and those that do not, such as hectares of land owned. In such cases, the direction of the association is not consistent across the regions.

Table 12: Child MAD Based on Agricultural Assets by Region

	All Four Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Owns agricultural land	-0.10	-0.08	-0.05	-0.13	-0.09
Hectares of agric. land	0.19	-0.40*	0.73*	-0.00	0.39
Owns animal cart	0.01	0.31**	0.11	-0.07	-0.01
Owns zebus	-0.00	0.03	-0.03	-0.13	0.20

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

3.2.C. IDENTIFYING KEY CORRELATES OF FOOD INSECURITY AND MALNUTRITION

In this final portion of the analysis, we set out to use machine learning algorithms to identify predictors for child stunting and child MAD. However, throughout all our child stunting and child MAD predictions, the constraints of our dataset became evident. Given that our data represented a smaller subset of the larger dataset used for the poverty outcome variable, the limited number of observations impeded our model's learning capability. As a result, we observed notably low accuracy scores. This limited dataset size resulted in the model struggling to accurately predict whether an individual child was truly stunted or did not have a minimum acceptable diet. In our focused analysis on child stunting and child MAD, certain variables such as the age of the head of household and education levels emerged as potentially relevant, because their inclusion in our machine learning model results in improved performance in predicting the outcome variables. Results are listed in Annex D.

4. CONCLUSIONS

4.1. RESTATEMENT OF PURPOSE

In the Madagascar context, a combination of environmental, political, and cultural factors have combined to create a situation where the humanitarian need is often greater than humanitarian actors have the capacity to completely fulfill. Therefore, USAID must be extremely strategic in targeting its assistance to the individuals and groups that are most in need of assistance. This SDA is intended to directly support these efforts by providing BHA with evidence to inform decisions that will be made in targeting and household selection criteria for the upcoming RFSA in Madagascar. Furthermore, this study was also designed to increase general understanding of the factors and characteristics that are linked with poverty, food insecurity, and malnutrition in the country, to benefit program design beyond the immediate targeting considerations.

4.2. SUMMARY OF KEY FINDINGS

After completing the descriptive, geospatial, econometric, and machine learning analysis across the key outcomes of poverty, child stunting, and child MAD, the results of this SDA point to four key overarching findings:

1. **Regional variation is notable**, particularly for results related to poverty. When comparing households that are and are not living in poverty, there are some differences that are only statistically significant in particular regions. In Anosy, for example, households living in poverty are more likely to have a younger household head, but this link does not hold true for the other regions. In Atsimo Atsinanana, households living in poverty are more likely to live in rural areas than households not in poverty, but again, this association does not apply to the other three regions. This trend is in line with the results of the Desk Review and Market Study and the Political Economy Analysis, which also highlight the importance of regional differences and as shown in the geospatial analysis, even district-by-district distinctions that will be important for the RFSA design teams to take into consideration.
2. **Socioeconomic variables are critical** for determining poverty status and should play a key role in targeting. When we compare the results across the two sets of variables (socio-demographic/health characteristics, and socioeconomic characteristics), socioeconomic variables are consistently more closely linked with the poverty outcome. Characteristics related to asset ownership and dwellings are especially important. Findings from the PEA also corroborated that land ownership is a key socio-economic characteristic. This result is clearly apparent in the machine learning analysis, which found socioeconomic characteristics such as roof type, floor type, cooking fuel, and

mobile phone ownership to be the strongest and most consistent predictors of a household's poverty status. This connection is also logical, as those living in poverty will necessarily have fewer resources to invest in home improvements and the purchase of major assets. The DRMS found that mobile phones, especially, are important tools for increasing income as they facilitate learning market prices in other locations, getting weather notifications, receiving remittances and other money transfers.

3. **Results were statistically significant across multiple regions more often for poverty than for outcomes related to food insecurity and malnutrition**. For example, in Research Question 3 when we compared children that are and are not experiencing stunting, there were very few significant differences between the two groups other than electricity and ownership of televisions and radios. The machine learning algorithm also struggled to successfully predict children that are experiencing stunting or meeting MAD with the same level of accuracy as the poverty predictions. This finding is related to the limitations of the DHS dataset, which includes far smaller sample sizes for data related to children.
4. **There is a strong association between poverty and education, and poverty and water, sanitation, and hygiene (WASH) characteristics**. Across all types of analysis, the demographic variable that was most consistently associated with poverty is the educational level of the household head. Households headed by someone with an education are less likely to live in poverty than households whose head has no formal education. There is also a link to poverty and WASH characteristics, especially lacking an unimproved water source and practicing open defecation. Households with an improved water source or toilet facilities are less likely to live in poverty than households with unimproved water sources or no toilet facilities. From the PEA, we have learned that the government has less incentive to provide public service provisions such as water and sanitation in rural areas, as they are less likely to meet operating costs in villages where there is a higher poverty rate.

4.3. IMPLICATIONS

Based on these results, the RFSA program design team should consider regional differences when developing the program targeting strategies. If the design teams decide to use the machine learning findings from Section 2.1.c, identifying key correlates to develop a targeting tool that identifies households most likely to be living in poverty, the targeting questionnaire should be modified based on regional results. For example, while all four regional tools might include questions about mobile phone ownership and roofing material, the Atsimo Andrefana questionnaire should also include questions relating to floor material, cooking fuel, open defecation, and the educational status of the household head, as these were all strong correlates of poverty for this region. It will also be important to incorporate additional evidence

– including from the DRMS and the PEA and geospatial analysis – on sub-regional heterogeneity.

Any targeting strategy should also consider focusing on socioeconomic factors, especially those identified in this SDA report as being most correlated with poverty status. This SDA has narrowed down the full list of assets and dwelling characteristics included in the DHS – into a pared-down list of only the socioeconomic factors with the strongest association with poverty. This will help implementers develop an efficient and focused tool that is feasible to implement on the ground. Furthermore, program implementation teams might also consider tracking changes in asset ownership and dwelling characteristics throughout the implementation of the program, or at the conclusion of the intervention, to see whether these measures have changed over time. Given the focus of the upcoming RFSA on the graduation approach, this might be one way to track whether households have been able to leverage the safety net provided within the RFSA program into longer-term, sustainable investments which could signify a move out of poverty.

Another important takeaway from this analysis is that, while it seems feasible to develop a targeting strategy to identify households most likely to be living in poverty, it would be difficult to develop a similar strategy to identify children with stunting or MAD based on the data available in DHS. The research team recommends that program design teams incorporate insights from other sources, including the DRMS and PEA, related to food security and malnutrition, possibly combined with their own formative research to better understand these characteristics in the Malagasy context.

Finally, based on this analysis, USAID might also decide to incorporate activities related to some of the factors most strongly linked to poverty, either as part of the upcoming RFSA or other activities within the Mission's portfolio. Given the importance of the household head's educational status, it might be worthwhile to implement activities to provide coaching and mentoring opportunities focused on life-skills, financial literacy, and training on how to run a business (Banerjee et al, 2015). There is also a clear connection between poverty status and WASH characteristics, so coaching programs might also include behavior change activities related to WASH, modeling graduation activities in Nobo Jatra in Bangladesh (Bernagros, 2022). Finally, there is also a potential link between maternal literacy and child dietary diversity, and therefore programs to improve maternal literacy might also play a role in reduced malnutrition. While this analysis is not able to determine causality between these factors, implementing and then monitoring the outcomes of activities focused on these related factors could help expand the evidence base and potentially reduce long-term poverty in the region.

ANNEX A: FULL SET OF TABLE AND FIGURES

This annex presents additional results tables for Research Question 1. There are separate sections for households living in poverty, children with stunting, and children meeting the MAD threshold.

ADDITIONAL DESCRIPTIVE ANALYSIS TABLES: POVERTY

This section presents additional tables for RQ1 with descriptive results related to households living in poverty. Please note that orange text indicates results are based on less than 50 unweighted observations and should be interpreted with caution.

Table A-1: Poverty Levels by Region (%)

Region	Proportion of Households Living in Poverty
Androy	44 (35, 54)
Anosy	47 (36, 57)
Atsimo Andrefana	39 (25, 55)
Atsimo Atsinanana	66 (56, 75)
All four regions	47 (40, 54)
F test	0.034

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-2: Households Living in Poverty by Region and Gender of Household Head (%)

Region	Male	Female
Androy	42 (33, 52)	47 (37, 58)
Anosy	47 (38, 57)	45 (32, 59)
Atsimo Andrefana	39 (25, 54)	41 (25, 59)
Atsimo Atsinanana	65 (56, 73)	69 (55, 81)
All four regions	46 (39, 53)	48 (40, 56)
F test	0.016	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-3: Proportion of Households Living in Poverty by Household Size (%)

Region	2 or fewer	3	4	5	6 plus
Androy	45 (31, 59)	51 (40, 61)	45 (36, 55)	41 (31, 52)	42 (31, 53)
Anosy	44 (31, 58)	43 (29, 58)	53 (41, 65)	38 (27, 51)	51 (40, 62)
Atsimo Andrefana	39 (23, 59)	39 (23, 57)	40 (24, 58)	38 (22, 57)	40 (25, 57)
Atsimo Atsinanana	69 (49, 83)	64 (50, 75)	64 (47, 78)	66 (53, 77)	67 (57, 76)
All four regions	46 (37, 55)	46 (38, 55)	48 (39, 56)	44 (36, 53)	48 (40, 55)
F test	0.011				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-4: Proportion of Households Living in Poverty by Age of Household Head (%)

Region	19 or younger	20-34	35-49	50 plus
Androy	57 (30, 80)	46 (35, 57)	46 (35, 58)	41 (31, 51)
Anosy	48 (25, 72)	53 (41, 64)	47 (35, 59)	39 (29, 50)
Atsimo Andrefana	34 (14, 62)	47 (29, 65)	32 (20, 48)	39 (25, 54)
Atsimo Atsinanana	55 (19, 86)	68 (55, 79)	64 (53, 73)	67 (56, 76)
All four regions	44 (29, 60)	51 (43, 60)	44 (36, 51)	45 (38, 52)
F test	0.010			

***Source**: 2021 Demographic and Health Surveys (DHS)*
Notes: The 95% confidence interval is shown in parentheses.
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-5: Proportion of Households Living in Poverty by Education of Household Head (%)

Region	None	Incomplete Primary	Complete Primary or higher
Androy	50 (41, 59)	40 (28, 53)	17 (9, 30)
Anosy	60 (51, 69)	42 (30, 54)	12 (5, 27)
Atsimo Andrefana	64 (51, 75)	33 (20, 49)	9 (5, 18)
Atsimo Atsinanana	81 (72, 87)	72 (63, 80)	31 (22, 42)
All four regions	62 (56, 67)	47 (39, 54)	14 (10, 20)
F test	0.000		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-6: Proportion of Households Living in Poverty by Number of Children Under 5 (%)

Region	0	1	2	3	4 plus
Androy	43 (32, 53)	44 (33, 57)	44 (34, 55)	48 (32, 65)	39 (23, 58)
Anosy	40 (29, 52)	44 (34, 54)	61 (50, 70)	63 (44, 79)	41 (12, 78)
Atsimo Andrefana	30 (17, 46)	36 (23, 51)	49 (32, 68)	61 (38, 80)	69 (43, 87)
Atsimo Atsinanana	66 (51, 77)	61 (52, 70)	71 (58, 81)	68 (55, 78)	91 (57, 99)
All four regions	41 (34, 49)	43 (36, 51)	55 (46, 63)	58 (48, 68)	57 (43, 71)
F test	0.001				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-7: Proportion of Households Living in Poverty by Number of Dependents (0-14, 65+) (%)

Region	0	1	2	3	4 plus
Androy	33 (18, 52)	51 (40, 62)	45 (36, 53)	49 (34, 64)	42 (32, 52)
Anosy	41 (28, 56)	38 (26, 52)	50 (37, 62)	43 (30, 57)	56 (46, 66)
Atsimo Andrefana	29 (15, 50)	33 (20, 49)	40 (24, 59)	39 (25, 55)	48 (32, 64)
Atsimo Atsinanana	68 (51, 82)	64 (51, 75)	64 (49, 78)	64 (53, 73)	69 (60, 77)
All four regions	38 (29, 48)	42 (34, 50)	47 (39, 56)	47 (40, 55)	51 (44, 59)
F test	0.003				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-8: Proportion of Households Living in Poverty by Household Possessions (%)

Region	Owns radio	Mobile Phone	Bicycle
Androy	11 (5, 24)	19 (11, 30)	22 (15, 30)
Anosy	5 (2, 14)	16 (8, 28)	8 (4, 17)
Atsimo Andrefana	4 (1, 13)	13 (7, 24)	12 (4, 31)
Atsimo Atsinanana	32 (23, 43)	25 (15, 39)	2 (0, 16)
All four regions	13 (8, 18)	16 (11, 22)	13 (7, 21)
F test	0.000	0.003	0.019

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-9: Proportion of Households Living in Poverty by Water and Toilet (%)

Region	Unimproved Water Source	Improved Water Source	Improved Toilet	Unimproved Toilet	Open defecation
Androy	52 (41, 63)	29 (20, 39)	22 (13, 36)	26 (17, 37)	62 (53, 71)
Anosy	57 (48, 66)	17 (10, 29)	33 (17, 55)	39 (25, 54)	54 (44, 64)
Atsimo Andrefana	54 (39, 68)	27 (12, 49)	2 (1, 7)	9 (3, 24)	57 (42, 70)
Atsimo Atsinanana	74 (66, 80)	30 (17, 49)	3 (1, 18)	39 (25, 55)	76 (69, 82)
All four regions	59 (53, 65)	26 (16, 39)	12 (7, 19)	27 (21, 35)	61 (55, 68)
F test	0.001		0.000		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-10: Proportion of Households Living in Poverty by Roof (%)

Region	Thatch Palm Leaf	Palm Bamboo	Metal	Other
Androy	59 (51, 67)	63 (30, 87)	0 (0, 2)	9 (5, 16)
Anosy	66 (55, 75)	47 (35, 59)	1 (0, 7)	55 (29, 78)
Atsimo Andrefana	59 (45, 72)	0 (0, 0)	0 (0, 0)	0 (0, 0)
Atsimo Atsinanana	77 (69, 83)	73 (53, 87)	3 (1, 11)	81 (29, 98)
All four regions	64 (57, 70)	68 (51, 81)	1 (0, 2)	29 (15, 50)
F test	0.000			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-11: Proportion of Households Living in Poverty by Floor (%)

Region	Earth Sand	Mats	Vinyl Asphalt	Cement	Other
Androy	56 (40, 70)	53 (45, 62)	13 (6, 25)	0 (0, 0)	31 (13, 58)
Anosy	57 (30, 80)	59 (50, 67)	10 (4, 24)	0 (0, 0)	23 (12, 40)
Atsimo Andrefana	53 (29, 75)	71 (58, 80)	10 (5, 19)	0 (0, 0)	28 (14, 48)
Atsimo Atsinanana	57 (24, 85)	75 (67, 82)	0 (0, 0)	0 (0, 0)	55 (44, 66)
All four regions	55 (43, 67)	65 (59, 70)	10 (6, 15)	0 (0, 0)	39 (29, 49)
F test	0.000				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases .Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-12: Proportion of Households Living in Poverty by Agricultural Assets (%)

Region	Own any livestock	Owns cows/bulls	Owns goats	Owns sheep	Owns poultry
Androy	41 (32, 50)	45 (33, 57)	40 (30, 50)	37 (28, 47)	43 (34, 52)
Anosy	41 (32, 50)	26 (15, 41)	56 (34, 76)	29 (20, 40)	38 (29, 48)
Atsimo Andrefana	33 (21, 49)	47 (29, 65)	36 (19, 56)	48 (32, 63)	34 (20, 50)
Atsimo Atsinanana	65 (57, 73)	55 (22, 84)	62 (36, 82)	60 (21, 90)	65 (57, 73)
All four regions	43 (37, 50)	41 (32, 51)	40 (30, 50)	39 (32, 48)	44 (38, 51)
F test	0.004	0.009	0.000	0.000	0.001

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-13: Proportion of Households Living in Poverty by Agricultural Assets (%) (cont'd)

Region	Owns zebus	Owns duck / geese / turkey	Owns pigs	Owns animal cart	Agricultural land
Androy	33 (23, 44)	40 (19, 64)	56 (9, 94)	16 (9, 27)	45 (36, 54)
Anosy	39 (28, 51)	28 (17, 42)	34 (22, 49)	28 (14, 49)	48 (39, 58)
Atsimo Andrefana	39 (26, 54)	22 (12, 39)	5 (1, 15)	32 (18, 51)	49 (34, 63)
Atsimo Atsinanana	59 (48, 69)	60 (49, 69)	60 (48, 71)	22 (4, 64)	67 (58, 76)
All four regions	42 (36, 48)	36 (27, 45)	35 (24, 47)	26 (18, 37)	52 (46, 57)
F test	0.007	0.002	0.000	0.004	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-14: Proportion of Households Living in Poverty by Rural/Urban Location (%)

Region	Rural	Urban
Androy	45 (36, 55)	29 (6, 72)
Anosy	51 (41, 61)	23 (5, 62)
Atsimo Andrefana	42 (27, 58)	26 (3, 80)
Atsimo Atsinanana	70 (59, 78)	19 (8, 38)
All four regions	50 (42, 57)	25 (8, 56)
F test	0.078	

ADDITIONAL DESCRIPTIVE ANALYSIS TABLES: CHILD STUNTING

This section presents additional tables for RQ1 with descriptive results related to children with stunting. Please note that orange text indicates results are based on less than 50 unweighted observations and should be interpreted with caution.

Table A-15: Proportion of Child Stunting by Region (%)

Region	
Androy	46 (41, 52)
Anosy	47 (39, 55)
Atsimo Andrefana	30 (25, 37)
Atsimo Atsinanana	48 (43, 53)
All four regions	44 (40, 47)
F test	0.001

Table A-16: Proportion of Child Stunting by Gender of Household Head (%)

Region	Male	Female
Androy	45 (39, 51)	49 (40, 58)
Anosy	50 (40, 59)	40 (28, 53)
Atsimo Andrefana	30 (23, 38)	31 (21, 43)
Atsimo Atsinanana	47 (41, 53)	53 (41, 65)
All four regions	43 (39, 47)	44 (39, 50)
F test	0.001	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-17: Proportion of Child Stunting by Household Size (%)

Region	2 or fewer	3	4	5	6 plus
Androy	72 (44, 90)	46 (29, 63)	39 (24, 56)	41 (32, 51)	48 (43, 54)
Anosy	61 (24, 89)	45 (29, 62)	44 (29, 60)	41 (29, 56)	50 (39, 60)
Atsimo Andrefana	49 (13, 87)	42 (24, 62)	24 (14, 38)	39 (25, 55)	28 (22, 35)
Atsimo Atsinanana	13 (1, 63)	62 (38, 81)	34 (22, 48)	47 (34, 60)	49 (43, 56)
All four regions	59 (39, 76)	48 (38, 58)	36 (28, 44)	42 (36, 49)	44 (41, 48)
F test	0.001				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-18: Proportion of Stunting by Age of Household Head (%)

Region	19 or younger	20-34	35-49	50 plus	F test
Androy	0 (0, 0)	46 (39, 54)	46 (36, 57)	47 (37, 58)	0.835
Anosy	57 (18, 89)	50 (41, 60)	42 (30, 54)	49 (33, 65)	0.606
Atsimo Andrefana	0 (0, 0)	25 (16, 37)	39 (33, 46)	27 (17, 40)	0.110
Atsimo Atsinanana	0 (0, 0)	48 (37, 59)	49 (41, 56)	47 (37, 58)	0.823
All four regions	42 (15, 74)	43 (39, 48)	44 (39, 49)	43 (37, 49)	0.980

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-19: Proportion of Child Stunting by Education of Household Head (%)

Region	None	Incomplete Primary	Complete Primary or higher
Androy	49 (43, 55)	35 (24, 48)	47 (34, 60)
Anosy	50 (41, 60)	47 (34, 60)	35 (23, 50)
Atsimo Andrefana	25 (19, 34)	38 (24, 54)	41 (29, 55)
Atsimo Atsinanana	52 (42, 61)	40 (31, 50)	46 (38, 55)
All four regions	0 (40, 49)	40 (34, 46)	43 (37, 50)
F test	0.000		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-20: Proportion of Child Stunting by Number of Children Under 5 (%)

Region	0	1	2	3	4 plus
Androy	45 (34, 57)	45 (36, 55)	47 (39, 55)	48 (35, 62)	45 (34, 57)
Anosy	48 (37, 59)	50 (38, 61)	38 (26, 52)	62 (19, 92)	48 (37, 59)
Atsimo Andrefana	29 (19, 40)	35 (27, 42)	35 (23, 49)	13 (6, 29)	29 (19, 40)
Atsimo Atsinanana	51 (43, 59)	47 (40, 55)	46 (33, 60)	48 (17, 80)	51 (43, 59)
All four regions	0 (38, 49)	45 (40, 49)	43 (37, 50)	38 (28, 49)	0 (38, 49)
F test	0.000				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-21: Proportion of Child Stunting by Number of Dependents (0-14, 65+) (%)

Region	1	2	3	4 plus
Androy	57 (37, 75)	37 (24, 51)	36 (23, 51)	50 (44, 56)
Anosy	52 (34, 70)	44 (28, 61)	45 (32, 59)	48 (38, 58)
Atsimo Andrefana	43 (21, 68)	33 (21, 48)	43 (25, 62)	24 (20, 30)
Atsimo Atsinanana	53 (32, 73)	36 (24, 49)	49 (40, 58)	49 (43, 56)
All four regions	0 (41, 62)	38 (31, 46)	44 (37, 50)	44 (40, 48)
F test	0.000			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-22: Proportion of Child Stunting by Household Possessions (%)

Region	Owns radio	Mobile Phone	Bicycle
Androy	46 (31, 62)	43 (35, 52)	50 (38, 63)
Anosy	38 (23, 56)	45 (31, 59)	46 (28, 65)
Atsimo Andrefana	26 (13, 44)	38 (29, 47)	40 (27, 54)
Atsimo Atsinanana	34 (26, 44)	40 (30, 52)	30 (20, 44)
All four regions	0 (29, 42)	2 (36, 47)	1 (37, 52)
F test	0.000	0.000	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-23: Proportion of Child Stunting by Water and Toilet (%)

Region	Unimproved Water Source	Improved Water Source	Unimproved or Improved Toilet	Open defecation
Androy	46 (39, 53)	48 (38, 58)	45 (36, 54)	48 (41, 54)
Anosy	46 (37, 55)	58 (44, 70)	50 (36, 65)	45 (37, 53)
Atsimo Andrefana	32 (24, 40)	26 (19, 35)	20 (12, 32)	32 (26, 39)
Atsimo Atsinanana	47 (41, 52)	61 (46, 75)	41 (32, 51)	50 (44, 56)
All four regions	43 (39, 47)	45 (38, 52)	43 (37, 50)	44 (40, 47)
F test	0.000		0.000	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-24: Proportion of Child Stunting by Roof (%)

Region	Thatch Palm Leaf	Palm Bamboo	Metal	Other
Androy	47 (40, 54)	0 (0, 0)	43 (32, 55)	54 (45, 63)
Anosy	42 (33, 51)	82 (56, 94)	45 (34, 55)	62 (45, 77)
Atsimo Andrefana	29 (23, 36)	0 (0, 0)	34 (24, 47)	36 (5, 86)
Atsimo Atsinanana	49 (43, 55)	49 (37, 62)	35 (24, 48)	100 (0, 0)
All four regions	42 (38, 46)	53 (38, 68)	41 (35, 47)	58 (48, 67)
F test	0.000			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-25: Proportion of Child Stunting by Floor (%)

Region	Earth Sand	Mats	Vinyl Asphalt	Cement	Other
Androy	53 (37, 69)	45 (38, 51)	50 (35, 65)	53 (30, 74)	35 (21, 52)
Anosy	40 (16, 70)	48 (38, 57)	50 (31, 69)	44 (29, 60)	42 (32, 53)
Atsimo Andrefana	50 (30, 70)	26 (20, 32)	59 (42, 74)	27 (15, 42)	40 (22, 62)
Atsimo Atsinanana	50 (5, 95)	46 (40, 53)	42 (18, 70)	39 (10, 78)	54 (43, 64)
All four regions	51 (38, 63)	42 (38, 46)	52 (42, 62)	38 (29, 48)	48 (40, 56)
F test	0.000				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-26: Proportion of Child Stunting by Agricultural Assets (%)

Region	Own any livestock	Owns cows/bulls	Owns goats	Owns sheep	Owns poultry
Androy	44 (37, 51)	46 (31, 62)	49 (41, 58)	56 (47, 65)	43 (34, 51)
Anosy	47 (34, 60)	48 (29, 67)	27 (8, 63)	27 (17, 40)	49 (35, 63)
Atsimo Andrefana	25 (18, 34)	13 (6, 27)	21 (11, 38)	25 (14, 39)	26 (18, 36)
Atsimo Atsinanana	47 (41, 54)	30 (14, 53)	46 (26, 67)	0 (0, 0)	46 (40, 53)
All four regions	46 (42, 51)	44 (41, 47)	44 (41, 48)	44 (41, 48)	45 (41, 49)
F test	0.000	0.005	0.000	0.000	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-27: Proportion of Child Stunting by Agricultural Assets (%) (cont'd)

Region	Owns zebus	Owns duck / geese / turkey	Owns pigs
Androy	56 (45, 65)	55 (26, 80)	40 (21, 63)
Anosy	42 (31, 54)	35 (14, 64)	80 (61, 91)
Atsimo Andrefana	19 (11, 32)	37 (23, 53)	38 (19, 62)
Atsimo Atsinanana	50 (42, 59)	45 (32, 58)	40 (25, 57)
All four regions	43 (39, 47)	44 (40, 47)	43 (40, 46)
F test	0.005	0.000	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-28: Proportion of Child Stunting by Rural/Urban Location (%)

Region	Rural	Urban
Androy	48 (42, 53)	37 (20, 59)
Anosy	45 (36, 54)	60 (43, 74)
Atsimo Andrefana	29 (24, 36)	38 (24, 54)
Atsimo Atsinanana	48 (43, 54)	41 (37, 46)
All four regions	43 (40, 47)	45 (35, 55)
F test	0.024	0

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

ADDITIONAL DESCRIPTIVE ANALYSIS TABLES: CHILD MAD

This section presents additional tables for RQ1 with descriptive results related to children meeting the MAD threshold. Please note that orange text indicates results are based on less than 50 unweighted observations and should be interpreted with caution.

Table A-29: Proportion of Child MAD by Region (%)

Region	
Androy	3 (1, 8)
Anosy	9 (5, 15)
Atsimo Andrefana	7 (3, 14)
Atsimo Atsinanana	10 (5, 18)
All four regions	7 (5, 10)
F test	0.231

Table A-30: Proportion of Child MAD by Gender of Household Head

Region	Male	Female
Androy	3 (1, 8)	4 (1, 14)
Anosy	11 (7, 18)	3 (0, 19)
Atsimo Andrefana	9 (4, 18)	0 (0, 0)
Atsimo Atsinanana	12 (7, 21)	1 (0, 8)
All four regions	8 (6, 12)	2 (1, 5)
F test	0.093	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-31: Proportion of Child MAD by Household Size (%)

Region	2 or fewer	3	4	5	6 plus
Androy	0 (0, 0)	4 (1, 25)	6 (2, 19)	4 (0, 25)	2 (1, 7)
Anosy	0 (0, 0)	8 (2, 27)	5 (1, 19)	19 (8, 37)	7 (3, 17)
Atsimo Andrefana	0 (0, 0)	0 (0, 0)	8 (2, 21)	15 (3, 47)	7 (4, 15)
Atsimo Atsinanana	0 (0, 0)	3 (0, 22)	0 (0, 0)	13 (4, 35)	13 (7, 25)
All four regions	0 (0, 0)	3 (1, 9)	6 (3, 12)	13 (6, 24)	7 (5, 11)
F test	0.000				

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-32: Proportion of MAD by Age of Household Head (%)

Region	34 or Younger	35-49	50 plus
Androy	4 (1, 12)	0 (0, 0)	6 (1, 19)
Anosy	6 (3, 14)	12 (6, 22)	14 (4, 40)
Atsimo Andrefana	5 (2, 14)	6 (2, 20)	13 (4, 34)
Atsimo Atsinanana	6 (2, 18)	12 (5, 27)	15 (7, 29)
All four regions	5 (3, 9)	7 (4, 12)	12 (6, 21)
F test	0.000		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-33: Proportion of Child MAD by Education of Household Head (%)

Region	None	Incomplete Primary	Complete Primary or higher
Androy	3 (1, 9)	0 (0, 0)	10 (3, 28)
Anosy	7 (4, 13)	9 (3, 22)	13 (5, 32)
Atsimo Andrefana	4 (1, 11)	9 (3, 29)	12 (6, 24)
Atsimo Atsinanana	13 (5, 28)	5 (1, 18)	17 (9, 29)
All four regions	5 (3, 9)	6 (3, 12)	13 (8, 19)
F test	0.000		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-34: Proportion of Child MAD by Number of Children Under 5 (%)

Region	1	2	3	4 plus
Androy	4 (1, 14)	4 (1, 12)	3 (1, 11)	0 (0, 0)
Anosy	7 (3, 17)	11 (6, 19)	6 (1, 33)	0 (0, 0)
Atsimo Andrefana	8 (3, 22)	7 (2, 17)	8 (2, 25)	6 (1, 29)
Atsimo Atsinanana	7 (2, 17)	12 (6, 22)	10 (2, 36)	0 (0, 0)
All four regions	7 (4, 12)	8 (5, 12)	6 (3, 13)	3 (0, 18)
F test	0.000			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-35: Proportion of Child MAD by Number of Dependents (0-14, 65+) (%)

Region	1	2	3	4 plus
Androy	5 (1, 28)	2 (0, 16)	7 (1, 35)	2 (1, 7)
Anosy	8 (2, 27)	5 (1, 16)	18 (8, 35)	6 (2, 16)
Atsimo Andrefana	0 (0, 0)	7 (2, 19)	11 (2, 37)	8 (4, 16)
Atsimo Atsinanana	3 (0, 23)	5 (1, 23)	15 (6, 31)	11 (5, 24)
All four regions	3 (1, 9)	5 (2, 11)	12 (7, 22)	7 (4, 11)
F test	0.283			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-36: Proportion of Child MAD by Literacy of Mother (%)

Region	Cannot Read at All	Able to Read Parts of or Whole Sentence
Androy	3 (1, 9)	4 (1, 10)
Anosy	9 (5, 16)	9 (3, 23)
Atsimo Andrefana	2 (1, 9)	12 (5, 25)
Atsimo Atsinanana	7 (2, 20)	15 (9, 24)
All four regions	5 (3, 8)	10 (6, 15)
F test	0.048	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-37: Proportion of Child MAD by Occupation

Region	Not Working	Agricultural – self	Other
Androy	2 (0, 13)	1 (0, 5)	25 (9, 53)
Anosy	8 (2, 32)	7 (3, 14)	19 (6, 43)
Atsimo Andrefana	9 (2, 31)	2 (0, 14)	6 (2, 20)
Atsimo Atsinanana	11 (5, 23)	9 (3, 21)	16 (7, 33)
All four regions	8 (4, 16)	4 (2, 7)	13 (8, 22)
F test	0.005		

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-38: Proportion of Child MAD by Household Possessions (%)

Region	Owns radio	Television	Mobile Phone	Bicycle
Androy	10 (1, 44)	40 (13, 74)	6 (2, 16)	7 (2, 24)
Anosy	17 (8, 34)	17 (12, 25)	17 (8, 31)	14 (2, 54)
Atsimo Andrefana	7 (2, 22)	19 (10, 32)	14 (6, 27)	13 (3, 40)
Atsimo Atsinanana	22 (13, 35)	38 (21, 59)	13 (7, 24)	10 (1, 50)
All four regions	12 (8, 20)	21 (14, 31)	12 (8, 19)	15 (5, 23)
F test	0.000	0.000	0.000	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-39: Proportion of Child MAD by Water and Toilet (%)

Region	Unimproved Water Source	Improved Water Source	Unimproved or Improved Toilet	Open defecation
Androy	3 (1, 8)	4 (1, 15)	5 (2, 12)	2 (0, 6)
Anosy	8 (4, 14)	11 (4, 28)	10 (5, 21)	8 (3, 16)
Atsimo Andrefana	4 (1, 11)	10 (5, 21)	15 (5, 36)	5 (2, 11)
Atsimo Atsinanana	10 (5, 19)	9 (3, 26)	23 (13, 37)	7 (3, 16)
All four regions	6 (4, 9)	9 (5, 16)	11 (7, 18)	5 (3, 8)
F test	0.035			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-40: Proportion of Child MAD by Roof (%)

Region	Thatch Palm Leaf	Palm Bamboo	Metal	Other
Androy	3 (1, 8)	0 (0, 0)	7 (2, 23)	0 (0, 0)
Anosy	8 (4, 16)	50 (0, 0)	12 (4, 28)	0 (0, 0)
Atsimo Andrefana	5 (2, 12)	0 (0, 0)	14 (8, 25)	0 (0, 0)
Atsimo Atsinanana	8 (4, 18)	10 (2, 34)	24 (11, 43)	0 (0, 0)
All four regions	6 (4, 9)	13 (4, 35)	13 (8, 19)	0 (0, 0)
F test	0.000			

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-41: Proportion of Child MAD by Floor (%)

Region	Earth Sand	Mats	Vinyl Asphalt	Cement	Other
Androy	0 (0, 0)	3 (1, 8)	0 (0, 0)	15 (4, 41)	0 (0, 0)
Anosy	0 (0, 0)	8 (4, 13)	6 (1, 36)	22 (11, 40)	0 (0, 0)
Atsimo Andrefana	0 (0, 0)	7 (3, 14)	0 (0, 0)	13 (6, 25)	4 (0, 23)
Atsimo Atsinanana	0 (0, 0)	8 (4, 17)	25 (7, 61)	35 (13, 67)	38 (3, 92)
All four regions	0 (0, 0)	6 (4, 9)	4 (1, 13)	15 (9, 24)	5 (1, 20)
F test	0.000				

***Source**: 2021 Demographic and Health Surveys (DHS)*
Notes: The 95% confidence interval is shown in parentheses.
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-42: Proportion of Child MAD by Agricultural Assets (%)

Region	Own any livestock	Owns cows/bulls	Owns goats	Owns sheep	Owns poultry
Androy	2 (1, 7)	9 (2, 30)	4 (1, 13)	2 (0, 15)	2 (1, 8)
Anosy	11 (6, 18)	0 (0, 0)	21 (10, 39)	27 (12, 50)	8 (4, 16)
Atsimo Andrefana	6 (2, 13)	12 (2, 48)	4 (1, 22)	6 (1, 29)	8 (3, 18)
Atsimo Atsinanana	11 (6, 21)	0 (0, 0)	0 (0, 0)	0 (0, 0)	12 (6, 21)
All four regions	7 (5, 10)	8 (3, 22)	5 (2, 12)	7 (3, 15)	8 (5, 12)
F test	0.001	0.050	0.000	0.000	0.000

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-43: Proportion of Child MAD by Agricultural Assets (%) (cont'd)

Region	Owns zebus	Owns duck / geese / turkey	Owns pigs
Androy	4 (1, 13)	20 (2, 71)	0 (0, 0)
Anosy	8 (3, 19)	17 (4, 50)	25 (9, 53)
Atsimo Andrefana	3 (0, 18)	4 (1, 24)	10 (1, 43)
Atsimo Atsinanana	16 (7, 35)	5 (1, 18)	15 (7, 28)
All four regions	7 (4, 13)	6 (2, 15)	13 (7, 25)
F test	0.160	0.002	0.002

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*

Table A-44: Proportion of Child MAD by Rural/Urban Location (%)

Region	Rural	Urban
Androy	3 (1, 8)	0 (0, 0)
Anosy	8 (5, 14)	13 (3, 43)
Atsimo Andrefana	7 (3, 16)	6 (3, 13)
Atsimo Atsinanana	10 (5, 18)	17 (15, 21)
All four regions	7 (5, 10)	8 (4, 15)
F test	0.080	0

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

Table A-45: Proportion of Child MAD by Health Status (%)

Region	ARI	Diarrhea
Androy	5 (1, 43)	0 (0, 0)
Anosy	3 (0, 0)	0 (0, 0)
Atsimo Andrefana	9 (0, 0)	0 (0, 0)
Atsimo Atsinanana	4 (0, 0)	0 (0, 0)
All four regions	0 (5, 10)	0 (4, 15)
F test	0.002	

***Source**: 2021 Demographic and Health Surveys (DHS)*
***Notes**: The 95% confidence interval is shown in parentheses.*
Numbers shown in orange were estimated using an unweighted sample size < 50 cases. Readers should interpret results with caution due to the reduced precision of these estimates.

ANNEX B: ADDITIONAL REGRESSION ANALYSIS

This annex presents additional results tables for Research Question 3. There are separate sections for households living in poverty, children with stunting, and children meeting the MAD threshold.

Table B-1 presents a set of compiled regression results for RQ3, with each row relating an individual indicator from a set of demographic, socio-economic, and agricultural asset indicators to poverty.

Table B-1: Additional Results for Research Question 3: Poverty

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Demographic				
Household head is female	0.05	-0.02	0.02	0.04
Age of household head	-1.69	-3.43**	-1.07	-0.65
Household size	-0.57***	0.22	-0.21	-0.46
Number of members under 5	0.03	0.26***	0.48***	0.09
Number of dependent members	-0.21	0.46***	0.55**	0.06
Ratio of dependent members	0.18*	0.36***	0.65***	0.29***
Socioeconomic				
Head education: none	0.17***	0.31***	0.48***	0.26***
Head education: incompl. primary	-0.03	-0.05	-0.05*	0.10**
Head education: primary	-0.02**	-0.02	-0.02	-0.01
Head education: incompl. secondary 1	-0.04*	-0.09***	-0.12***	-0.09***
Head education: secondary 1	-0.02**	-0.04***	-0.06***	-0.05**
Head education: incompl. secondary 2	-0.03**	-0.05**	-0.10***	-0.09***
Head education: secondary 2	-0.02**	-0.03***	-0.07***	-0.07***
Head education: higher than secondary	-0.01**	-0.03	-0.06***	-0.05***
Household has improved water source	-0.21***	-0.31***	-0.28**	-0.28***
Household has improved toilet	-0.09**	-0.07*	-0.31***	-0.11***
Household has un-improved toilet	-0.29***	-0.10*	-0.17***	-0.23***
Household practices open defecation	0.38***	0.17**	0.48***	0.34***
Dwelling roof: thatch or leaf	0.45***	0.47***	0.55***	0.34***
Dwelling roof: palm or bamboo	0.01	0.00	0.00	0.05
Dwelling roof: metal	-0.35***	-0.50***	-0.54***	-0.39***
Dwelling roof: other	-0.10**	0.02	-0.01***	0.00

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Dwelling floor: earth or sand	0.05**	0.01	0.03	-0.01
Dwelling floor: wood planks	-0.06**	-0.03**	-0.00	-0.08**
Dwelling floor: palm or bamboo	0.00	0.00	0.00	0.03
Dwelling floor: mats	0.24***	0.36***	0.62***	0.28***
Dwelling floor: vinyl or asphalt	-0.08***	-0.12***	-0.10***	-0.07***
Dwelling floor: cement	-0.18***	-0.23***	-0.50***	-0.10***
Dwelling floor: other	0.03	-0.01	-0.04	-0.05**
Dwelling has electricity	-0.05***	-0.19**	-0.37***	-0.24***
Main cooking fuel: charcoal	-0.12***	-0.20***	-0.52***	-0.25***
Main cooking fuel: wood	0.01	0.18**	0.50***	0.26***
Main cooking fuel: straw or shrub	0.11*	0.04	0.04	0.00
Main cooking fuel: other	-0.01	-0.02	-0.02***	-0.02
Number of rooms used for sleeping	-0.24***	-0.25***	-0.68***	-0.46***
Household owns: radio	-0.10***	-0.21***	-0.31***	-0.41***
Household owns: mobile phone	-0.29***	-0.39***	-0.51***	-0.48***
Household owns: bicycle	-0.10***	-0.13***	-0.14***	-0.15***
Lives in urban location	-0.04	-0.15	-0.08	-0.14***
Agricultural assets				
Household owns: agric. land	0.03	0.06	0.20**	0.05
Household owns: animal cart	-0.15***	-0.06*	-0.03	-0.01**
Hectares of agric. land owned	-0.01	-0.13	-0.09	-0.24**
Household owns: livestock	-0.08**	-0.12*	-0.12**	-0.03
Household owns: cows	0.00	-0.05**	0.01	-0.01
Household owns: horses	-0.01**	0.00	-0.00	0.00
Household owns: goats	-0.05	0.02	-0.02	-0.00
Household owns: sheep	-0.06**	-0.06**	0.03	-0.00
Household owns: poultry	-0.03	-0.12**	-0.09**	-0.02
Household owns: zebus	-0.11***	-0.08	-0.00	-0.09
Household owns: ducks	-0.01	-0.04**	-0.09***	-0.04
Household owns: pigs	0.00	-0.03*	-0.09***	-0.05
Number owned: poultry	-0.34	-1.57***	-1.30***	-2.77***
Number owned: zebus	-0.56***	-0.53	-0.08	-0.55

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

Table B-2 presents a set of compiled regression results for RQ3, with each row relating an individual indicator from a set of demographic, socio-economic, and agricultural asset indicators to child stunting.

Table B-2: Additional Results for Research Question 3: Child Stunting

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Demographic				
Household head is female	0.05	-0.02	0.02	0.04
Age of household head	-1.69	-3.43**	-1.07	-0.65
Household size	-0.57***	0.22	-0.21	-0.46
Number of members under 5	0.03	0.26***	0.48***	0.09
Number of dependent members	-0.21	0.46***	0.55**	0.06
Ratio of dependent members	0.18*	0.36***	0.65***	0.29***
Socioeconomic				
Head education: none	0.17***	0.31***	0.48***	0.26***
Head education: incompl. primary	-0.03	-0.05	-0.05*	0.10**
Head education: primary	-0.02**	-0.02	-0.02	-0.01
Head education: incompl. secondary 1	-0.04*	-0.09***	-0.12***	-0.09***
Head education: secondary 1	-0.02**	-0.04***	-0.06***	-0.05**
Head education: incompl. secondary 2	-0.03**	-0.05**	-0.10***	-0.09***
Head education: secondary 2	-0.02**	-0.03***	-0.07***	-0.07***
Head education: higher than secondary	-0.01**	-0.03	-0.06***	-0.05***
Household has improved water source	-0.21***	-0.31***	-0.28**	-0.28***
Household has improved toilet	-0.09**	-0.07*	-0.31***	-0.11***
Household has un-improved toilet	-0.29***	-0.10*	-0.17***	-0.23***
Household practices open defecation	0.38***	0.17**	0.48***	0.34***
Dwelling roof: thatch or leaf	0.45***	0.47***	0.55***	0.34***
Dwelling roof: palm or bamboo	0.01	0.00	0.00	0.05
Dwelling roof: metal	-0.35***	-0.50***	-0.54***	-0.39***
Dwelling roof: other	-0.10**	0.02	-0.01***	0.00
Dwelling floor: earth or sand	0.05**	0.01	0.03	-0.01
Dwelling floor: wood planks	-0.06**	-0.03**	-0.00	-0.08**
Dwelling floor: palm or bamboo	0.00	0.00	0.00	0.03
Dwelling floor: mats	0.24***	0.36***	0.62***	0.28***
Dwelling floor: vinyl or asphalt	-0.08***	-0.12***	-0.10***	-0.07***
Dwelling floor: cement	-0.18***	-0.23***	-0.50***	-0.10***

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Dwelling floor: other	0.03	-0.01	-0.04	-0.05**
Dwelling has electricity	-0.05***	-0.19**	-0.37***	-0.24***
Main cooking fuel: charcoal	-0.12***	-0.20***	-0.52***	-0.25***
Main cooking fuel: wood	0.01	0.18**	0.50***	0.26***
Main cooking fuel: straw or shrub	0.11*	0.04	0.04	0.00
Main cooking fuel: other	-0.01	-0.02	-0.02***	-0.02
Number of rooms used for sleeping	-0.24***	-0.25***	-0.68***	-0.46***
Household owns: radio	-0.10***	-0.21***	-0.31***	-0.41***
Household owns: mobile phone	-0.29***	-0.39***	-0.51***	-0.48***
Household owns: bicycle	-0.10***	-0.13***	-0.14***	-0.15***
Lives in urban location	-0.04	-0.15	-0.08	-0.14***
Agricultural assets				
Household owns: agric. land	0.03	0.06	0.20**	0.05
Household owns: animal cart	-0.15***	-0.06*	-0.03	-0.01**
Hectares of agric. land owned	-0.01	-0.13	-0.09	-0.24**
Household owns: livestock	-0.08**	-0.12*	-0.12**	-0.03
Household owns: cows	0.00	-0.05**	0.01	-0.01
Household owns: horses	-0.01**	0.00	-0.00	0.00
Household owns: goats	-0.05	0.02	-0.02	-0.00
Household owns: sheep	-0.06**	-0.06**	0.03	-0.00
Household owns: poultry	-0.03	-0.12**	-0.09**	-0.02
Household owns: zebus	-0.11***	-0.08	-0.00	-0.09
Household owns: ducks	-0.01	-0.04**	-0.09***	-0.04
Household owns: pigs	0.00	-0.03*	-0.09***	-0.05
Number owned: poultry	-0.34	-1.57***	-1.30***	-2.77***
Number owned: zebus	-0.56***	-0.53	-0.08	-0.55

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

Table B-3 presents a set of compiled regression results for RQ3, with each row relating an individual indicator from a set of demographic, socio-economic, and agricultural asset indicators to children meeting the MAD threshold.

Table B-3: Additional Results for Research Question 3: Child MAD

Indicator Domains	All 4 Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Demographic					
Household head is female	-0.17***	0.04	-0.20**	-0.20***	-0.17***
Age of household head	3.90*	3.52	2.32	2.52	7.27*
Household size	0.33	-1.28*	0.33	0.67	0.69
Number of members under 5	-0.12	-0.34*	-0.07	-0.05	-0.03
Number of dependent members	0.17	-0.82	-0.13	0.75	0.22
Ratio of dependent members	-0.11	0.28	-0.52***	0.15	-0.14
Socioeconomic & Health					
Head education: none	-0.13	-0.06	-0.12	-0.26*	0.11
Head education: incompl. primary	-0.04	-0.22***	0.01	0.06	-0.24*
Head education: primary	-0.00	-0.04**	-0.03**	0.03	-0.03
Head education: incompl. secondary 1	-0.04*	-0.04***	-0.00	-0.09***	0.01
Head education: secondary 1	-0.00	0.11	-0.02	-0.04**	0.02
Head education: incompl. secondary 2	0.01	-0.03**	0.02	-0.00	0.03
Head education: secondary 2	0.19***	0.12	0.09	0.33**	0.08
Head education: higher than secondary	0.04	0.17	0.07	-0.02	0.05
Mother's occupation: not working	-0.03	-0.06	-0.01	0.05	0.03
Mother's occupation: agriculture	-0.01	-0.43**	-0.14	-0.33**	-0.09
Mother's occupation: sales	0.18**	-0.03**	0.21	-0.01	0.06
Mother's occupation: unskilled labor	0.02	-0.03**	-0.07	0.31	-0.06**
Mother's occupation: other	-0.26***	0.55***	0.00	-0.02	0.06
Mother's literacy: able to read parts or whole of sentence	0.06	0.07	-0.01	0.35***	0.21
Child health: suffered from diarrhea in last two weeks	0.10	0.17	-0.08	0.03	-0.10
Child health: suffered from ARI in last two weeks	0.08	0.07	-0.02	-0.01	-0.03*
Household has improved water source	0.11	0.11	0.08	0.26*	-0.01

Indicator Domains	All 4 Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Household has improved toilet	0.11*	0.48**	-0.08	0.16	0.04
Household has un-improved toilet	0.10	-0.22	0.16	0.14	0.23*
Household practices open defecation	-0.21**	-0.27*	-0.08	-0.29	-0.28**
Dwelling roof: thatch or leaf	-0.17**	-0.13	-0.08	-0.23**	-0.14
Dwelling roof: palm or bamboo	0.04	0.00	0.10	0.00	0.00
Dwelling roof: metal	0.17***	0.23	0.09	0.24**	0.14
Dwelling roof: other	-0.05***	-0.10**	-0.11*	-0.01	-0.00
Dwelling floor: earth or sand	-0.05***	-0.11***	-0.03**	-0.04***	-0.02*
Dwelling floor: wood planks	-0.01	-0.03	-0.02**	0.00	-0.00
Dwelling floor: palm or bamboo	0.02	0.00	0.00	0.00	0.04
Dwelling floor: mats	-0.09	-0.11	-0.09	-0.05	-0.16
Dwelling floor: vinyl or asphalt	-0.03	-0.05***	-0.03	-0.07***	0.04
Dwelling floor: cement	0.17***	0.34	0.19	0.20**	0.05
Dwelling floor: other	-0.01	-0.04**	-0.02	-0.04	0.06
Dwelling has electricity	0.15**	0.16	0.17	0.17	0.07
Main cooking fuel: charcoal	0.28***	0.42**	0.18	0.33**	0.23
Main cooking fuel: wood	-0.22***	-0.49***	-0.12	-0.22	-0.23
Main cooking fuel: straw or shrub	-0.06	0.07	-0.05	-0.11***	0.00
Main cooking fuel: other	-0.00	-0.00	-0.01	0.00	0.00
Number of rooms used for sleeping	0.25	-0.07	0.17	0.00	0.76**
Household owns: radio	0.13*	0.17	0.11	-0.02	0.31***
Household owns: mobile phone	0.26***	0.27	0.24*	0.39***	0.08
Household owns: bicycle	0.05	0.18	0.05	0.08	-0.00
Lives in urban location	0.01	-0.07***	0.08	-0.03	0.04
Agricultural Assets					
Household owns: agric. land	-0.10	-0.08	-0.05	-0.13	-0.09
Household owns: animal cart	0.01	0.31**	0.11	-0.07	-0.01
Hectares of agric. land owned	0.19	-0.40*	0.73*	-0.00	0.39
Household owns: livestock	-0.01	-0.16	0.12	-0.12	0.10
Household owns: cows	0.01	0.22	-0.09**	0.04	-0.01
Household owns: horses	-0.00	0.00	-0.01	-0.01	-0.00
Household owns: goats	-0.04	0.12	0.08	-0.07	-0.01
Household owns: sheep	-0.01	-0.08	0.19	-0.02	-0.00

Indicator Domains	All 4 Regions	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Household owns: poultry	0.04	-0.17	-0.03	0.05	0.11
Household owns: zebus	-0.00	0.03	-0.03	-0.13	0.20
Household owns: ducks	-0.02	0.15	0.05	-0.07	-0.14
Household owns: pigs	0.07	-0.01	0.08	0.03	0.10
Number owned: poultry	0.19	0.02	-0.07	-0.60	-0.02
Number owned: zebus	-0.00	0.06	-0.20	-0.45	0.58

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

ANNEX C: KEY RESULTS TABLES AND FIGURES WITH ALTERNATIVE CUTOFFS FOR OUTCOME MEASURES

The table below presents additional results for Research Question 3, using the bottom two quintiles of the wealth index to define poverty. Table C-1 presents a set of compiled regression results, with each row relating an individual indicator from a set of demographic, socio-economic, and agricultural asset indicators to poverty.

Table C-1: Poverty (Bottom Two Quintiles of the Wealth Index)

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Demographic				
Household head is female	0.10**	-0.06*	0.01	0.03
Age of household head	-4.10**	-4.39***	0.24	0.84
Household size	-1.47***	0.48*	-0.21	0.26
Number of members under 5	-0.03	0.35***	0.42***	0.25***
Number of dependent members	-0.89***	0.63***	0.65***	0.62***
Ratio of dependent members	-0.07	0.42***	0.70***	0.45***
Socioeconomic				
Head education: none	0.25***	0.43***	0.53***	0.35***
Head education: incompl. primary	-0.02	0.03	0.00	0.18***
Head education: primary	-0.02	-0.01	-0.01	-0.03
Head education: incompl. secondary 1	-0.08***	-0.15***	-0.16***	-0.07**
Head education: secondary 1	-0.04**	-0.07***	-0.07***	-0.09***
Head education: incompl. secondary 2	-0.05**	-0.10***	-0.12***	-0.15***
Head education: secondary 2	-0.02*	-0.05***	-0.09***	-0.12***
Head education: higher than secondary	-0.03**	-0.07*	-0.08***	-0.09***
Household has improved water source	-0.21***	-0.48***	-0.32***	-0.39***
Household has improved toilet	-0.04	-0.13***	-0.37***	-0.20***
Household has un-improved toilet	-0.35***	-0.19**	-0.16***	-0.26***
Household practices open defecation	0.39***	0.32***	0.53***	0.46***
Dwelling roof: thatch or leaf	0.72***	0.62***	0.74***	0.44***
Dwelling roof: palm or bamboo	0.01	0.04	0.00	0.12**
Dwelling roof: metal	-0.72***	-0.70***	-0.73***	-0.56***
Dwelling roof: other	-0.00	0.04	-0.01**	0.00*
Dwelling floor: earth or sand	0.04	0.03*	0.04**	-0.02

Indicator Domains	Androy	Anosy	Atsimo Andrefana	Atsimo Atsinanana
Dwelling floor: wood planks	-0.06*	-0.02	-0.00	-0.14***
Dwelling floor: palm or bamboo	0.00	0.00	0.00	0.08**
Dwelling floor: mats	0.47***	0.59***	0.68***	0.44***
Dwelling floor: vinyl or asphalt	-0.05	-0.13***	-0.06**	-0.12***
Dwelling floor: cement	-0.42***	-0.45***	-0.63***	-0.19***
Dwelling floor: other	0.02	-0.02	-0.03	-0.05**
Dwelling has electricity	-0.10***	-0.38***	-0.50***	-0.40***
Main cooking fuel: charcoal	-0.22***	-0.40***	-0.64***	-0.38***
Main cooking fuel: wood	0.10	0.19*	0.58***	0.40***
Main cooking fuel: straw or shrub	0.13**	0.22**	0.07**	0.00
Main cooking fuel: other	-0.02	-0.01	-0.01	-0.01
Number of rooms used for sleeping	-0.45***	-0.35***	-0.78***	-0.40***
Household owns: radio	-0.15***	-0.37***	-0.40***	-0.44***
Household owns: mobile phone	-0.36***	-0.52***	-0.53***	-0.59***
Household owns: bicycle	-0.06	-0.16***	-0.19***	-0.24***
Lives in urban location	-0.16*	-0.34**	-0.17	-0.28***
Agricultural assets				
Household owns: agric. land	0.01	0.22*	0.27***	0.11**
Household owns: animal cart	-0.20***	-0.05	-0.00	-0.02*
Hectares of agric. land owned	-0.05	-0.05	0.07	-0.19*
Household owns: livestock	-0.01	-0.08	-0.12*	0.11
Household owns: cows	-0.06*	0.00	0.01	0.01
Household owns: horses	-0.02	0.00	-0.00	0.00
Household owns: goats	0.02	0.01	-0.00	0.00
Household owns: sheep	-0.04	-0.02	0.06**	0.00
Household owns: poultry	0.08	-0.09	-0.10*	0.06
Household owns: zebus	-0.17***	-0.01	0.05	0.01
Household owns: ducks	-0.04	-0.05***	-0.09***	-0.01
Household owns: pigs	0.00	-0.02	-0.12***	0.03
Number owned: poultry	-0.64	-1.39**	-1.01**	-1.25
Number owned: zebus	-0.89***	-0.17	0.08	-0.20

Source: 2021 Demographic and Health Surveys (DHS)
*Notes: Significance levels - *p<0.1, **p<0.05, ***p<0.01*

ANNEX D: ADDITIONAL RESULTS FOR MACHINE LEARNING ANALYSIS

This annex presents additional results for Research Question 4. Table D-1 presents the confusion matrix for our machine learning model for predicting household poverty, with data pooled across four regions and individually by region.

Table D-1: Confusion Matrix for Household Poverty

	Predicted Not Poor	Predicted Poor	Ratio Correct	Accuracy Score	Mean Squared Error
All four regions					
Actually Not Poor	439	118	0.788	0.854	0.146
Actually Poor	32	437	0.932		
Anosy					
Actually Not Poor	112	27	0.806	0.794	0.206
Actually Poor	28	100	0.781		
Androy					
Actually Not Poor	130	33	0.798	0.837	0.1629
Actually Poor	11	96	0.897		
Atsimo Andrefana					
Actually Not Poor	132	17	0.886	0.888	0.112
Actually Poor	11	90	0.891		
Atsimo Atsinanana					
Actually Not Poor	71	29	0.71	0.842	0.158
Actually Poor	9	132	0.936		

Source: 2021 Demographic and Health Surveys (DHS)

Table D-2 presents the confusion matrix for our machine learning model for predicting children living with stunting, with data pooled across four regions.

Table D-2: Confusion Matrix for Child Stunting (Cross Fold = 10 Most Accurate)

Confusion Matrix			
	Predicted Not Stunted	**Predicted Stunted**	**Ratio Correct**
Actually Not Stunted	247	17	0.94
Actually Stunted	173	9	0.05

Accuracy score is 0.574

Mean Squared Error: 0.426

Source: 2021 Demographic and Health Surveys (DHS)

Table D-3 presents the confusion matrix for our machine learning model for predicting children meeting the MAD threshold, with data pooled across four regions.

Table D-3 Confusion Matrix for Child MAD (No Difference across Folds)

Confusion Matrix			
	Predicted Not Child MAD	**Predicted Child MAD**	**Ratio Correct**
Actually Not Child MAD	217	0	1
Actually Child MAD	11	0	0

Accuracy score is 0.952

Mean Squared Error: 0.05

Source: 2021 Demographic and Health Surveys (DHS)

ANNEX E: ADDITIONAL GEOSPATIAL INFORMATION AND RESULTS

This annex provides additional information related to the indicators used for the geospatial analysis and the maps of indicators identified by the LBR analysis to have significant relationships with poverty in multiple geographic clusters.

GEOSPATIAL ANALYSIS VARIABLES

Graduation Variables	
Derived Wealth Index: Percent of Households in Lowest Poverty Quartile	
Dietary Diversity for Children	
Derived Percentage of All Children That Have Wasting	
The Woman Has Final Say in Family Decisions	
Woman Is Decision Maker for Family Planning	
Skilled Antenatal Care	
Woman's Occupation: Not Working, Agriculture, Sales, Unskilled Manual Labor	
Main Water Source for Household: Improved or Unimproved/Surface Water	
Number Of Poultry Owned, Number of Zebus Owned	
Demographic Variables	
Number of Household Members	
Number of Children Under 5 In Household	
Age Of Head of Household	
Sex Of Head of Household	
Women Literacy	
Men's Occupation: Not Working, Agriculture, Sales, Unskilled Manual Labor	
Contextual Variables	
Administrative Boundaries	Boundaries for Nation, Regions, Districts
Populated Places	Location of Key Towns and Villages

MAPS OF VARIABLES WITH A SIGNIFICANT, POSITIVE RELATIONSHIP TO POVERTY

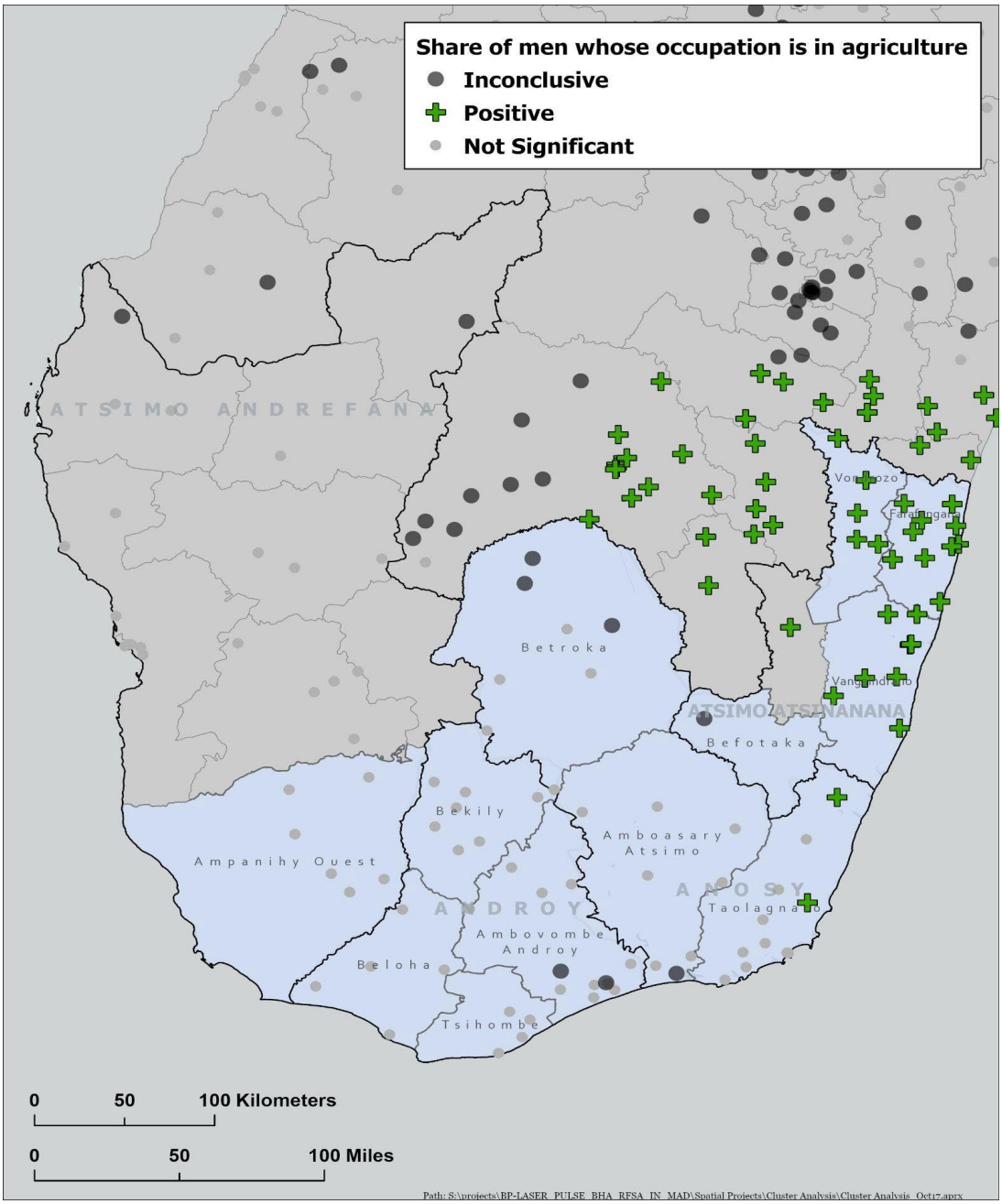

Figure E-1: LBR Results for Share of Men Whose Occupation is in Agriculture and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

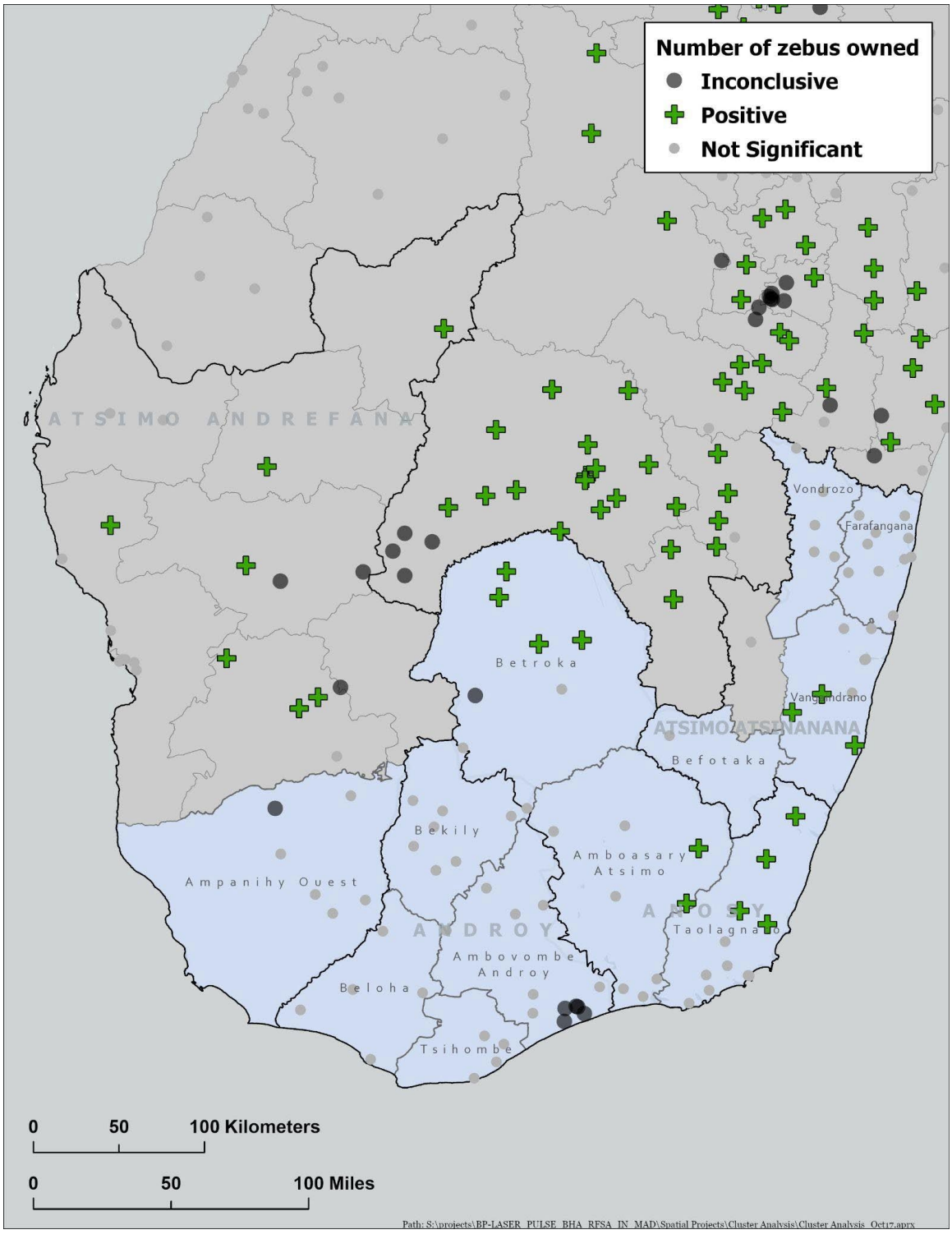

Figure E-2: LBR Results for Number of Zebu Owned and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

MAPS OF VARIABLES WITH A SIGNIFICANT, NEGATIVE RELATIONSHIP TO POVERTY

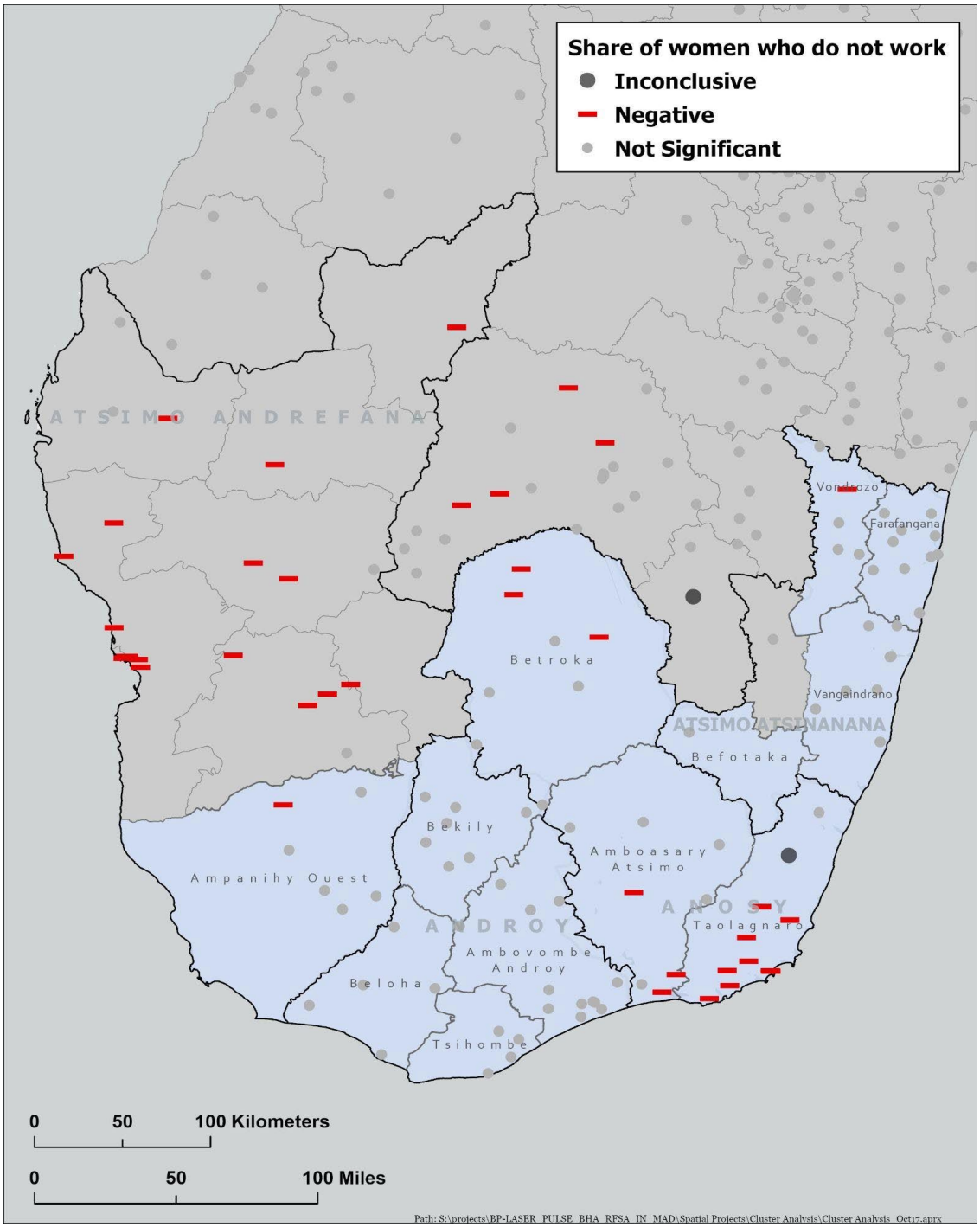

Figure E-3: LBR Results for Women who Do Not Work and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

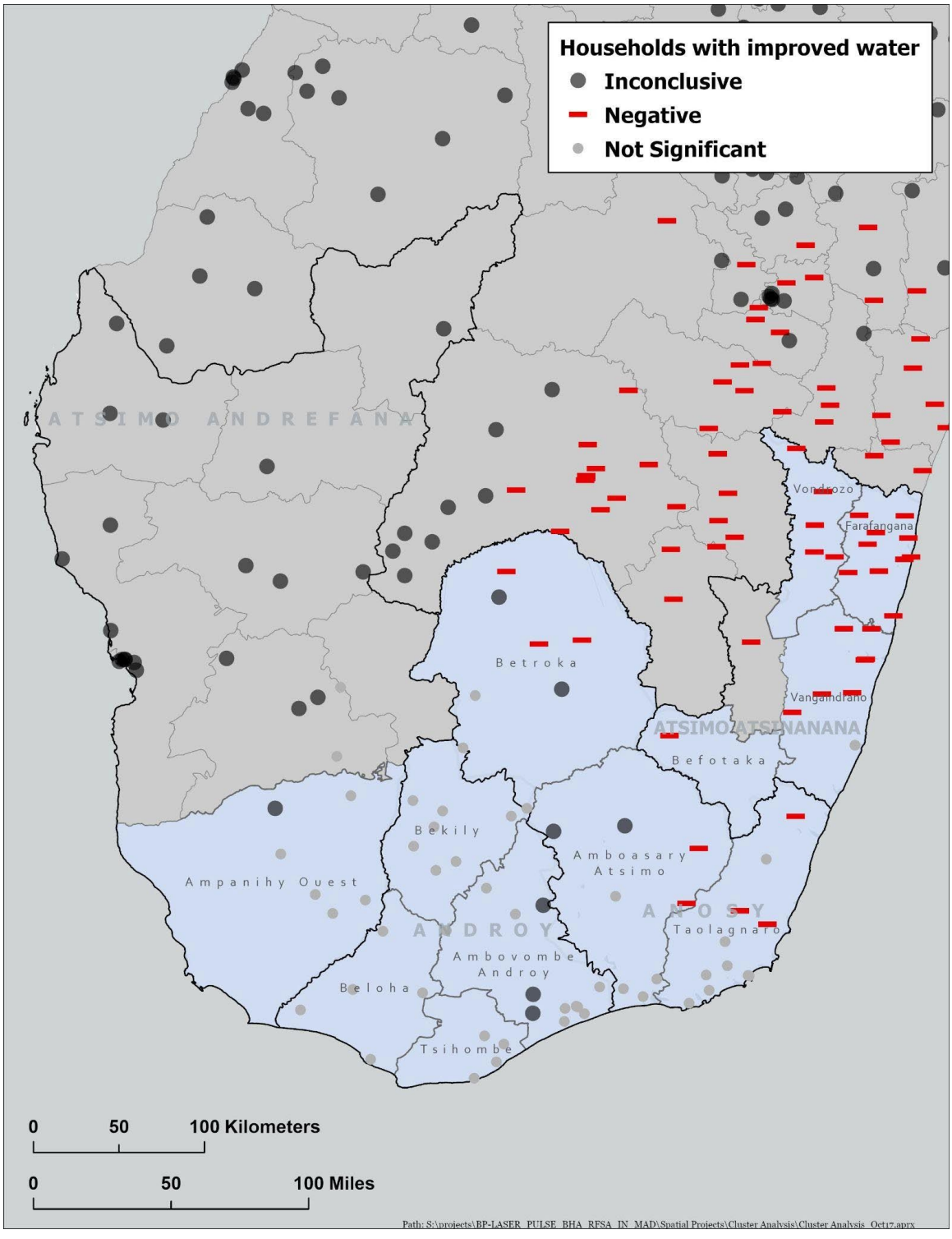

Figure E-4: LBR Results for Households with Improved Water and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

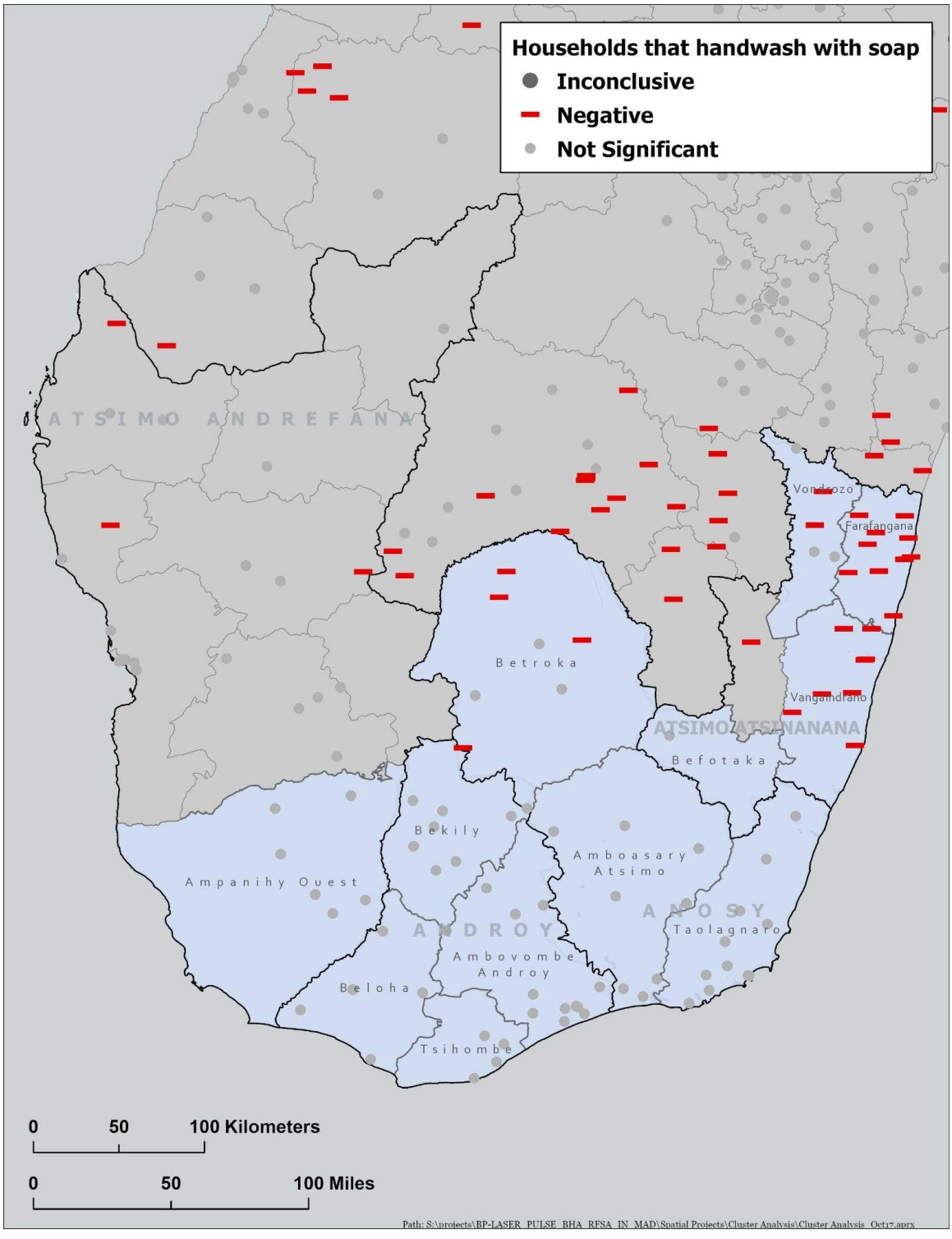

Figure E-5: LBR Results of Households that Handwash with Soap and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

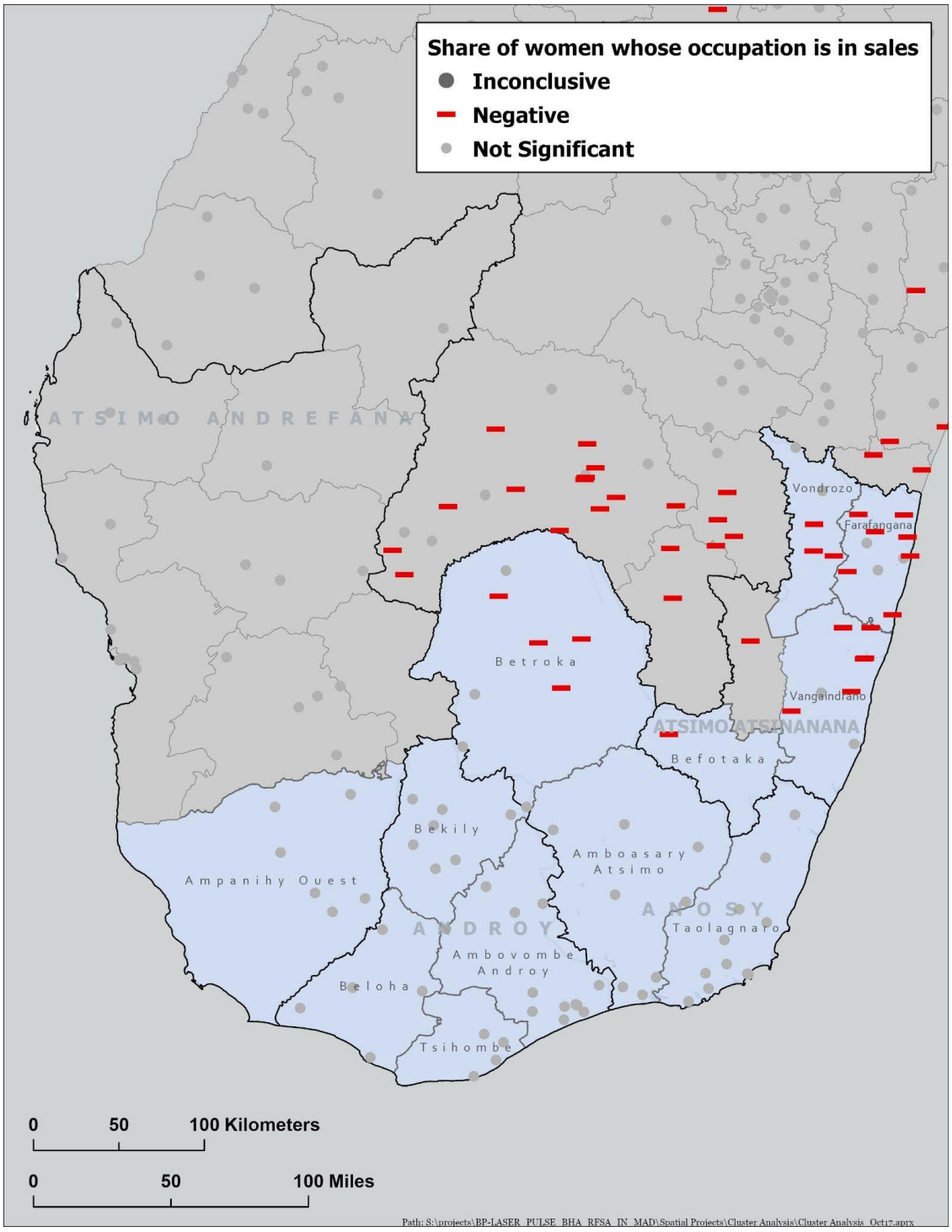

Figure E-6: LBR Results for Share of Women Whose Occupation is Sales and Poverty Status

Source: 2021 Demographic and Health Surveys (DHS)

LBR analysis was conducted for the following variables, however the results were not statistically significant so maps will not be included: household head based on age, female household head, number of children under 5, number of poultry owned, share of children achieving minimum dietary diversity, share of children with wasting, share of men who do not work, share of men whose occupation is sales, share of men whose occupation is unskilled labor, share of women whose occupation is in sales, share of women whose occupation is other, share of women whose occupation is unskilled labor, woman solely or jointly with partner made decision to not use family planning, woman solely or jointly with partner made decision to not use family planning, woman solely or jointly with partner made decisions related to health, purchases, and woman solely or jointly with partner made decisions related to health visits.

ANNEX F: METHODOLOGY DETAILS

This annex provides details for the methods used to address RQ3 and RQ4.

1. Descriptive analysis and regression equations

$$y_i = \sum_{j=1}^{J} \beta_j I_{ji} + \varepsilon_i$$

To understand differences in the socio-demographic and socioeconomic characteristics of households in the target population and those who are not, we employed a regression model with household characteristics as the left-hand-side variable and the target population indicators as the right-hand-side variable. For example, Ij could be indicators for households living in poverty/not living in poverty depending on whether the household falls within the bottom wealth quintile. In that case, J=2 because there are two poverty categories: 1=living in poverty, 2=not living in poverty. β1, the coefficient for living in poverty, is the mean value of y among households living in poverty. For example, if y is a binary variable for whether the household has running water in their dwelling or not, β1 would be the proportion of poor households who have running water.

2. Machine Learning SFS Algorithm Implementation

For RQ4 we used machine learning to select indicators that were strongly correlated with the outcomes of interest. We implemented our analysis in Python using the sklearn package. It contains the function Sequential Feature Selector (SFS) which runs the algorithm. We implemented the following steps to determine the ten most significant features:

- We first partitioned the full sample, which included all four regions, into training and test samples. The training sample for each outcome included 70 percent of cases, which could be households or children depending on the analysis. For the poverty analysis, the training sample included 70 percent of households from the full analysis sample, and for the child stunting and MAD analyses, the training samples included 70 percent of children from the full analysis sample. For each analysis, there was a corresponding test sample, which included 30 percent of cases from the respective samples. For the regional analysis, we partitioned the sample for each region into training and test samples using the same split.
- We then ran the SFS procedure on the pooled and regional training samples using cross-fold validation. Cross-fold validation (CV) is a procedure to split the training dataset into subsets or 'folds' with an equal number of sample observations in each fold. The results are then averaged across the different folds. This process further reduces the likelihood of selecting a set of variables that are correlated to the outcome because of random error specific to the training dataset. For this analysis we split the training dataset in three ways – using 5, 10, and 20 folds. In total, we ran the SFS procedure 15 times for each outcome – 3 CV for each of the regional samples (1 pooled + 4 separate regions).

- We then estimated the predicted poverty status of households in the test samples using the indicators selected from each run of the SFS procedure on the training samples. For each test sample we calculated the accuracy score and associated confusion matrix for each CV specification. The confusion matrix (Annex Table D-1) shows predicted poverty status among household living and poverty and households not living in poverty.
- Finally, we selected the set of indicators that yielded the highest accuracy score across the three CV folds. To train and test our model we used a technique called cross-fold validation which is used by splitting the dataset into multiple subsets, also known as folds, and running the model on all but one-fold. In our case, we used 5, 10, and 20 folds to ensure robustness of our results and compared across the different results choosing the one with the highest accuracy score and most accurate confusion matrices.

The algorithm performed by Sequential Feature Selector applies a transformation to the variables to improve its computational efficiency. Assuming the variables conform to a standard normal distribution, each variable is multiplied by a corresponding scalar adjustment to simulate a standard normal distribution. This scaling approach is applied to independent variables in both the training and testing data, but not the dependent variable (y). This sort of scaling technique is common in machine learning algorithms because it expedites convergence and subsequently reduces computational time (Ahsan et al. 2021).

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