AN ABSTRACT OF THE DISSERTATION OF

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Title: Who Benefits from Development Aid? Exploring Agroforestry Technology Adoption, Food Security, and Path Dependence in Rural Tanzania

Abstract approved:

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Rural farmers in Tanzania depend on subsistence agriculture for their livelihood. Poor soil conditions, and the danger of drought, increases the risk of cyclical poverty conditions. Aid organizations, including the World Agroforestry Centre (ICRAF) and the Millennium Development Projects (MDP), as well as industrial tobacco industry, have provided development programs with the goal of lifting those in Tabora, Tanzania from poverty. In this dissertation I investigate which household characteristics associate with adoption of agroforestry systems, and if those who have adopted are more likely to be food secure. Furthermore, I explore how development projects have impacted communities, through the lens of path dependence.

The first chapter uses multinomial logistic regression methods to explore household characteristics that associate with adoption of agroforestry systems. Findings suggest that short-term illness is negatively associated with the likelihood of adopting planted woodlots, whereas long-term illness is positively associated with the likelihood of adopting planted woodlots. This may be because once treed systems are established they need little maintenance to accrue benefits. Furthermore, access to a health clinic is

positively associated with the relative odds of adopting partial intercropping systems, as well as planted woodlots; yet, negatively associated with planting of *Gliricidia sepium*. Evidence suggest that household health improves labor availability, especially for when agricultural systems require active management. Furthermore, credit access is positively associated with the relative odds of adopting treed systems. I also explore the use of mobile-banking, which significantly increases the relative odds of adopting *Gliricidia sepium* and the combination of *Gliricidia sepium* and woodlots. Access to banking and credit services may increase households' ability to manage savings, purchase novel seed varieties, or hire labor.

Chapter two examines the impacts on food security of agroforestry adoption decisions by subsistence farmers in Tabora, Tanzania. Agroforestry systems, specifically, intercropping with pigeonpea and cassava, and planting *Gliricidia sepium*, have been introduced to rural villages in Tanzania to increase food security. In this chapter, I estimated an endogenous switching regression model (ESRM) to account for unobserved heterogeneity in adoption behavior, and to measure the effect of agroforestry adoption on households' food security using total market value of household agricultural production (TVP) as a proxy for food security. I used the estimated ESRM to predict counterfactual outcomes for adopters and non-adopters. I found that households who adopted agroforestry systems through ICRAF interventions were more food secure, compared to the counterfactual of non-adoption. Furthermore, access to agroforestry information through interactions with ICRAF, credit, and banking can all support agroforestry adoption.

Chapter three explores if past experiences with aid organizations impact potential future adoption of aid technologies. This chapter incorporates discussions from focus groups about the MDPs, as well as ICRAF and the tobacco industry, to better understand the impact and sustainability of aid projects. Unique to this study is the qualitative use of the path dependence. I found that households have experienced some poor long-term outcomes from development aid organizations. Yet, focus group participants were still open to accepting aid. This may be because some of the introduced projects remain partially functional. Furthermore, focus group participants reported that when aid organizations are actively in the village they experienced increases in economic activity through increased crop production. In this dissertation, using mixed methods, I provided some ex-post insights of the welfare effects and sustainability of aid interventions. Overall, the findings from this dissertation can assist aid agencies when targeting households for novel agricultural technology projects.

Who Benefits from Development Aid? Exploring Agroforestry Technology Adoption, Food Security, and Path Dependence in Rural Tanzania

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Sonia R. Bruck

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Sonia R. Bruck, Author

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Olli-Pekka Kuusela (co-author on Chapter One and Two), provided guidance for informing the overarching research questions, methods, and model conclusions. He supervised and aided in survey development as well as econometric work.

Badege Bishaw aided in collaboration with ICRAF, as well as assisted in deciding on the final research location. He aided in research question development, as well as provided feedback on the manuscript.

Mark Needham provided critical feedback on qualitative work. He aided in qualitative coding design, and contributed to the revision of chapter three.

Bill Jaeger provided instruction and advice on survey design, econometric theory, and guidance on international research.

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DEDICATION

To the data collection team and participants in Tabora

ABBREVIATIONS

CGIAR – The Consultative Group on International Agricultural Research

GDP – Gross Domestic Product

Gliricidia – Tree species *Gliricidia sepium*, common name Forest Lilac

HFIAS – Household Food Insecurity and Access Scale

ICRAF – International Centre for Research in Agroforestry

IITA – International Institute for Tropical Agriculture

MDP – Millennium Development Projects

MDV – Millennium Development Villages

MDG – Millennium Development Goals

RUM – Random Utility Model

UNDP – United Nations Development Program

USAID – United States Agency for International Development

GENERAL INTRODUCTION

Background

The United States' (U.S) interest in foreign development aid began after WWII, in 1947, with the Truman Doctrine. The original purpose of international aid was to support European countries from withstanding communist pressures. By 1949, President Truman expressed the desire to assist emerging economies in Asia, Africa, and South America. About a decade later, President Kennedy established the Agency for International Development Aid (USAID), to further engage in post-colonial Africa. The goal for the U.S. was to create self-sustained growth through free market capitalism and thus, communist-free Africa. Even though significant sums of money flowed to developing countries during the 1960s, the gap between the rich and the poor increasingly widened. By the 1970s, aid organizations began to question the relationship among aid, growth, and the relief of poverty (Grant 1979).

In the meantime, international aid agencies were formed in Africa to assist Africans. These agencies were primarily funded by other nations, including: the U.S. (USAID), the United Kingdom (*United Kingdom Agency for International Development*), Switzerland (*Swiss Agency for Development and Cooperation*), Ireland (*Irish Aid*), Germany (*Federal Ministry for Economic Cooperation and Development*), and others. The International Centre for Research in Agroforestry (ICRAF), known as the World Agroforestry Centre, is one international aid organization that is funded by many of these nations. Formed in 1978, ICRAF is a research institute under the umbrella organization the Consultative Group on International Agricultural Research (CGIAR). *Agroforestry is*

the practice of intentionally incorporating crops or livestock with woody perennial species, which can occur simultaneously or sequentially on the same unit of land. ICRAF's current goal is to aid in "an equitable world where all people have viable livelihoods supported by healthy and productive landscapes" (ICRAF 2018). ICRAF aims to reduce poverty, increase food security, and improve environmental services.

By the turn of the century, many African countries still suffered from food insecurity, AIDS, malaria, other preventable diseases, deteriorating infrastructure, and environmental degradation. The Millennium Development Goals (MDGs) were developed to relieve poverty and re-set Africa on a new course for the 21st century. The United Nations, World Bank, International Monetary Fund, and other bilateral aid agencies, along with world leaders, came together to attain the standard of living promised to Africa more than 40 years prior (Easterly 2009).

The original eight MDG targets to have been achieved by 2015 were: 1) eradicate extreme poverty and hunger, 2) achieve universal primary education, 3) promote gender equality and empower women, 4) reduce child mortality by two-thirds, 5) improve maternal health by reduction of maternal death by three-fourths, 6) combat HIV/AIDS, malaria, and other diseases, 7) ensure environmental sustainability, and 8) develop a global partnership for development. Garrity (2004) identified seven ways in which agroforestry could help to meet those goals: 1) eradicate hunger through pro-poor food production systems through soil fertility and land regeneration, 2) lift poor through market driven tree systems that generate income and build assets, 3) advance health and nutrition through agroforestry, 4) conserve biodiversity through conservation-development solutions such as own-farm production of firewood, 5) protect watershed

services, 6) climate change adaptation strategies and carbon mitigation through tree cultivation and carbon markets, and 7) build human and institutional capacity in agroforestry research and development.

Agroforestry contributes to food security through nutrient cycling, increased food diversity and dietary intake, and reduced risk of crop failure due to drought, pests, or disease (Franzel et al. 2001). Furthermore, subsistence farmers have removed large quantities of plant nutrients without replenishing organic matter, equaling an estimated annual loss equivalent to $4 billion USD worth of fertilizer. For example, commercial fertilizers can cost two to six times as much in Africa as compared to Asia, thereby reducing optimal use. This problem has been compounded by poorly functioning markets and road infrastructure (Garrity 2004).

To combat this problem, three fertilizer tree systems have been identified as promising for fixing nitrogen and incorporating organic matter in semi-arid regions of Africa, including: 1) improved fallows using trees and shrubs such as *Sesbania sesban* or *Trephrosia vogelii* 2) mixed intercropping with *Gliricidia sepium*, and 3) biomass transfer with wild sunflower (*Tithonia diversifolia*) or *Gliricidia sepium* (Garrity 2004). Through controlled trials, yield increases are typically two-to-three times that of current farmer management. Furthermore, a 1% yield increase in food-crops is associated with a 1% drop in the number of individuals living on less than $1 USD a day (Garrity 2004). Increased on-farm production can result in greater food security, and opportunities for increased financial and capital assets for rural poor.

In Tanzania, the agricultural sector supports 28% of GDP and employs more than 75% of the national labor force (Mkonda 2018). Tanzania has almost 110 million acres of

arable land, yet only 24% of arable land and 4% of irrigation potential has been harnessed. The mean annual rainfall varies considerably across the country, from 400 mm to more than 2,500 mm per year. Rainfall across Tanzania is erratic, where only 21% of the country can expect rain more than 750mm with 90% confidence (Mkonda 2018).

Mkonda (2018) collected data from 1980 to 2015 to explore the crop production among 10 regions in Tanzania. From 1996 to 2015, the area cultivated for maize has tripled and the area of sorghum, millet, and cassava has doubled. Yet, during that same period the population has also doubled. Furthermore, due to poor infrastructure and storage facilities, distribution of food is not uniform across the country. For example, in 2014, sufficient yields were produced in five regions, but due to lack of storage facilities and transportation, many regions of the country had food shortages during the same year. Furthermore, some farmers were forbidden by the government to sell crops across borders due to concerns of famine in-country. This brought enormous losses to some farmers who had market connections in neighboring countries, but no buyers in Tanzania (Mkonda 2018).

Solutions for subsistence farmers to rise from poverty include on-farm technologies, including improved seed varieties and low-impact technologies such as agroforestry. Organizations that have promoted improved farm technologies include ICRAF, the United National Development Program through the Millennium Development Projects (MDPs), and to a lesser extent commercial tobacco industry, which has promoted planting woodlots for fuelwood. The motivations for this dissertation were to explore the household characteristics that are associated with adoption of agroforestry systems, as well as to observe whether those households who have adopted

agroforestry systems are more food secure. Furthermore, I explore rich qualitative accounts pertaining to the impacts of development aid organizations on the beliefs of future potential aid to recognize how aid agencies can meet the development needs of the study region communities.

To investigate these issues, I chose the study region of Tabora, Tanzania (Appendix A). Tabora, the name of both the region and the capital town, is located in semi-arid west-central Tanzania. The elevation is 3,904ft (1,190m) and has a mean annual temperature of 73° F (23° C). Tabora is the capital of the Nyamwezi people and served as a trade link between the Democratic Republic of Congo and Tanzania's capital city and port, Dar es Salaam. The study region has experienced multiple development organizations intervene, often with overlapping project goals.

ICRAF has promoted planted woodlots for nitrogen fixation, as well as on-farm fuelwood resources, and erosion prevention for nearby farmland. The most common trees promoted are native acacias. The tree *Gliricidia sepium* (Gliricidia or common name Forest Lilac) is also promoted as a nitrogen fixing species that thrives in semi-arid conditions. Similar to ICRAF, the tobacco industry has promoted tree planting. However, the primary purpose for planting woodlots for the industry is to have an on-farm source of fuelwood to cure tobacco. Notably, the industry promotes planting non-native species such as eucalypts.

ICRAF has also introduced intercropping, which is simply defined as: incorporating multiple crops in the same field. The intercropping system promoted was of pigeonpea and cassava. The MDPs also introduced agricultural education and management techniques, including optimal spacing, fertilization, hybrid seed varieties,

and storage techniques. The organizations had a similar means to an end, which included increased food production, reduction of poverty, and environmental conservation.

There are three chapters in this dissertation. I seek to answer the following questions:

Chapter 1: In chapter one, I ask: What household characteristics are associated with adoption of agroforestry systems, specifically: planted woodlots, *Gliricidia sepium*, partial intercropping methods, and full adoption of intercropping pigeonpea and cassava?

Chapter 2: In chapter two, I ask: Are those households who adopted ICRAF interventions (full adoption of intercropping and/or *Gliricidia sepium*) more food secure?

Chapter 3: In chapter three, I seek to qualitatively explore the following research questions: 1) What were the most common aid interventions in Tabora and which aid agency brought them? 2) Which projects were still maintained, or partially maintained? 3) What are the recommendations for future aid development? and, 4) Do villagers still accept aid based on their experiences with previous aid projects?

I collected cross sectional data using a survey instrument[1] from six villages in Tabora, Tanzania from July to August, 2019 among 435 randomly sampled households

[1] The questionnaire was broken into nine sections: 1) consent and willingness to adopt (30 Questions), 2) planting practices (9 Questions), 3) prices and labor hours (10 Questions), 4) household labor allocations (9 Questions), 5) Recall and Millennium Development Interaction (11 Questions), 6) farming preferences, community groups, and

using Offline Qualtrics, LLC. Heads of households were asked to participate in follow-up focus groups to discuss experiences with development organizations and to better understand farming practices (n = 63). I employ a mixed methods approach to addressing my research questions, using both questionnaires and focus groups. As an outsider to the communities, using a mixed methods approach can ensure I am expressing overarching themes and meaningful details from villagers' perspectives. Furthermore, collecting both qualitative and quantitative data allows for a richer set of evidence for interpretation (Quandt et al. 2017).

DISSERTATION ORGANIZATION

Chapter One, authored by Sonia Bruck and Olli-Pekka Kuusela, goes beyond the binary adoption decision (adopt or non-adopt) and explores partial adoption of agroforestry systems, as well as novel combinations of adoption. Using econometric methods, we explore how household health and access to health services, credit access and mobile banking use, land tenure and firewood access, and extension services are associated with agroforestry adoption. A large portion of the literature focuses on adoption and non-adoption through the lens of binary regression methods. We specifically use multinomial logistic analyses to explore the association of several household characteristics, known to influence adoption behavior, and their unique impact on novel combinations of adoption. Results indicate the importance of access to credit for tree planting, which is significantly associated to the adoption of the fertilizer tree

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self-efficacy (6 Questions), 7) household health (7 questions), 8) Household Food Insecurity and Access Scale via the Food and Agricultural Organization (17 Questions), and 9) basic household information (10 Questions), for a total of 109 questions (See Appendix B).

Gliricidia sepium, and the combination of *Gliricidia sepium* and planted woodlots. We also find that acres farmed, education, and extension services are significantly associated to the adoption of the full agroforestry package (adoption of pigeonpea and cassava intercropping). Different household characteristics are associated with partial adoption of the intercropping package (pigeonpea or cassava with other food crops), including land tenure, health clinic access, and whether firewood is collected from the commons. Implications of these findings can be used by ICRAF or other agencies promoting novel land management techniques to understand what factors contribute to the likelihood of agroforestry adoption.

Chapter Two is authored by Sonia Bruck and Olli-Pekka Kuusela. The objective of this chapter is to explore if households who have adopted the introduced agroforestry systems from ICRAF (pigeonpea and cassava intercropping and/or plantings of *Gliricidia sepium*) have promoted higher food security. In this chapter, we estimate an endogenous switching regression model (ESRM) using total market value of household agricultural production (TVP) as a proxy for food security. ESRM accounts for unobservable household characteristics, such as motivation, and enables the prediction of counterfactual scenarios. We find that adopters of ICRAF interventions have a higher TVP than non-adopters. Furthermore, that adopters of ICRAF innovations have a higher TVP compared to had they non-adopted. Additionally, we corroborate these findings with qualitatively reported Household Food Insecurity and Access (HFIAS) scores. Households who adopted, on average, report lower levels of moderate food insecurity, but higher levels of severe food insecurity. Interestingly, though they report higher severe food insecurity, this may be explained by the fact that agroforestry crops may be more

difficult to store. Thus, planting a diversity of crops through agroforestry systems may result in periods of the year when people are more food insecure. Alternatively, this could also suggest that selection bias is an issue, or that self-reported HFIAS scores suffer from social desirability bias, which means that respondents provided answers that are consistent with perceived viewpoints of the interviewer (Vaske 2008). This may have caused respondents to report higher food insecurity to gain access to potential future benefits from data results. Furthermore, it may be that households who are extremely food insecure are likelier to adopt agroforestry practices.

Chapter Three, authored by Sonia Bruck, investigates the sustainability of aid projects through the lens of path dependence. This chapter uses qualitative methods to investigate how path dependency concepts impact sustainable aid adoption behavior. Using focus groups from 63 individuals held across all six villages, I explore how the Millennium Development Projects, and to a lesser extent ICRAF and Tobacco Industry have impacted economic development. Oversight of economic incentives may have resulted in an overexploitation of common pool resources, such as schooling and health, and potentially increased the perceived riskiness of adopting private technologies. I found that health aid and to a lesser extent agricultural aid were the projects with the most longevity overall. Yet, those projects to-date are only partially functional. Finally, I summarize feedback from participants on potential improvements that can be made for future aid development projects, to enhance future potential aid.

LIMITATIONS

A significant body of work has been amassed on agricultural innovations and technology adoption across scientific disciplines (Rogers 1962; Jacoby 1993; Abdulai

2014; Afsaw 2012). Following past research, I also use econometric methods that are grounded in the Random Utility Model, where households are assumed to choose the option with the greatest utility given the set of feasible choices. Households' utilities are unobserved, whereas actual choices are observed. Additionally, sociological scales, such as the Household Food Insecurity and Access Scale (HFIAS), were collected and scrutinized for relevancy. Ultimately the HFIAS was helpful in comparing food security outcomes (Chapter Two). Moreover, qualitative methods were used for analysis in Chapter Three. There are many ways to view adoption decisions and behavior, but we believe that the methods chosen provide a robust and novel perspective.

One limitation of observational studies is that the adoption status is not randomly assigned. Random experiments provide the gold standard for assessing treatment effects (e.g. Banerjee & Duflo 2011). However, the econometric methodology applied in this dissertation aims at removing concerns related to selection bias. Furthermore, some of the underlying assumptions behind multinomial logit models, such as the Independence of Irrelevant Alternatives (IIA), can be restrictive. We minimized such concerns by carefully defining the choice scenarios and using a statistical test to reject the violation of IIA. Computationally more intensive methods are also available, but we leave the application of those methods for future research.

These chapters represent a case study of six villages in rural Tanzania, and do not represent Tanzania as a whole. Measures were taken to ensure that data were randomly selected from villages, therefore ensuring a representative sample of adoption behavior. Few households did not consent to participation. Furthermore, enumerators were trained on best-practices during two training courses, where, for example, the data collection

team worked on dialogue of how to interact with participants in difficult situations (such as answering questions on why not everyone in the village could participate in the questionnaire). Furthermore, the dataset represents a snap-shot of land management, and does not include dis-adoption of agroforestry systems, or combinations over time. Additionally, qualitative measures of food security may have been biased, due to the time of year data was collected. Ideally, observational data should be collected using repeated samples of the same households over time. However, this was not possible for this dissertation due to lack of time and funding resources.

Furthermore, the decision of what to include in the questionnaire was limited to what the literature deemed relevant to agricultural technology adoption. The questionnaire, while long in its final form, was shortened to reduce respondent burden. There is always the possibility we may have missed critical household attributes, which would have resulted in omitted variable bias. However, we believe that through our exhaustive literature review, we identified key attributes that control for drivers of agroforestry adoption decisions.

Finally, the focus group participants were selected from those individuals who participated in the questionnaire, and also had cellular telephone access. Thus, focus group participants were not randomly sampled. However, their dialogue was corroborated with government documents that explained Millennium successes and failures. Where phenomena were not explained by documentation, focus group participants reached a saturation point of consistent dialogue, thus representing reliability across villages and subsistence farmers in the region.

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CHAPTER ONE

How Health and Market Access Associate with Agroforestry Adoption Decisions: Evidence from Tabora, Tanzania

1. Introduction

The practice of agroforestry is actively promoted as an important strategy for subsistence farmers in developing countries to cope with environmental risks and to enhance food security and income (Franzel et al. 2001; Garrity 2004). Agroforestry is defined as the intentional combination and management of livestock and/or food crops and woody perennials. Such integration of production activities may yield many benefits, including improved human nutritional intake, increased soil productivity and nutrient cycling, and alternative fuelwood sources. Direct and indirect benefits from agroforestry systems may become increasingly important for subsistence farmers who largely depend on home gardens for the majority of their food intake, and who rely on open-access lands for fuelwood.

Development organizations have introduced and assisted in implementing pieces of agroforestry systems (e.g. tree planting or improved seed varieties separately), or an entire agroforestry system at once. As an example, in Tanzania, the World Agroforestry Centre, also known as the International Centre for Research in Agroforestry (ICRAF), typically introduces the entire agroforestry package that includes pigeonpea, cassava, and the tree species *Gliricidia sepium* (common name: Forest Lilac). However, in practice, households can choose, and have chosen, to adopt only parts of an agroforestry package. Households have also preferred to intercrop with either cassava (*Manihot ecuelenta*) or pigeonpea (*Cajanus cajan*) and other crops such as maize (*Zea mays*) or cow peas (*Vigna unguiculata*). This illustrates the difficulty in specifying how agroforestry technologies are adopted and which parts of them are ultimately utilized. Temporal sequencing of

agroforestry systems is also a commonly observed practice around the world, including in eastern Africa (Bekele-Tesemma 2007).

Advantages of agroforestry have been widely acknowledged, yet the adoption of agroforestry crops and practices have been slow and incremental in many regions, including in eastern Africa (Afsaw et al. 2012). Understanding reasons for adoption and non-adoption behavior, together with the intensity of adoption, provides critical information for development agencies, and for governments seeking to increase the use of agroforestry technologies. Questionnaires completed by a survey of sample of people provide one useful way of measuring and assessing adoption rates, as well as collecting information on potential explanatory variables for observed choice behavior. However, the richness of possible adoption combinations creates a challenge for data analysis, since the decision to adopt may not be a simple binary decision (adopt or non-adopt); but a multi-stage decision problem, where the household first decides whether to adopt a new practice, and then at what intensity or with what type of combination (Feder and Slade 1984, Ghadim and Pannell 1999, Ersado et al. 2004, Gebreegziabher and van Kooten 2013).

The richness of observed adoption choices goes hand in hand with the heterogeneity of household characteristics and circumstances. Some common sources of variation in household specific factors include history of health conditions, and access to important markets and financial services. However, household health condition remains a surprisingly understudied factor in explaining the degree and type of adoption choices. Two exceptions are Amacher et al. (2004) and Ersado et al. (2004) who study the effects of health status on tree planting decisions and on agricultural technology adoption in

Tigray, Ethiopia. They find that increased burden on women to care for sick family members reduces tree planting efforts and also decreases the likelihood of adopting new farming technologies.

One possible way in which health status may be related to agroforestry adoption behavior is also via the labor supply channel, as both on-farm and off-farm labor supply may become constrained due to persistent illnesses or sustained injuries of household members. Whether this will positively or negatively be related to the likelihood of agroforestry adoption has received minimal empirical attention, especially in the context varying degrees and types of agroforestry adoption. The access to financial services, such as credit and banking, may also be important factors in explaining the likelihood of agroforestry adoption. It is possible that better integration with markets and banking services reduces the need for diversification of crop production to sustain negative shocks; on the other hand, better integration with markets may provide important sources of credit for investments and outlets for selling produce.

The purpose of our study is to determine the factors related to subsistence farmers' choices over combinations of agroforestry systems, including both cropping systems and treed systems. The majority of studies in the field uses binary choice models (logit or probit). However, such models do not fully account for the multiplicity of adoption decisions by households. To analyze what household specific factors are associated with agroforestry adoption, we used an original dataset collected in Tabora, Tanzania in 2019 and estimated agroforestry choices using multinomial logistic methods. Our data contains information about the degree and type of adoption choices together with distance and access information. We also included health status indicators and

access to a health clinic as explanatory variables. Few studies have observed the role of household health on agroforestry adoption decisions. Our results reveal that these variables are associated with agroforestry adoption decisions and the breadth and combination to which those adoption decisions are made.

2. Review of Agroforestry Adoption Studies

Feder et al. (1985) identified several key factors that have been found to influence the lack of adoption of agricultural technologies in developing countries. These include lack of credit and information, risk aversion, small farm sizes, inadequate land tenure arrangements and human capital, and deficiencies in infrastructure and in access to equipment and complementary inputs. These findings have been corroborated in several subsequent studies. For example, in their study of farm level climate adaptation strategies from more than 8,000 farms in 11 African countries, Hassan and Nhemachena (2008) found that the role of improved access to credit and information in enhancing farmers' awareness of novel technologies were crucial in making adoption decisions and land management planning. Furthermore, better access to markets reduces transportation and other market related transaction costs. Market access makes it easier for farmers to buy new crop varieties, and access new technologies.

In the standard neoclassical model of agricultural household production, the presence of complete and perfect markets for inputs, labor, and outputs lead to the "separability" of production and consumption decisions (Benjamin 1992; Jacoby 1993). The household maximizes profits from productive activities, while at the same time maximizes utility from consumption and leisure. However, missing markets for certain critical inputs such as fuelwood, or for labor due to the seasonality of farm work, lead to

non-separability of choices (Jacoby 1993, Benjamin 1992, Cooke et al. 2008). Hence, consumption demand and demands for production inputs become complex functions of household characteristics, preferences, production technology, market wages and prices, and exogenous income (Cooke et al. 1998). Such non-separability also extends to technology adoption decisions, such as the adoption of agroforestry, as smallholder farmers face missing markets for production inputs, credit, and labor (Afsaw et al. 2012).

The literature investigating several of these aspects as pertaining to agroforestry adoption decisions are already extensive. For example, Pattanayak et al. (2003) summarized 120 studies across Africa, Asia, and South America exploring the adoption of alley cropping, live hedges, intercropping, contour hedgerows, tree planting, home gardens, and many other agroforestry systems. They identified five broad categories of factors that influence technology adoption behavior: 1) preferences, 2) resource endowments, 3) market incentives, 4) biophysical factors, and 5) risk and uncertainty. Additionally, Franzel et al. (2001) found in their review that household characteristics influencing the adoption of agroforestry systems include 1) feasibility, 2) profitability, 3) acceptance of the innovation, 4) labor constraints, and (5) institutional support. Given that examples of dichotomous choice models in the literature are numerous, we have chosen key examples that best represent agricultural technology adoption in our study area and studies from elsewhere that are closely aligned with our research.

Polson and Spencer (1991) used both probit and logit models to estimate the factors related to the likelihood of adopting cassava in Southwestern Nigeria. Their results highlight the importance of information and farm size in predicting adoption likelihood. However, family size was not a significant factor in explaining adoption.

There are several subsequent studies in Africa that have also found farm size to be a significant factor explaining the decision to adopt various agroforestry practices (Ersado et al. 2004, Mugonola et al. 2013, Faße and Grote 2013, Ndayambaje et al. 2015). One exception is Gebreegziabher and van Kooten (2013) who found that the area cultivated is negatively associated with the likelihood of tree planting in Northern Ethiopia. Better information via extension agents or associations has also been confirmed by many studies to be an important factor explaining agroforestry adoption in many studies (e.g. Schuck et al. 2002, Nkamleu and Manyong 2005, Afsaw et al. 2012a, Mugonola et al. 2013).

In contrast to findings in Polson and Spencer (1991), others have found the number of household members to be positively related to the likelihood of adopting various forms of agroforestry practices (Nkamleu and Manyong 2005, Ndayambaje et al. 2015). Additionally, Nkamleu and Manyong (2005) found that a higher number of males in the household increases the likelihood of agroforestry adoption. Similarly, Gebreegziabher and van Kooten (2013) found that a higher number of males in the household was a positively associated with tree planting.

Amacher et al. (2004) estimate the likelihood of eucalyptus planting in Ethiopia in the context of introduced microdams, which increase standing water and consequently the incidence of waterborne diseases. Their results show that females spent three-times more time at home taking care of sick family members in regions where microdams had been introduced. Tree planting was also negatively affected due to a decrease in overall labor time at the household level. Ersado et al. (2004) reported similar findings with respect to agricultural technology adoption using a multinomial logit approach. They also found that a greater distance to markets was negatively associated with the likelihood of

adoption. Similarly, Nkamleu and Manyong (2005) found that a greater distance to a village can negatively influence the likelihood of agroforestry adoption. Some other studies, however, have not found distance to a market or village to be a significant factor in explaining agroforestry choices (Faße and Grote 2013, Afsaw et al. 2012a, 2012b)

Furthermore, education of the household head can be an additional household characteristic explaining agroforestry adoption (e.g. Ersado et al. 2004). Cedamon et al. (2018) use a multinomial logit model to better understand agroforestry adoption and adaptation in Nepal. They categorize systems into four groups: (1) adapting trees on terrace risers, (2) adapting trees on terrace risers and non-arable lands, (3) adapting trees on non-arable lands, and (4) adapting trees on other locations such as farm borders. They found that education is significantly related to the type of adaptation. Those adopting trees on other locations (sporadic treed systems), tend to have lower education levels, and thus tend to adopt a less organized agroforestry system than households who have senior high school level or higher education. Using the findings from these studies, we were able to build a robust econometric model to explain adoption behavior in our study region.

3. Econometric Model and Methods

The influence of various factors on households' adoption decisions can be modeled using the random utility model (RUM). Each household *i* can choose from *K* different agroforestry options (one option being non-adoption). For example, agroforestry adoption choices include woodlots and intercropping systems with full or partial utilization, or non-adoption of either system (monoculture). Partial utilization can be seen frequently in intercropping systems, where the household chooses to adopt one of the

new plant varieties yet chooses to mix it with a more familiar crop. Some examples include intercropping with pigeonpea and cassava, intercropping with cassava and another crop (such as maize), or intercropping with pigeonpea and another crop (such as maize).

The utility received from choosing alternative k is denoted by U_{ik} with $k \in (1, \dots, K)$. The household i will choose the alternative k if and only if $U_{ik} > U_{il}$ for all $l \neq k$. The researcher cannot observe the utilities associated with various alternatives, but they can observe the actual choices and household characteristics, such as household wealth, and also attributes associated with the adoption choices, such as prices and yields. Letting h_i denote the vector of household characteristics and x_{ik} the vector of attributes associated with the agroforestry option k, the representative utility from choice k can then be written as:

$$V_{ik} = V(h_i, x_{ik}).$$

The above represents the observed component of the utility and is typically assumed to be linear in attributes and characteristics. The actual utility U_{ik} can be expressed as a sum of this observed part and an unobserved component ε_{ik}:

$$U_{ik} = V_{ik} + \varepsilon_{ik}. \qquad (1)$$

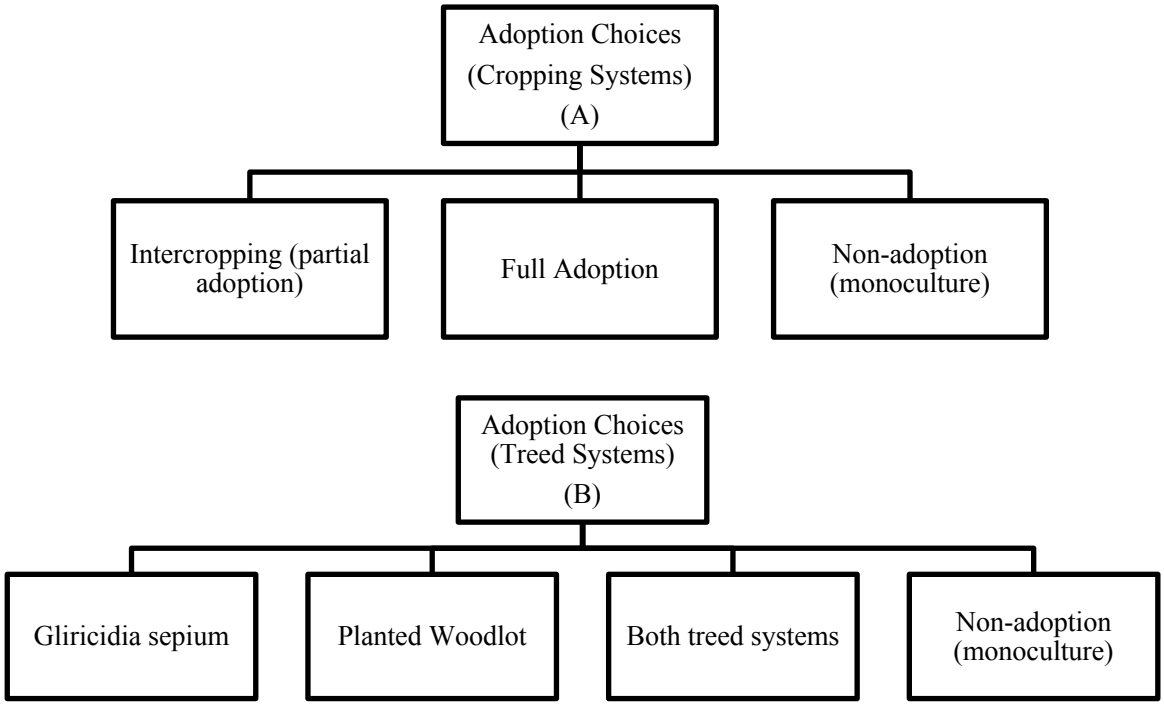
The assumed distributional function for ε_{ik} gives rise to alternative choice models.

3.1. Multinomial logit

In a multinomial logit model, the unobserved component, ε_{ik}, is assumed to be independent and extreme value distributed. The example we use to illustrate the multinomial logit model corresponds with the choices faced by subsistence farmers in

rural Tanzania: planted woodlot, *Gliricidia sepium* (Gliricidia), intercropping, partial intercropping systems, and the combinations of these systems. Figure 1 illustrates the set of choices faced by a household i. Here, $K = 3$ in (A) and $K = 4$ in (B), as there are three adoption alternatives in A and four adoption alternatives in B. Note that we model the choices made in intercropping systems (Model A) and treed systems (Model B) separately. The reason for this is to create interpretable discrete categories, based on realistic land management opportunities for farmers.

FIGURE 1: Agroforestry adoption decisions: cropping systems (A) and treed systems (B). A representation of the types of land management choices households make.



In a multinomial logit model, the observable component of the utility is determined only by the household characteristics (also called choice invariant variables). To be more precise, the utility of choosing option *k* can be written as:

$$U_{ik} = h_i\gamma_k + \varepsilon_{ik} \qquad (2)$$

Note that parameter vector γ_k varies from one choice to another. In other words, the invariant household characteristics can have differing effects on utilities depending on the choice. For example, the household's distance to the nearest market might not have a big effect on the utility from partial adoption if the new products are mainly designated for own use, but it could have a greater effect on utility from full adoption if the household plans to sell a significant part of the new yield.

The researcher observes the choice outcomes Y_i. The choice probabilities in the multinomial model take the following form (e.g. Cameron and Trivedi 2010):

$$\Pr(Y_i = k|h_i = h) = \frac{\exp(h'\gamma_k)}{1 + \sum_{j=2}^{K} \exp(h'\gamma_j)},$$

for choices $k = 2, \ldots, K$ and for $k = 1$:

$$\Pr(Y_i = 1|h_i = h) = \frac{1}{1 + \sum_{j=2}^{K} \exp(h'\gamma_j)}.$$

To identify the coefficients, one of the choices must be normalized (here $k = 1$). Hence the results must be interpreted as being relative to the choice alternative that forms the reference level. Given the choice probabilities, the multinomial logit model can be estimated using the maximum likelihood method.

One limitation of the multinomial logit model is that it implies a property called the independence of irrelevant alternatives (IIA), which stems mainly from the assumed independence of the unobserved components. The IIA property means that the ratio of choice probabilities (odds ratio) between any two alternatives does not depend on the presence of other alternatives. The IIA assumption holds only if the addition of another choice does not impact the original preference ordering (Cheng & Long 2007). Whether the IIA property is problematic or not depends on the application, and therefore those choices must be carefully identified.

We can reasonably assume that the given the choices present in both Model A and Model B, categories are sufficiently different in nature. For example, if adoption and non-adoption of intercropping systems (Model A) were the only two choices, and half chose adoption and the other half chose non-adoption, then the ratio of probabilities sums to one in equal proportion. Then, the choice of partial adoption is added. We can assume that the probabilities would continue to sum to one in equal thirds, where some households from both adoption and non-adoption would choose partial adoption in equal proportion (Cheng & Long 2007). This thought experiment can also hold for the treed systems, where the choices are sufficiently discrete in nature. It is also possible to test whether the IIA property holds in the data.[2] There exist alternative, computationally more intensive models that relax the IIA assumption. However, in the next section we reject the null hypothesis of IIA being violated and hence deem the multinomial model to be

[2] Long and Freese (2006) develop a method to test the IIA assumption in STATA (*mlogtest, hausman*); however, they do believe that tests of IIA are limited, and categories should first make qualitative sense.

adequate for our purposes. In the following section, we explore the household characteristics associated with adoption of cropping and treed agroforestry systems in the case study region.

4. Data and Model Specification

4.1. Study Region and Data Collection

For this study, data collection was conducted in Tabora, Tanzania which is located approximately 800 km (500 mi) to the west of Dar es Salaam, the largest city in the country (Appendix A). The average rainfall in the study area is approximately 902 mm (35.5 inches) per year and the average annual temperature is 23.1° C (73.6° F). According to the World Food Programme (WFP) (UN WFP 2010), Tabora is a food insecure region, where potential crop failure peaks in the planting and crop development stages. Hence, Tabora has been identified as one of the areas where agroforestry systems could be most beneficial in improving livelihoods. Suggested tree species include *Sesbania sesban* and *Gliricidia sepium* (Gliricidia) (Bekele-Tesemma 2007). The International Centre for Research in Agroforesry (ICRAF), has chosen to promote cassava and pigeonpea intercropping, which are woody leguminous perennials that fix nitrogen in the soil. Furthermore they have promoted plantings of Gliricidia.

All of the villages surveyed for this project were clustered west of Tabora Town (population 226,999, as of 2012 Tanzania National Census). After revising the questionnaire, based on a pilot study conducted in February to March 2019, the final data collection was conducted in six villages from July to August 2019: Mbola, Isila,

Msiliembe, Mbiti, Ibiri, and Migungumalo (Appendix A).[3,4] Completed lists of all household heads were collected by the hired local guides from March to May 2019 (n = 2,286 heads of household names). A sample of 550 households was randomly selected using the list of all households. Villages were stratified according to their total population and final sample percentages reflect consent to participate in the survey. In total, 435 individuals consented to taking the questionnaire (Ibiri $n = 76$, Isila $n = 55$, Mbiti $n = 50$, Mbola, $n = 100$, Migungumalo, $n = 104$, Msiliembe, $n = 50$; Response Rate = 79%). Households who left questions unanswered were dropped from the sample, reducing the number of observations in the model. No payments or gifts were given to survey participants.

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[3] After working closely with village leaders, we collected 43 questionnaires for pretesting reliability and validity of questions. In the questionnaire revision we asked targeted questions about intercropping with other crops (such as maize), and about additional tree-crops that may be planted or left on-farm.

[4] The questionnaire was disseminated using the offline cellular telephone application Qualtrics, LLC, which had both English and Swahili question and answer capability. Enumerators were hired via recommendation from the Agricultural College Tari-Tumbi. A two-day training was conducted in February 2019 to familiarize enumerators with the data collection telephone-application. Enumerators were also given an in-depth informed consent and ethics training. An enumerator re-training was held in July 2019.

TABLE 1: Intercropping Summary Statistics of Independent Variables

Continuous Variables	**Full Adoption of Intercropping Mean (*n*=102)**	**Standard Deviation *(Min/Max)***	**Partial Adoption of Intercropping Mean (*n*=158)**	**Standard Deviation *(Min/Max)***	**Monoculture (Non-Adoption) Mean (*n*=126)**	**Standard Deviation *(Min/Max)***
Number of adults [level]	6.04	4.36 *(1/32)*	5.54	3.77 *(1/26)*	5.08	3.06 *(1/17)*
Farm area acres [level]	10.39	9.68 *(1/69)*	6.99	14.05 *(1/133)*	6.06	4.83 *(1/30)*
Distance to Tabora Town in hours	6.88	8.9 *(0/85)*	4.09	5.26 *(1/35)*	5.56	4.83 *(0/31)*
Education in Years	8.18	2.81 *(1/16)*	8.09	2.65 *(1/14)*	7.18	3.65 *(1/13)*
Binary Variables	**Percent No (0)**	**Percent Yes (1)**	**Percent No (0)**	**Percent Yes (1)**	**Percent No (0)**	**Percent Yes (1)**
Credit access	67.65	32.35	82.28	17.72	78.57	21.43
Use cell phone banking	24.51	75.49	47.47	52.53	38.89	61.11
Access to a health clinic	46.08	53.92	13.92	86.08	30.95	69.05
Long-term illness	87.25	12.75	91.14	8.86	87.3	12.7
Short-term illness or injury	83.33	16.67	81.01	18.99	81.75	18.25
Has heard of ICRAF	33.33	66.67	67.72	32.28	69.05	30.95
Firewood from commons	58.82	41.18	20.25	79.75	39.89	61.11
Rental land	96.08	3.92	98.1	1.9	91.27	8.73
Mbola	67.65	32.35	81.01	18.99	84.13	15.87

TABLE 2: Treed Systems Summary Statistics of Independent Variables

Continuous Variables	**Non-Adoption Mean (n=190)**	**Standard Deviation *(Min/Max)***	**Gliricidia Adoption Mean (n=64)**	**Standard Deviation *(Min/Max)***	**Woodlot Adoption Mean (n=80)**	**Standard Deviation *(Min/Max)***	**Both Gliricidia and Woodlot Adoption Mean (n=52)**	**Standard Deviation *(Min/Max)***
Number of adults [level]	6.18	4.09 *(1/32)*	5.27	2.98 *(1/14)*	4.54	3.14 *(1/17)*	4.92	3.70 *(1/20)*
Farm area acres [level]	6.27	9.62 *(1/119)*	6.33	4.57 *(2/22)*	10.04	16.35 *(2/133)*	10.23	8.04 *(2/34)*
Distance to Tabora Town in hours	5.44	5.34 *(0/35)*	6.77	5.43 *(1/31)*	4.33	9.96 *(0/85)*	4.54	2.89 *(1/13)*
Education in Years	7.92	2.95 *(1/13)*	7.52	3.16 *(1/13)*	7.86	3.39 *(1/16)*	7.77	2.97 *(1/13)*
Binary Variables	**Percent No (0)**	**Percent Yes (1)**	**Percent No (0)**	**Percent Yes (1)**	**Percent No (0)**	**Percent Yes (1)**	**Percent No (0)**	**Percent Yes (1)**
Credit access	86.84	13.16	57.81	42.19	80	20	61.54	38.46
Use cell phone banking	49.47	50.53	26.56	73.44	38.75	61.25	13.46	86.54
Access to a health clinic	24.21	75.79	43.75	56.25	23.75	76.25	28.85	71.15
Long-term illness	90	10	93.75	6.25	87.5	12.5	80.77	19
Short-term illness or injury	85.79	14.21	84.38	15.62	72.5	27.5	78.85	21.15
Has heard of ICRAF	67.89	32.11	71.88	28.12	41.25	58.75	38.46	61.54
Firewood from commons	32.11	67.89	25	75	48.75	51.25	48.08	51.92
Rental land	94.21	5.79	95.31	4.69	97.5	2.5	96.15	3.85
Mbola	74.21	25.79	81.25	18.75	91.25	8.75	71.15	28.85

Table 1 provides summary statistics for the intercropping systems, and Table 2 describes the treed systems. From the total sample, (n = 435) participants fell between the ages of 20 and 96 years old (average age = 45 years), 28% of participants were female, and 72% male, and 87% of participants report being the head of the household. The majority of participants had completed Grade 7 (62.5%). The village with the highest adoption of the full intercropping system and partial adoption of intercropping systems was Mbola Village. Mbola Village also has the highest rate of Gliricidia adoption (17%), and combination of planted woodlot and Gliricidia adoption (34.5%). Ibiri Village had the highest rate of planted woodlot planting per household (22%).

Tabora had a large market where trade from other regions takes place. People from the villages generally assume that if they have a surplus of crops and are able to reach Tabora Town, they can find a buyer. We asked the participants the number of hours it takes to reach Tabora Town. For example, Mbola Village is approximately 35 km (22 mi) from Tabora Town. From the multinomial model, full adopters of intercropping systems, report on average, 6.9 hours to reach town, followed by partial adopters (4.1 hours), and those practicing monoculture (5.6 hours) to reach town to sell surplus crops. The most common way to travel to town is by bike or a van for a small fee.

Approximately 24% of the full sample reported access to credit for farming. Of those who had fully adopted the intercropping system 32% reported they had access to credit, 17% of partial adopters, and 21% of non-adopters reported access to credit. Similarly, of those who had adopted a woodlot, 20% reported having access to credit for farming, 42% of Gliricidia adopters, and 38% of woodlot and Gliricidia adopters reported

having access to credit for farming. Yet, only 13% of non-adopters of treed systems reported having access to credit for farming. Furthermore, we ask households if they use mobile banking services. Over 75% of the total sample reported owning at least one cellular phone in the home. Additionally, approximately 75% of full intercropping adopters reported using cell banking services, followed by monoculture adopters (61%), and partial intercropping adopters (53%).

We asked participants about health factors that could limit their ability to work on own-farm. From the full sample, 18% reported an illness or injury during the last agricultural season that impacted ability work on own-farm, whereas 11% reported a long-term (chronic) illness. Full adopters of intercropping systems and adopters of both Gliricidia and woodlots reported the highest incidence of long-term illness for their respective systems at 13% and 19%, respectively. Furthermore, of those who experienced short-term illness, partial adopters of intercropping and woodlots report the highest incidence at 19% and 28%, respectively. Approximately 72% of participants from the full sample reported having access to a health clinic. Yet, interestingly, full adopters of intercropping systems reported the lowest access to health clinics at 54%.

It is common in the literature to include extension interactions in adoption choice models (Schuck et al. 2002, Nkamleu and Manyong 2005, Afsaw et al. 2012a, Mugonola et al. 2013). We asked participants if they had heard of ICRAF prior to the questionnaire dissemination, assuming that those who had heard of ICRAF may be more likely to adopt agroforestry. Full adopters of intercropping systems heard about ICRAF the most frequently in the cropping systems (67%) (Model A), and adopters of both Gliricida and

woodlot adoption heard of ICRAF the most frequently (62%) for treed systems (Model B).

We also asked participants if they collected firewood from the surrounding woodlands (commons), assuming that those who have more access to resources off-farm may opt to not adopt woodlots. We found 51% of woodlot adopters collected firewood from the commons, while 75% of Gliricidia adopters reported collecting firewood from the commons, followed by 68% of non-adopters (Model B). Furthermore, households were asked to report whether they own or rent land to indicate land tenure. Agroforestry systems, in general, take many years to manage before benefits are realized. Hence, tenure security could be an important factor in determining adoption behavior. However, renting is not very common in our sample. In Model B, non-adopters of treed systems had the highest rate of renting (non-ownership) at 6%, whereas in Model A those managing monoculture had the highest rate of renting at 9%.

Household characteristics for the regressions were chosen carefully via previous studies in the field. It is possible for multicollinearity, or a statistical phenomenon in which two more predictor variables in a regression are highly correlated or associated occur. Multicollinearity does not bias coefficients, but can make them unstable. The general rule, is that if simple correlation coefficient between two regressors is greater than .8 or .9, the multicollinearity is a serious problem (Midi et al. 2010). We did not find serious multicollinearity issues to be the case in our models.

5. Results

Using a set of independent variables that we hypothesized had an impact on adoption behavior, we estimate two separate multinomial logit models: one for cropping

choices (Model A) and one for treed-system choices (Model B). The cropping choices available to households were: 1) non-adoption of intercropping (monoculture), 2) full adoption of the introduced agroforestry system (pigeonpea and cassava), and 3) partial adoption (pigeonpea and other crops, or cassava and other crops). The treed system choices available to households were: 1) non-adoption of treed systems, 2) adoption of *Gliricidia sepium*, 3) adoption of planted woodlots, and 4) adoption of both Gliricidia and planted woodlots. It is possible that any combination of adoption was not realistically within the household's choice set due to lack of knowledge, but there are no biophysical reasons why a household cannot adopt any tree or crop combination.

TABLE 3: Multinomial Logit Results of Cropping and Treed Systems Adoption (Base Outcome: Non-Adoption/Monoculture)

	MODEL A				**MODEL B**					
	Full Intercropping		**Partial Intercropping**		**Gliricidia**		**Woodlots**		**Gliricidia and Woodlots**	
	Coefficient*	**S.E.**	**Coefficient***	**S.E.**	**Coefficient***	**S.E.**	**Coefficient***	**S.E.**	**Coefficient***	**S.E.**
Number of adults (ln)	1.45	(0.344)	1.245	(0.28)	**0.431*** **	(0.123)	**0.168*** **	(0.054)	**0.245*** **	(0.079)
Farm area acres (ln)	**1.392***	(0.263)	1.007	(0.212)	**1.866*** **	(0.435)	**3.894*** **	(1.178)	**3.380*** **	(1.041)
Credit access	1.059	(0.358)	0.716	(0.243)	**4.674*** **	(1.701)	1.546	(0.664)	**3.716*** **	(0.582)
Use cell phone banking	0.868	(0.297)	0.93	(0.285)	**2.249****	(0.839)	0.858	(0.351)	**4.114*** **	(2.053)
Rental land	0.555	(0.340)	**0.217****	(0.158)	1.094	(1.051)	0.752	(0.575)	1.221	(1.358)
Education	**1.099****	(0.053)	**1.079***	(0.0467)	**0.893****	(0.047)	0.965	(0.055)	**0.889****	(0.0522)
Long-term illness	1.154	(0.757)	0.414	(0.232)	0.711	(0.510)	**0.293****	(0.178)	1.724	(1.162)
Short-term illness or injury	0.844	(0.418)	1.811	(0.790)	1.138	(0.560)	**3.321*** **	(1.520)	0.935	(0.564)
Has heard of ICRAF	**3.605*** **	(1.389)	**2.364****	(0.866)	**0.502***	(0.195)	**2.551****	(0.982)	1.961	(0.867)
Distance to Tabora Town	1.004	(0.0153)	0.945	(0.0427)	1.015	(0.014)	0.963	(0.097)	**0.931***	(0.036)
Firewood from commons	1.13	(0.421)	**2.945*** **	(1.091)	**2.788*** **	(1.096)	0.772	(0.359)	1.464	(0.654)
Mbola	**2.779*** **	(1.000)	1.159	(0.402)	0.581	(0.244)	**0.149*** **	(0.071)	0.72	(0.290)
Access to a health clinic	0.71	(0.249)	**2.319****	(0.777)	**0.403****	(0.144)	**2.543***	(1.251)	1.707	(0.730)
Constant	**0.067*** **	(0.0511)	**0.138*** **	(0.101)	0.521	(0.388)	0.428	(0.404)	**0.102*** **	(0.084)

Observations (N) = 386

**Exponentiated coefficients; Standard errors in parentheses*

Pseudo R^2 Cropping = .14 Wald Chi^2 = 95.04

Pseudo R^2 Treed = .21 Wald Chi^2 = 170.10

* p<0.10, ** p<0.05, *** p<0.01

Econometric results for adopted cropping systems are reported in the left-hand side of Table 3.[5] Due to missing values, the number of observations in the estimated sample is 386. McFadden pseudo r^2 is .21. We tested the IIA assumption and can reject the null that the IIA has been violated for both multinomial regressions estimated.[6] Coefficients in the multinomial model can be interpreted in the same way as binary logit model parameters with comparison to the base category. In other words, the odds ratio is a probability of choosing the agroforestry system to non-adoption. The coefficients have also been exponentiated to represent relative odds; therefore, a coefficient value greater than one means an increase in the likelihood of adoption in the corresponding dependent variable and a value less than one means a decreasing effect on the likelihood of adoption. The coefficients represent the multipliers for the log ratios, where for continuous variables the multiplier is constant *e* (2.72).

Starting with Model A, statistically significant characteristics that were associated with full adoption of intercropping systems included farm size, highest education in the household, and whether the household heard of ICRAF prior to the questionnaire interview. Household characteristics that were associated with partial adoption of intercropping included, if the household owns or rents land, highest education in the household, whether the household heard of ICRAF prior the

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[5] The mlogit command in STATA 14.2 fits a multinomial logit model for a categorical dependent variable with outcomes that have no natural ordering.

[6] We can reject the assumption that IIA has been violated by way of the Hausman-McFadden Test for both multinomial logit models.

questionnaire interview, firewood collection from the commons, and access to a health clinic. We provide a full discussion of these results in the next section.

For a farm that is about 2.72 times larger, then the relative log-odds of choosing to fully adopt the intercropping system is expected to be 1.39 times that, relative to non-adoption.[7] Increasing the highest level of education in the household by one year increases the relative odds of choosing to fully adopt the intercropping system by 1.10 times relative to non-adoption. Furthermore, a household who reported hearing of ICRAF prior to questionnaire dissemination has an increased relative odds of choosing to fully adopt than non-adoption. Finally, living in Mbola village increases the relative odds of choosing to fully adopt the intercropping system by 2.89 times relative to non-adoption.

Farm area is not as important as owning land for partial adoption of intercropping systems. Renting land decreases the relative odds of choosing to partially intercrop by 0.22 times relative to non-adoption. Similar to full adoption of intercropping systems, one more year of education in the household increases the relative odds of choosing to partially adopt 1.08 times relative to non-adoption, and hearing of ICRAF increases adoption of partial intercropping 2.36 times relative to non-adoption. Furthermore, collecting firewood from the commons increases the relative odds of choosing to partially intercrop 2.95 times relative to non-adoption.

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[7] The farm acreage and the number of members in a household are in natural logarithmic form. Hence, the coefficient estimate must be interpreted to represent the change in relative log-odds caused by about 2.72 time increase in the independent variable.

Finally, access to a health clinic increases relative odds of choosing to partially adopt 2.32 times relative to non-adoption.

Econometric results for adopted treed systems (Model B) are reported in the right-hand side of Table 3. The number of observations in the estimated sample is n = 386, and McFadden pseudo r^2 is 0.211. Statistically significant factors that influenced adoption of treed agroforestry systems include number of adults in the household, acres farmed, credit access, mobile banking use, highest education in the home, long-term and short-term illness, health clinic access, if the household heard of ICRAF prior to the questionnaire, distance to Tabora Town, firewood collection from the commons, and whether the household is in Mbola village.

For a farm that is about 2.72 times larger, then the relative log-odds of choosing to adopt Gliricidia is expected to be 1.87 times that, relative to non-adoption. Interestingly, if the number of households members becomes 2.72 times larger, then the likelihood decreases by a multiple of 0.43, relative to non-adoption. Furthermore, one more year of education in the household increases the relative odds of choosing to adopt Gliricidia by 0.89 times, and hearing of ICRAF is weakly significant, where Gliricidia adoption decreases by a multiple of 0.50 relative to non-adoption. Additionally, access to a health clinic decreases relative odds of adopting Gliricidia by 0.40 times, relative to non-adoption. Credit access and cell-banking increases the relative odds of choosing to adopt Gliricidia by 4.67 and 2.25 times respectively, compared to non-adoption. Furthermore, collecting firewood from the commons increases adoption 2.79 times, relative to non-adoption.

Similarly, if farm size becomes about 2.72 times larger, then the relative log-odds of choosing to adopt planted woodlots becomes 3.89 times, relative to non-adoption. Furthermore, if the number of household members becomes 2.72 times larger, then the likelihood of adopting a planted woodlot decreases by a multiple of 0.17 times, relative to non-adoption. Illness seems to play a larger role in woodlot adoption, where long-term illness decreases the relative odds of adopting a woodlot by 0.29 times relative to non-adoption. Yet, short-term illness experienced in the household does not hinder adoption, where short-term illness increases the relative odds of choosing to adopt a woodlot by 3.32 times. Furthermore, access to a health clinic increases the relative odds of adopting a woodlot by 2.54 times, and households who have heard of ICRAF have an increased relative odds of choosing to adopt woodlots 2.55 times compared to non-adoption. Households living in Mbola have a decreased relative odds of choosing to adopt planted woodlots by 0.15 times, relative to non-adoption.

Finally, we explore household who choose both Gliricidia and woodlot adoption. If the farm-land becomes about 2.72 times larger, then the relative log-odds of choosing to adopt both treed systems becomes 3.38 times, relative to non-adoption. Additionally, if the number of household members becomes 2.72 times larger, then the likelihood of adopting both treed systems increases by a multiple of 0.25 times, relative to non-adoption. Furthermore, one more year of education in the household decreases the relative odds of adoption of both treed systems. Interestingly, households who live further away from Tabora Town have a lower relative odds of choosing to adopt both treed systems by a multiple of 0.93, relative to non-adoption.

Finally, credit and cell-banking use increase the relative odds of adopting both treed systems by 3.72 and 4.11 times respectively, relative to non-adoption.

To further assess the performance of the estimated models, we also calculated the predicted probabilities for each adoption outcome for each household and compared these predictions to actual chosen land management types. The predicted outcome is defined by the management choice with the highest probability of being chosen, where the probabilities sum to one. For the intercropping model the percent agreement is 59.3% and the treed model is 58.9%. We also estimated standard logit model where any one of the adoption choices in respective models were coded as one. Overall, the logit results confirm the signs and significance of the variables, but the multinomial results provide much more nuanced view on adoption behavior.

6. Discussion and Conclusions

6.1 Adult Household Members

We found the number of adult household members does not significantly associate with cropping choices. This may indicate that the labor time it takes to manage the different cropping systems is not as important as other characteristics of the household. Yet, interestingly, a greater number of adult household members decreases the likelihood of adoption of all treed systems. This may be because once treed systems are established, they need little labor to accrue potential benefits, which include soil erosion prevention and nitrogen fixation.

Furthermore, it is possible that those who choose to establish treed systems hire more labor for tree planting. Therefore, fewer adults in the household does not impact labor supply for tree planting, which is typically a one-time event and can

occur outside of the typical agricultural season. This is important because hired labor can be in short supply during the cropping season. Tree planting allows for households to engage in active land management that can improve farm fertility, even if labor is in short supply. Dewees and Saxena (1997) validate these findings, where they explain the intensity with which crops are managed is partly a function of labor availability. Tree planting has overall less labor and active management costs required to make land productive, therefore we expect to see less household labor available for households managing treed systems.

6.2 Household Health

Our results show that poor health can lower household productivity. A study drawing from panel data in Kagera region Tanzania estimates the impact of prime age deaths on activities and time allocation of individuals among surviving household members (Ainsworth et al. 2005). Results indicated that households most vulnerable to prime-age deaths may be those without access to new household members. Males typically work in commercial agricultural fields, and females generally are the caretakers for sick family members. Therefore, a sick or deceased male member of the family significantly reduces crop output, compared to a sick or deceased female member. Although, our data does not reveal the gender of the sick household member we found that both long-term and short-term illness impact adoption decisions.

Households who report long-term illness are less likely to adopt woodlots, yet households who report short-term illness in the last agricultural season are more likely to report adopting woodlots. Reasonably, this may be because households did not adopt a planted woodlot in the last agricultural season, where long-term illness

could have prevented the household from having the capital or capacity necessary to establish the plot historically. Yet, we find reports of short-term illness have a similar effect as the household characteristic, adult household members, where fewer adult members increases the adoption of treed systems. This is likely because once the tree plot is established it requires little household labor.

Furthermore, households who report access to a health clinic are more likely to adopt a planted woodlot, or are more likely to adopt partial intercropping systems, yet are less likely to adopt Gliricidia. Substantial evidence suggests there is a relationship between labor productivity and health (Ersado et al. 2004; Jack 2011). Long-term health and access to health services significantly impact the adoption decision for some agroforestry choices, and may impact the sustainability of productive agroforestry systems, especially if labor is in short supply at the time of active management.

6.3 Distance to Market

Similar to Ersado et al. (2004), who found that a greater distance to market negatively was negatively related to the likelihood of agricultural technology adoption, we found that the farther away households are from Tabora Town, the less likely they are to plant both Gliricidia and a woodlot. According to Ersado et al. (2004) farmers living far from the market face high transactions costs for information, and limited access to input and output markets. Farmers farther from the market may have limited capacity to access capital inputs or hire labor to establish treed systems. Furthermore, there is evidence to suggest that households with better access to markets are more efficient in activities such as fuelwood collection, which in turn

could also mean that they are more likely to adopt new technologies, given the more efficient use of labor time (Kuusela et al. 2020).

6.4 Bank and Credit Access

Credit and banking access associated with the agroforestry adoption decision. Markedly, only 13% of Tanzanians use formal commercial banks, due to lack of money to create an account, fees, and transactions costs such as distance to reach traditional banking services (Mashenene and Mkende 2019). In sub-Saharan Africa the use of mobile banking services (cellular phone banking) is on the rise. Cellular phone distribution and services have significantly increased over the past decade. The study region in Tabora received cellular towers in the mid 2000s. Yet, cellular phone banking is relatively new across sub-Saharan Africa, and few studies have explored its usefulness as a driver of agroforestry adoption. It is likely that users of mobile banking services can access the benefits of traditional banking services, such as savings management and cash liquidity, with lowered transactions costs and increased ease of use.

We found that use of mobile banking services and access to credit for farming were statistically significant factors related to the likelihood of Gliricidia adoption, and the combination of Gliricidia and woodlot adoption. Those without credit access or cash liquidity may be unable to generate enough savings to invest in tree seedlings, travel for education or machinery, or potentially hire more labor. Credit and access to small loans have been heavily studied in development literature. For example, in Tanzania, Bullock et al. (2014) assessed cardamom agroforestry adoption. Similar to

our findings, they discovered that access to credit was significant and exerted positive influence on adoption behavior.

6.5 Education of the Head of Household

We found that households with more years of education had a higher relative odds of planting the full intercropping and partial intercropping system. Yet, households with fewer years of education were more likely to adopt Gliricidia, and both Gliricidia and Woodlots. Findings for education of the household impact land management adoption decisions differently, where we find evidence from across the literature. Foster and Rosenzweig (1996) discovered that households with at least one adult who completed primary schooling were significantly more likely to adopt improved seed technology, controlling for land size. Afsaw et al. (2012a) found education of the household head positively influence likelihood of adopting improved pigeonpea in rural Tanzania, yet was not a significant factor in Ethiopia. Kalineza et al. (1999) conducted a case study in Tanzania observing factors influencing soil conservation technologies, including tree planting. Their dataset indicates that those heads of household who are tree planting have fewer years of education than any of the other soil conservation practices. It may be the case that extension education is the driving force behind successful tree planting, while cropping system choice is complementary with years of formal education. Along with math and language class, grade-school children in Tabora also participate in formal farming education. It may be the case that those with more years of education learn more about favorable agricultural production practices in school, thus increasing the likelihood of adopting novel cropping systems as adults. Furthermore, those who are more educated may

have more wealth, on average, and therefore the resources to invest in novel cropping technologies that may be riskier. Conversely, it may be the case that there are more available extension agents available to discuss treed systems, and perhaps even target individuals who seem to need more education on tree system establishment.

6.6 ICRAF Extension

Extension visitation and adoption behavior have been well-described in the literature (Afsaw et al. 2012, Schuck et al. 2002). Knowledge is passed from NGOs or government extension agents to the farmer, who may educate his neighbors or allow them to passively observe the technology change. Those who reported hearing of ICRAF prior to questionnaire dissemination have a higher likelihood of planting the full intercropping system, partial intercropping system, as well as planted woodlots. Interestingly, those who reported hearing of ICRAF have a lower relative odds of planting Gliricidia.

Gliricidia takes multiple years to accumulate soil benefits. Villagers may learn from a neighbor or friend about Gliricidia, or from ICRAF. Assuming ICRAF fully informs potential Gliricidia adopters about the time and management input it takes to receive full soil benefits, potential adopters may actively choose to not adopt. Those who learned from neighbors may be less informed on how long it takes to realize benefits. Therefore, those who have heard from ICRAF may be less likely to adopt Gliricidia than those who learn from others in the community if they have hyperbolic time preference, or prefer to see benefits sooner.

6.7 Land Tenure and Farm Area

Agroforestry systems often take many years to accrue full benefits. Participants who reported renting their land are less likely to partially adopt intercropping systems, relative to non-adoption or monoculture. Furthermore, we found that farm size is positively associated with and highly significant for all adoption choices, except partial adoption of intercropping. This may indicate that farmers who own their land, but do not necessarily have a large land area, may be more adept at partially adopting intercropping systems. Often, households have learned about intercropping from their parents as a labor-saving skill on small land-parcels. Full adoption of intercropping, as well as the treed systems, have been introduced from ICRAF. More land area could increase the household's ability to experiment with novel agroforestry systems.

Additionally, land tenure has been well documented in the agroforestry adoption literature (Nkamleu and Manyong 2005). When land ownership is secure, people tend to invest in the long-term benefits of their farmland. Households who report renting their farmland are less likely to partially adopt intercropping systems. This indicates that households choose to monocrop on rented farmland, perhaps because long-term depletion of soil nutrients is not prioritized as a potential consequence.

6.8 Firewood from Commons

Surrounding woodlands to the study region, known as the Miombo woodlands, range from Angola to Tanzania, and are central to the livelihoods for millions of rural and urban people (Abdallah and Monella 2007). Goods provided

include medicines, fuelwood, food, fiber, and cultural and spiritual values. Yet, woodlands have been severely degraded, to cure tobacco and for domestic use. We postulated that households planting agroforestry systems would be less likely to collect firewood from the commons, substituting on-farm production of fuelwood for labor intensive off-farm collection. Yet, those who reported partially intercropping and those who planted Gliricidia report collecting firewood from the commons. Pigeonpea, cassava, and Gliricidia are all woody perennials that can be burned for domestic use, but do not burn as well as firewood from woodlots or surrounding open-access woodlands. Furthermore, it is most likely that Gliricidia and partial intercropping have not produced enough woody biomass to act as a perfect substitute for collecting from open access lands.

6.9 Conclusions

Significant research has been conducted to understand the factors that influence agroforestry adoption decisions of subsistence farmers, but a majority of those case studies have focused primarily on dichotomous choice methodology, such as logit and probit. We collected randomly sampled questionnaires from Tabora, Tanzania using a reliable survey instrument to observe agroforestry adoption behavior. Our work used multinomial methods to better identify partial adoption and combined adoption strategies. By using these methods, we were able to draw stronger conclusions about household characteristics that associated with the extent and diversification of agroforestry systems.

Promoting agroforestry systems is a relatively low-cost way of enhancing rural livelihoods. Agroforestry can support food security through food diversification,

as well as increase environmental services. Furthermore, aspects of agroforestry are already used on-farm by subsistence farmers in Tabora. Therefore, it is not an enormous stretch to enhance managerial aspects of subsistence land management operations through agroforestry systems. We found that mobile banking and credit access has successfully promoted adoption of treed agroforestry systems that may need more front-end capital inputs, such as seedlings and more labor. Furthermore, access to health services, and reports of long-term and short-term health seem to have had a positive association with some agroforestry adoption behavior. Access to a health clinic increased adoption of partial intercropping, and woodlots, yet decreased adoption of Gliricidia. Furthermore, long-term illness decreased adoption of woodlots and short-term illness increased adoption of woodlots. Additional results suggest that strengthening ICRAF interactions may enhance adoption.

This work opened more lines of questioning. Future research can assess whether agroforestry meets intended socio-economic, and environmental goals. In other words, are adopters more food secure, and do they have a higher standard of living due to adoption? Furthermore, additional research could be conducted to better understand substitutability between agroforestry adoption and collection of fuelwood from the commons, which could heighten the goal of reducing deforestation of the Miombo Woodlands. Additionally, we suggest time series data to better assess dis-adoption of agroforestry systems. Dis-adoption, in this case, is defined as those households who try agroforestry systems, but then decide to discontinue use for a myriad of potential reasons, such as inadequate knowledge on up-keep and

management. Such time series data could help to enhance the sustainability of agroforestry systems to meet the full extent of intended benefits.

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CHAPTER TWO

Do Agroforestry Interventions Improve Food Security? Evidence from Rural Tanzania

1. Introduction

Rural farmers in Tanzania primarily depend on subsistence agriculture for their livelihood. However, due to low soil fertility and lack of access to fertilizers, farmers face increasing food insecurity (Bekele-Tesemma 2007; Afsaw 2012). Additionally, crops are largely rain-fed and are impacted by variable climate and weather patterns (Bekele-Tesemma 2007). Common climate change adoption strategies include adjustment of planting and harvesting time, crop diversification, improved crop varieties, adoption of soil and water conservation practices, irrigation, agroforestry, and tree planting (Adego et al. 2019). To assist farmers with adaptation, development organizations, such as the International Centre for Research in Agroforestry (ICRAF), have introduced and supported agroforestry farming techniques to increase organic soil nutrients and mitigate potential drought-risk.

Adoption of new agricultural technologies can assist in alleviating poverty and food insecurity for many people in developing countries; yet, innovations are often adopted slowly, or not at all (Bandiera & Rasul 2006). Feder et al. (1985) identify several factors that influence a lack of adoption of agricultural technologies in developing countries, including lack of credit and managerial information, risk aversion, small farm size, inadequate land tenure arrangements and human capital, and deficiencies in infrastructure and access to equipment and complementary inputs. Development organizations such as ICRAF act to alleviate these constraints, by demonstrating the use of novel land management technologies and by providing access to seeds and other important inputs needed to implement agroforestry systems.

The agroforestry packages introduced and supported by ICRAF in the study region include: 1) intercropping of pigeonpea and cassava, 2) plantings of Gliricidia sepium (Gliricidia or common name Forest Lilac), and 3) planted woodlots for fuelwood and fodder.[8] Land-scarce farmers can intensify land use by intercropping, which allows for poor families to offset risks by diversification and meet food and cash needs when there is crop failure (Afsaw et al. 2012). For example, Kwesiga et al. (2003) found that maize yields increased an average of 3.8 Mg ha^{-1} from *Gliricidia sepium* and 1.7 Mg ha^{-1} from pigeonpea fallows in Zambia, depending on soil types, climate, and variation in crop management. Agencies that support the adoption of these land management systems anticipate that households will be able to increase crop yields and sell excess yield for profit. Households are also anticipated to become more food secure in the long-run through improved diversification of crops. Monitoring the success of agroforestry interventions can be accomplished through an impact analysis that answers the question, have the agroforestry packages supported by ICRAF improved the measurable food security of participants?

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[8] Cassava is a tuber commonly farmed in sub-Saharan Africa to offset periods of drought. Young leaves are added to stews and the tuber is washed and dried into thin strips or ground into flour. Pigeonpea is a drought tolerant leguminous species that can provide a non-animal source of protein and fix nitrogen in soils. Additionally, *Gliricidia sepium* is a shrub that supports nitrogen fixation and can prevent erosion. Woodlots supported by ICRAF are typically native acacia species, while woodlots introduced by tobacco industries are often non-native eucalyptus. ICRAF has supported woodlot plantings as a sustainable source of fuelwood and fodder. Similarly, the tobacco industry has supported woodlots primarily for curing tobacco for export.

In general, analyzing welfare impacts of agricultural technology adoption poses two primary econometric challenges when using observational data: unobserved heterogeneity (such as ability and effort) and selection bias (Aswaf et al. 2012b). Reverse causality also arises when technology adoption may result in productivity enhancement for small-scale producers, thus increasing household food security, but those who are already better-off may have more ability to adopt new land management systems to begin with. Thus, simple comparisons of the sample averages of welfare indicators between adopters and non-adopters, such as total market value of household agricultural production (TVP), does not reveal the true effect of adoption on household food security. It is critical to address these sources of endogeneity when assessing the welfare impacts of agricultural interventions.

A common approach used in previous literature on technology adoption is to estimate an endogenous switching regression (ESR) model (Maddala 1983). An additional advantage of the ESR model is that it enables the prediction of counterfactual outcomes, such as what would have been the TVP among adopters of an agroforestry package had they not adopted. Such predictions are then used to calculate the "average treatment effect on the treated" households (ATET) and "average treatment effect on the untreated" households (ATEU). These measures give more accurate information than simply comparing the "treatment on treated" (TT) and the "treatment on untreated" (TU) groups.

Similar studies have used the ESR modeling strategy to study climate change adaptation behavior. Di Falco et al. (2011) explored climate change adaptations in Ethiopia using household food productivity as the determinant of food availability.

They found that farming households with access to credit are more likely to adapt to climate change. Furthermore, households that are informed about the effects of climate change and that interact more with extension agencies are more likely to adopt climate change adaptations. Using ESRM these authors determined that adopters are better-off adopting, and that non-adopters could have produced the same amount of food as the adopters had they adopted. Furthermore, Sileshi et al. (2019) assessed the impact of soil and water conservation practices on food security in eastern Ethiopia. Using a cross-sectional household survey, they found that adoption of soil and water conservation strategies positively impacts the per capita food consumption expenditure and net crop value and also significantly reduces the probability of farmers being food insecure. To determine household food insecurity status, they used the amount of money required to achieve the daily minimum caloric requirement. Results revealed that 57.5% of adopters were categorized under the stable food security status, compared to 34.1% for non-adopters.

Alem et al. (2015) explored the impact of climate-friendly rice farming in Tanzania. Results from the ESRM suggest that adoption of system of rice intensification (SRI) practices, in fact, do increase yield by 58% on average. However, adopters on average had higher costs per acre due to increased labor demand for households and hired labor. Similarly, Noltze et al. (2012) assessed the management of SRI in Timor Leste using ESRM, who found no significant difference in household characteristics between adopters and non-adopters of SRI. In another setting, Kiyingi et al. (2015) estimated the average treatment effects of adopting eucalyptus and carbon forestry woodlots on consumption expenditure per adult and

daily calorie acquisition per adult in Uganda. Farm forestry has been purported as a tool to reduce deforestation and address climate change, as well as supply rural households with on-farm wood products. Results indicated that adoption of eucalyptus woodlots increased calorie acquisition per adult equivalent by 36% and 13.1% respectively, and adoption of carbon forestry increased calorie acquisition per adult equivalent by 22% and 26.9% respectively.

Shiferaw et al. (2014) use ESRM on a nationally representative dataset of farming households in Ethiopia. They used a per capita food consumption measure of food security to assess adoption of improved wheat, and then checked those measures with self-reported food security, to assess subjectivity and consistency of households' own economic welfare. They found that adoption was negative and significant in most cases, suggesting that farmers with lower than average per capita consumption expenditure and probability of food security were more likely to adopt improved wheat varieties. Furthermore, results were consistent across quantitative and qualitative reporting methods. Other related studies include Kuntashula and Mungatana (2013), Coulibaly et al. (2017), and Teklewold and Mekonnen (2017).

The purpose of this article is to evaluate the effects of agroforestry adoption on food security and welfare in Tabora, Tanzania. We used data from a 2019 survey of randomly selected households in Tabora. The original dataset contained a rich set of variables describing farming practices, outcomes, and household characteristics. As a proxy for food security, we used the total market value of household agricultural production (TVP). After estimating the model, we predict ATET and ATEU measures to assess the impact of agroforestry programs in Tabora on TVP.

2. Methods

2.1 Estimation Strategy

The goal of our analysis was to evaluate the impact of an agroforestry intervention on households' food security. Rubin (1974) introduced the concept of a potential outcome which will be useful in defining the "treatment effect." Let variable y_{i0} denote some measure of food security of household *i,* for example the total market value of household agricultural production (TVP), when the household is a non-adopter (0). Let y_{i1} denote the measure of food security when the household is an adopter (1). The intervention effect would be given by:

$$y_{i1} - y_{i0} \tag{1}$$

However, given that we are not able to observe the actual outcome and the counterfactual outcome for the same household, we are left with comparing outcomes of non-adopters and adopters. This gives rise to the problem of selection bias (Lan & Yin 2017; Heckman 2001). To eliminate the effect of selection bias, researchers aim to randomly assign the treatment to households. However, with post-intervention observational data, such randomization is simply not feasible and poses ethical limitations even if it were possible (Rubin 1974). Hence, alternative econometric approaches are needed to address the selection bias (Lan and Yin 2017).

One popular model to overcome selection bias and to predict counterfactual outcomes is the ESRM (Maddala 1983). The adoption equation follows the standard latent variable approach, where the latent variable captures the expected benefits from the adoption choice with respect to not adopting:

$$A_i^* = a + \gamma z_i + \varepsilon_i,$$

(2)

and this, in turn determines the observable adoption choice:

$$A_i = \begin{cases} 1 & if\ A_i^* > 0 \\ 0 & otherwise \end{cases}$$

(3)

The above equations specify that the household *i* chooses to adopt (A_i^*= 1) agroforestry systems if the latent variable is positive, A_i^*> 0, and non-adopt otherwise. The term z_i represents a vector of explanatory variables, γ is a vector of coefficients to be estimated, and ε_i is a normally distributed mean zero random error. We can interpret variable A_i^* as the unobserved utility from adopting agroforestry.

Depending on the adoption status, the outcome equation of interest in the ESRM becomes:

$$y_{i1} = \alpha_1 + \beta_1 x_{1i} + e_{1i} \quad if\ A_i = 1$$

(4a)

$$y_{i0} = \alpha_2 + \beta_2 x_{2i} + e_{2i} \quad if\ A_i = 0$$

(4b)

In the above equations, x_i is the list of explanatory variables that consists of household and farm characteristics, and e_i represents the error term. Household and farm characteristics enter the equations in (4a and 4b) because the subsistence farmers are simultaneously both producers and consumers who are likely subject to market constraints, thus resulting in non-separability of production and consumption choices (Benjamin 1992, Jacoby 1993). Note that the ESRM differs from a standard single equation regression model because both the intercept and the slope coefficients in (4a

and 4b) may differ depending on the adoption status, whereas in the single equation case, only the intercept may change due to adoption.

The error terms from equations (2) and (4) are independent across individuals and independent of the explanatory variables and follow a trivariate normal distribution with mean vector zero and a covariance matrix:

$$\Omega = \begin{bmatrix} \sigma_{\varepsilon}^2 & \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} \\ \sigma_{\varepsilon 1} & \sigma_1^2 & . \\ \sigma_{\varepsilon 2} & . & \sigma_2^2 \end{bmatrix}$$

In the above matrix, σ_{ε}^2 is the variance of the error term from the adoption equation (2). This is assumed to equal one since the coefficients in γ are estimable only up to a scale factor (Maddala 1983; Di Falco 2011). Variance terms σ_1^2 and σ_2^2 are associated with the error terms in the equations in (4); parameter $\sigma_{\varepsilon 1}$ is the covariance of ε_i and e_{1i}; and parameter $\sigma_{\varepsilon 2}$ is the covariance of ε_i and e_{2i}. Note that the values of y_{1i} and y_{2i} are never observed simultaneously for the same individual. Therefore, the covariance between e_{1i} and e_{2i} is not defined (Maddala 1983; Lee & Trost 1978). An important implication of this error structure is that since the error term ε_i is correlated with the error terms of the welfare outcomes in (4), and the expected values of e_{1i} and e_{2i} conditional on the sample selection are nonzero (e.g. Di Falco et al. 2011):

$$E[\varepsilon_{1i}|A_i = 1] = \sigma_{\varepsilon 1}\lambda_{1i}, \qquad E[\varepsilon_{2i}|A_i = 0] = \sigma_{\varepsilon 2}\lambda_{2i},$$

where

$$\lambda_{1i} = \frac{\phi(\gamma z_i)}{\Phi(\gamma z_i)}, \qquad \lambda_{2i} = -\frac{\phi(\gamma z_i)}{1 - \Phi(\gamma z_i)}.$$

Functions $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability density and the standard normal cumulative density functions, respectively. If the estimated covariances are statistically significant, there is evidence for selectivity bias. This means that the decision to adopt and the outcome variable, such as TVP, are correlated (Di Falco et al. 2011). An efficient method to estimate ESRM is the full information likelihood estimator (Lee and Trost 1978).

Once model parameters are estimated it is possible to calculate conditional expectations to compare outcomes from adopter and nonadopter households. Four cases can be estimated, as described in Table 4: (a) The expected TVP of those who have adopted, (b) The expected TVP of those who did not adopt, (c) The adopter TVP had they not adopted, and (d) The non-adopter TVP had they adopted. Cases (a) and (b) represent the actual expectations observed in the sample, while (c) and (d) are the counterfactual expected outcomes. The four cases can be presented as follows:

$$E[\varepsilon_{1i}|A_i = 1] = \boldsymbol{X_{1i}}(\boldsymbol{\beta_1}) + \sigma_{\varepsilon 1}\lambda_{1i} \tag{5a}$$

$$E[\varepsilon_{2i}|A_i = 0] = \boldsymbol{X_{2i}}(\boldsymbol{\beta_2}) + \sigma_{\varepsilon 2}\lambda_{2i} \tag{5b}$$

$$E[\varepsilon_{2i}|A_i = 1] = \boldsymbol{X_{1i}}(\boldsymbol{\beta_2}) + \sigma_{\varepsilon 2}\lambda_{1i} \tag{5c}$$

$$E[\varepsilon_{1i}|A_i = 0] = \boldsymbol{X_{2i}}(\boldsymbol{\beta_1}) + \sigma_{\varepsilon 1}\lambda_{2i} \tag{5d}$$

TABLE 4: Conditional Expectations, Treatment, and Heterogeneity Effects

Sub-samples	Decision Stage		Treatment Effects
	Adopt	Non-Adopt	
Households that adopted	(a) $E[\varepsilon_{1i}\|A_i = 1]$	(c) $E[\varepsilon_{2i}\|A_i = 1]$	TT
Households that did not adopt	(d) $E[\varepsilon_{1i}\|A_i = 0]$	(b) $E[\varepsilon_{2i}\|A_i = 0]$	TU
Heterogeneity Effects	BH_1	BH_2	TH

$A_i = 1$, if the household adopted agroforestry systems; $A_i = 0$ if the household did not adopt agroforestry systems.
ε_{1i} = TVP of households that adopted
ε_{2i} = TVP of households that did not adopt
TT is the effect of the treatment on the treated, agroforestry adoption on the household that adopted
TU is the effect of the treatment on the untreated, households that did not adopt agroforestry
BH_1 is the effect of base heterogeneity for households that adapted
BH_2 is the effect of base heterogeneity for households that did not adopt
TH = (TT – TU), the transitional heterogeneity effect

The effect of the treatment on the treated (TT) is the difference between (a) and (c), which represents the difference in TVP if adopters would have not adopted:

$$\begin{aligned} \text{TT} &= E[\varepsilon_{1i}|A_i = 1] - E[\varepsilon_{2i}|A_i = 1] \\ &= \boldsymbol{X_{1i}}(\boldsymbol{\beta_1} - \boldsymbol{\beta_2}) + (\sigma_{\varepsilon 1} - \sigma_{\varepsilon 2})\lambda_{1i} \end{aligned} \tag{6}$$

The effect of the treatment on the untreated (TU) is the difference between (d) and (b), which represents the difference in TVP if the non-adopters would have adopted:

$$\begin{aligned} \text{TU} &= E[\varepsilon_{1i}|A_i = 0] - E[\varepsilon_{2i}|A_i = 0] \\ &= \boldsymbol{X_{2i}}(\boldsymbol{\beta_1} - \boldsymbol{\beta_2}) + (\sigma_{\varepsilon 1} - \sigma_{\varepsilon 2})\lambda_{2i} \end{aligned} \tag{7}$$

Calculating the TT and TU make it possible to observe counterfactual scenarios, as well as heterogeneity effects due to unobservable factors such as management skill, represented by BH_1, the difference between (a) and (d):

$$\begin{aligned} BH_1 &= E[\varepsilon_{1i}|A_i = 1] - E[\varepsilon_{1i}|A_i = 0] \\ &= (\boldsymbol{X_{1i}} - \boldsymbol{X_{2i}})\boldsymbol{\beta_{1i}} + \sigma_{\varepsilon 1}(\lambda_{1i} - \lambda_{2i}) \end{aligned} \tag{8}$$

As well as, BH_2, the difference between (c) and (b):

$$\begin{aligned} BH_2 &= E[\varepsilon_{2i}|A_i = 1] - E[\varepsilon_{2i}|A_i = 0] \\ &= (\boldsymbol{X_{1i}} - \boldsymbol{X_{2i}})\boldsymbol{\beta_{2i}} + \sigma_{\varepsilon 2}(\lambda_{1i} - \lambda_{2i}) \end{aligned} \tag{9}$$

The transitional heterogeneity effect (TH) can be assessed to determine whether the impact of adopting ICRAF interventions are larger or smaller for the households that actually adopted the technologies or for the farm household that actually did not adopt had they adopted in the counterfactual, which is the difference between equations 6 and 7 (Heckman et al. 2001; Di Falco 2011; Kuntashula & Mungatana 2013).

Finally, for model identification purposes, the variables included vector z in (2) should include at least one element that is not included in vector x in (4) (Afsaw et al. 2012a). An appropriate instrument should only directly influence the adoption choice and not the outcome of interest. Previous literature gave us a starting place to choose appropriate exclusion restrictions (Table 5). Commonly used exclusion restrictions include access to information, markets, and extension services (e.g. Di

Falco et al. 2011, Afsaw et al. 2012a, Abdulai and Huffman 2014, Shiferaw et al. 2014, Coulibaly et al. 2017).

TABLE 5: Exclusion Restrictions for Food Security Outcomes

Author (Year)	Technology Adopted	Instruments
Adego et al. (2019)	Climate Adaptation Strategies	Climate information and distance to market
Di Falco et al. (2011)	Climate Adaptation Strategies	Government extension, farmer to farmer extension, information from the radio and neighborhood
Coulibaly et al. (2017)	Agroforestry Trees	Participation in agroforestry extension training
Jaleta et al. (2015)	Improved Maize Adoption	Distance to seed dealers (in walking minutes), number of traders known to the farmer, and number of relatives who could provide support in and outside the village
Abdulai and Huffman (2014)	Soil and Water Conservation Strategies	Distance to extension services
Shiferaw et al. (2014)	Improved Wheat Adoption	Distance to seed market, government extension interactions, and farmers cooperatives
Alene and Manyong (2007)	Improved Cowpea Education	Ecological characteristics (land fertility)
Teklewold and Mekonnen (2017)	Tillage Methods	Oxen owned and social capital (number of relatives in and outside the village, and number of groups to which the household belongs)

Common exclusion restrictions used in novel agricultural adoption literature include extension interactions, climate information, and distance to markets or seed dealers.

3. Data Collection

Data were collected in six rural villages in Tabora, Tanzania. Tabora is located approximately 800 km (500 mi) to the west of Dar es Salaam and borders the Democratic Republic of Congo to the east (400 km, 250 mi). The average rainfall in the study area is approximately 902 mm (35.5 inches) per year and the average annual temperature is 23.1° C (73.6° F). All of the villages surveyed for this project were clustered west of Tabora Town (Appendix A).[9] After revising the questionnaire based on a pilot study conducted in February to March 2019, the final data collection was conducted in six villages from July to August 2019: Mbola, Isila, Msiliembe, Mbiti, Ibiri, and Migungumalo. Complete lists of all household heads were collected by the hired local guides from March to May 2019 (a census of N = 2,286 heads of household). A sample of 550 households was randomly selected from the census list of all households. Villages were stratified according to their total population and final sample percentages reflect consent to participate in the survey. From the full sample, 435 individuals consented to taking the questionnaire (Response Rate = 79%).

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[9] The survey instrument and data collection protocol were approved by Oregon State University Institutional Review Board (IRB) for both pre-testing and final survey data collection. Additional approvals were granted by the Tanzania Commission for Science and Technology (COSTECH). The survey was translated from English to Swahili by the ICRAF Tanzania office. The survey was disseminated using the offline cellular phone application Qualtrics, LLC, which had both English and Swahili question and answer capability. Enumerators were hired via recommendation from the Agricultural College Tari-Tumbi. A two-day training was conducted in February, 2019, to familiarize enumerators with the data collection phone-application. Enumerators were also given an in-depth informed consent and ethics training. An enumerator re-training was held in July 2019.

The goal of our study is to measure whether specifically ICRAF interventions (intercropping with pigeonpea and cassava and/or planting Gliricidia) have had a positive impact on potential household income. The survey questionnaire contained detailed questions about agroforestry practices and household and farm characteristics. However, given that it is not possible to identify the households who have adopted woodlots from ICRAF interventions or the tobacco industry, we exclude woodlot adoption from our analysis.[10]

3.1 TVP Calculation

The potential household farm income is defined as the total market value of household agricultural production (TVP). The method we use to compute it is similar to Coulibaly et al. (2017), who calculated the value of food crops for adopters and non-adopters of agroforestry in Malawi. Households were asked how many kilos of commonly produced crops were produced in the agricultural season. A variety of crops are planted during the rainy season from February through May, and those crops are harvested from June through August. The typical food-insecure period occurs from October through February, where the highest reported food insecure months from our sample were December (51%) and January (56%).

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[10] ICRAF typically supported plantings of native tree species, while the tobacco industry has introduced non-native eucalypt species. Eucalypts typically grow very fast, but use a significant amount of water resources, lowering the water table. Water is already a scarce resource in the region. ICRAF trees were generally introduced for erosion prevention and domestic use. Tobacco industry woodlots were introduced to create a supply of fuelwood for curing tobacco. Both ICRAF and the tobacco industry introduced woodlots to substitute for gathering fuelwood from surrounding open access woodlands.

Participants were then asked how many Tanzanian Shillings (TSH) each crop typically sold for in the market; this was converted to USD for analysis (1 TSH = 2300 USD). Furthermore, we asked the number of livestock owned and calculated the potential price of livestock via GALVMed's[11] average price for each animal (Table 6). To incorporate the value of the livestock in our TVP measure, we assume that 25% of livestock is consumed during an agricultural season, while 75% acts as a wealth stock producing on-farm fertilizer and social capital.[12]

[11] GALVmed is a Registered Charity, which aims to bring affordable livestock vaccines, and medicines to developing countries. Partnered with the Food and Agricultural Organization (FAO), GALVmed provides research and product development, as well as works to support livestock keepers. We used their average livestock prices for Tanzania, as reported in Table 5 (https://www.galvmed.org/).

[12] The results remain robust to a reasonable range of percentage values assumed.

TABLE 6: Crops and Livestock per Kilogram and Animal Unit

Crops	**Mean Price per Kilo/USD**
Cassava	0.12
Pigeonpea	0.05
Maize	0.94
Rice	0.20
Millett	0.03
Yams	0.12
Green Vegetables	0.10
Tree Fruit	0.09
Watermelon	0.04
Sunflower	0.13
Tobacco	0.58
Cow Pea	0.14
Bambara Nut	0.10
Peanut	0.67
Squash	0.03
Tomato	0.06
Livestock per Animal Unit	
Chicken	3.00
Goat	46.00
Cow	310.00

3.2 Summary Statistics

Among the villages surveyed, Mbola had the highest rate of ICRAF intervention adoption (37%), followed by Ibiri (16%), Msiliembe (15%), Isila (12%), Migungumalo (12%), and Mbiti (9%) (Table 6). Approximately, 25% of adopters reside in Mbola village, while 21% of non-adopters reside in Mbola (Table 7).

TABLE 7: Adopters of ICRAF Interventions (Full Sample $n = 435$)

	Ibiri	Isila	Mbiti	Mbola	Migungumalo	Msiliembe	**Total**
Non-Adoption of Agroforestry	57	41	40	57	90	33	**318**
Adoption of Agroforestry	19	14	10	43	14	17	**117**

Summary statistics of household characteristics are presented in Table 8. The average TVP for adopters is $1285.52 and non-adopters is $1362.41. The number of adult household members for adopters is approximately 5.5 per household, and non-adopters is 5.9. Adopters have on average 6.23 acres, and nonadopters have 4.57 acres. Households who own livestock are typically wealthier. Interestingly, adopters have on average slightly fewer cows and goats, whereas adopters have 3.3 cows, and non-adopters have 3.8 cows. Furthermore, adopters and non-adopters have approximately the same number of goat holdings (3.2 goats). Adopters generally have more chickens (15.3), compared to non-adopters households (14.7). Typically, adopters report longer travel time to Tabora Town (6.1 hours), compared to non-

adopters (4.3 hours). Additionally, adopters tend to have more years of education (8.1 years), compared to non-adopters (7.7 years).

Capital assets were included in the model. On average, more adopters owned a plow (22.4%) and water well (21.6%), compared to non-adopters (21.6% and 5.9% respectively). Adopters and non-adopters equally owned an oxcart (about 6.5%). Furthermore, we asked individuals if they resided in the village they were born in, 52.8% of adopters were born in the village they currently reside, compared to 55.6% of non-adopters.

The final household characteristics included in the ESRM are credit access, traditional banking and mobile banking use. Approximately 36% of adopters report having credit access for farming, whereas 7.8% of non-adopters report credit access. Furthermore, 45.6% of adopters report traditional banking access, whereas 15% of non-adopters report bank access. Finally, 79.2% of adopters report mobile banking use, and 43.1% of non-adopters use mobile banking. This indicates that overall agroforestry adopters have more access to financial services and cash liquidity.

The instruments used to control for household TVP are: 1) an indicator of membership in an agroforestry group, and 2) an indicator of whether or not the household had heard of ICRAF prior to the questionnaire dissemination. It is common to include extension interactions as an instrument in agricultural technology adoption, as it is assumed that extension agents do not discriminate based on household wealth. However, we know that extension agents may visit those who request more interaction, or they may visit households that are poorer on average, because they may be perceived as the best receivers of the technology. We include the variable,

"heard of ICRAF," because adoption is dependent on either hearing from an ICRAF extension agent or from a neighbor, and is not as subject to the biases associated with direct extension visits to the household. The number of general extension interactions does not include learning about a technology or organization from neighbors. We believe the variable, "heard of ICRAF," includes households who learned from ICRAF extension agents, as well as households who learned about ICRAF technologies from neighbors.

Furthermore, it is assumed that belonging to an agroforestry group does not discriminate based on household TVP. Approximately, the same number of adopters and non-adopters belong to an agroforestry group (6.5%). Furthermore, 52.8% of adopter households have heard of ICRAF, while only 20.9% of non-adopters have heard of ICRAF.

Additionally, we test our exclusion restrictions in the same way as Jaleta et al. (2015), Adego et al. (2019), and Di Falco et al. (2011). The falsification test is a way of checking whether the instrumental variables are valid, meaning it identifies whether the instrument effects the adoption decision but not the outcome variable. Both of our instruments, belonging to an agroforestry group and hearing of ICRAF, pass this test.

TABLE 8: Summary Statistics of Independent Variables and Instruments

	Adopters (N =125)	Non-Adopters (N =153)
Total market value of household agricultural production in USD (TVP)	1285.52 (1427.22)	1362.41 (1697.97)
Continuous Variables		
Adult Members	5.46 (3.95)	5.91 (3.74)
Farm Acres	6.23 (0.78)	4.57 (0.77)
Cow Stock	3.31 (9.37)	3.78 (9.20)
Chicken Stock	15.34 (14.93)	14.74 (16.71)
Goat Stock	3.18 (5.91)	3.21 (6.47)
Distance to Tabora Town in hours	6.11 (4.33)	4.31 (4.67)
Highest Education	8.08 (2.10)	7.74 (3.09)
Binary Variables		
Plow Owned	0.224 (.419)	0.216 (.413)
Water Well Owned	.216 (.413)	0.059 (.236)
Oxcart Owned	0.064 (.246)	0.065 (0.248)
Born in Village Lived	0.528 (0.501)	0.556 (0.499)
Credit Access	0.360 (0.482)	0.078 (0.270)
Bank Access	0.456 (0.500)	0.150 (0.359)
Mobile Banking Use	0.792 (0.408)	0.431 (0.497)
Mbola Village Household	0.248 (0.434)	0.209 (0.408)
Instruments		
Belong to Agroforestry Group	0.064 (0.246)	0.065 (0.248)
Heard of ICRAF	0.528 (0.501)	0.209 (0.408)

Continuous Variables: Mean, (Standard Deviation in Parentheses)

4. ESRM Results

Table 9 presents the ESRM results. The first and second column present the estimated coefficients of the food security functions with respect to TVP (equation 4a) and (equation 4b), for households that did and did not adopt ICRAF interventions. Note, the dependent variable, TVP is in natural log. The third column presents the estimated coefficients of the selection equation on adopting ICRAF interventions or not (equation 3). The results of the estimation of equation 3, suggest that the main drivers related to households' decision to adopt ICRAF interventions were mobile banking use, as well as traditional banking access, and credit access. Moreover, ownership of a water-well has a significant positive impact on the adoption decision. Additionally, fewer household members actually increases the decision to adopt ICRAF interventions, likely because treed systems (Gliricidia), require less maintenance and labor once established (Dewees and Saxena 1997). Finally, the instruments: 1) belonging to an agroforestry group, and 2) hearing of ICRAF are both significant at $p < .10$ and $p < .05$, respectively.

The estimates presented in columns I and II account for the endogenous switching in the food security function (TVP). Both the estimated coefficients of the correlation terms, denoted by *r1* and *r2* in Table 9, are not significantly different from zero, yet are jointly significant at $p < .01$. This implies that the hypothesis of absence of sample selectivity bias may not be rejected, and that the likelihood ratio test for joint dependence is significant, indicating that the three equations are dependent on each other.

Additionally, there are some household characteristics, such as “born in village lived,” that effects adopters and non-adopters differently. The difference in the sign of coefficients reflect the presence of heterogeneity between adopters and non-adopters; In this case, social pressures from community members may inhibit those from within the community from adopting (Rogers 1962). Other interesting differences between adopter and non-adopter households are number of goat stock owned and if a plow is owned. It may be the case that non-adopter households are spending more labor time investing in livestock management and cultivation with livestock.

TABLE 9: Estimated Coefficients of Agroforestry Adoption and TVP per Household

Variables	(Column I) Adopter TVP per Household		(Column II) Non-adopter TVP per Household		(Column (III) Selection Equation	
Adult Members	-0.997	(0.025)	1.008	(0.031)	-0.957*	(0.026)
Farm Acres	1.376**	(0.133)	1.564***	(0.170)	1.116	(0.140)
Cow Stock	0.051***	(0.011)	0.033**	(0.015)	-0.002	(0.011)
Chicken Stock	0.020***	(0.006)	0.015*	(0.008)	-0.004	(0.007)
Goat Stock	0.001	(0.019)	0.048**	(0.020)	-0.01	(0.018)
Oxcart Owned	0.171	(0.360)	-0.076	(0.484)	0.018	(0.397)
Water Well Owned	-0.469**	(0.222)	-1.003*	(0.516)	0.510*	(0.29)
Plow Owned	0.197	(0.220)	0.512*	(0.305)	-0.192	(0.241)
Highest Education	0.035	(0.029)	0.015	(0.034)	-0.011	(0.029)
Born in Village Lived	0.07	(0.178)	0.517**	(0.207)	-0.217	(0.175)
Credit Access	0.616**	(0.296)	-0.919*	(0.502)	0.582*	(0.312)
Bank Access	0.026	(0.291)	0.621	(0.392)	0.525*	(0.288)
Mobile Banking Use	0.295	(0.254)	-0.153	(0.270)	0.469**	(0.211)
Distance to Tabora Town	-0.006	(0.021)	-0.050*	(0.026)	0.031	(0.020)
Mbola Village Household	-0.515**	(0.207)	0.003	(0.255)	-0.069	(0.217)
Constant	5.009***	(0.496)	4.912***	(0.403)	-0.608*	(0.319)
Belongs to Agroforestry Group					-0.684*	(0.376)
Has heard of ICRAF					0.459**	(0.225)

Observations (N) = 278

Exponentiated coefficients; Standard errors in parentheses
Statistical Significance Levels: * p<0.10, ** p<0.05, *** p<0.01

Log Likelihood = -557.549

Wald Chi2 = 123.02

$r1$ = -0.094 (0.334)

$r2$ = -0.047 (0.365)

Table 10 presents the average treatment effect results from the ESR model on the impact of ICRAF intervention adoption on household logarithmic TVP. The four cases estimated are as shown, where: (a) represents the expected log TVP of those who have adopted (Column I, (6.57)), (b) the expected log TVP of those who did not adopt (Column II, (6.35)), (c) the adopter log TVP had they not adopted (Column II, (6.04)), and (d) the non-adopter log TVP had they adopted (Column I, (6.39)). Cells (c) and (d) represent the counterfactual scenarios. This indicates, households who actually adopted could expect adoption of ICRAF interventions to have increased TVP by about 53-percentage points compared to if the household did not adopt ICRAF interventions (Column III, TT). Households who actually adopted could expect $1262.87 USD, while if adopters had not adopted could expect $791.30 USD. This indicates we can expect that adopters are more food secure from having adopted ICRAF interventions.

However, the treatment effect for the treatment on untreated (Column III, TU) is not significant; in that, we fail to reject the null hypothesis of a no difference of means in TVP between the non-adopter had they adopted and the actual non-adopter. Additionally, the transitional heterogeneity effect (Column III, TH) is positive, that is, the effect is larger for the households that actually did adopt relative to those that did not adopt. Even though the treatment effect for the TU is not significant, it may be the case that adopters have unobservable household characteristics that make them better adopters than the non-adopters, irrespective of household TVP.

TABLE 10: Counterfactual Scenarios via Transitional Heterogeneity Effects

		Decision Stage		
Outcome Variable	**Farm Household Type and Treatment Effect**	**(Column I) Adopt**	**(Column II) Non-Adopt**	**(Column III) Treatment Effect**
TVP Ln/USD	TT	6.57 (.083) [a]	6.04 (.087) [c]	0.530 (.065) ***
	TU	6.39 (.083) [d]	6.35 (.084) [b]	0.034 (.048)
	Heterogeneity Effects	0.18 (BH_1)	-0.31 (BH_2)	0.496 (TH)

*Standard errors in parentheses. ***Significant at the 1% level.*

Column I, represents the estimated mean TVP of actual adopters of ICRAF interventions [a], and the estimated mean TVP of the non-adopters had they adopted ICRAF interventions [d]. Column II, represents the estimated mean TVP of the adopters had they not adopted ICRAF interventions [c], and the estimated mean TVP of the actual non-adopters of ICRAF interventions [b]. Column III, represents the average treatment effects. We conducted a simple t-test to determine the treatment effects. The treatment on the untreated (TU) is not significant, in that, we fail to reject the null hypothesis of a no difference in TVP of the non-adopter had they adopted and the actual non-adopter. However, we reject the null hypothesis of no difference in TVP of the actual adopters and the adopters had they not adopted.

As an additional robustness check, we followed Shiferaw et al. (2014) and compared qualitatively reported food security with adopters and non-adopters of ICRAF interventions. The scale codes households into four groupings: 1) Food secure, 2) mildly food insecure, 3) moderately food insecure, and 4) severely food insecure.[13] We found that 11.2% of adopters, compared to 17.7% of non-adopters, reported moderate food insecurity. Conversely, 51.2% of adopters, compared to 12.4% of non-adopters reported severe food insecurity. The HFIAS scale is generally a good qualitative indicator of how households view their food security, but may suffer from reporting bias or annual changes. For example, a household may feel compelled to answer questions in such a way as to secure potential food support, if they believe our dataset will encourage future aid. Furthermore, households were surveyed during a poor crop year, where drought had impacted the total harvestable yield. Therefore, the outcome of the HFIAS scores likely represent the discomfort and apprehension many of the households were feeling at the time, but may not be generally representative of food security.

5. Discussion

The intended purpose of ICRAF interventions are to increase productivity for small-scale producers, thus increasing household food security. Analyzing welfare impacts of novel agricultural technologies pose econometric challenges, including unobserved heterogeneity and selection bias (Aswaf et al. 2012). The ESRM model

[13] The Household Food Insecurity and Access (HFIAS) scale is an adaptation from the United States food insecurity scale, which captures reliable food insecurity responses that can be quantified and compared across households.

helps to address these problems by controlling for unobserved household characteristics.

Results from the ESRM imply that ICRAF interventions may increase the expected market value of crops produced by the adopting household, where adoption is defined as the implementation and management of *Gliricidia sepium* or an intercropping of both pigeonpea and cassava. Our findings align with much of the agricultural technology adoption literature concerned with food security outcomes, where adopters of improved agricultural technologies can achieve greater levels of food security through increased crop production, and face decreased risk from climatic changes (Khonje et al. 2015; Afsaw 2012; Di Falco 2011).

As a proxy for food security we calculated the total market value of household agricultural production for adopter and non-adopter households. Households who adopted ICRAF innovations could expect a higher TVP (a-b). However, relying on this simple comparison is misleading, and comparing the counterfactual scenarios are a better interpterion of the model. We found that adopter households would have expected a TVP approximately 53 percentage points less, had they not adopted.

5.1 Limitations of TVP

We asked households to report the crops produced in the 2019 agricultural season. Respondents reported the number of kilograms produced, and the price they received if those crops were sold to market. Furthermore, we asked households to report livestock assets and assigned a conservative price for approximately 25% of livestock holdings, assuming they are consumed or sold during the year. Similar to Coulibaly et al. (2017), we accepted that households who reported a higher TVP had

higher crop and livestock production, and could either consume on-farm production, or sell surplus to market for savings, to purchase capital assets, or other consumer goods. However, we also acknowledge that TVP may not accurately portray how the household views their own food security.

We compared qualitative reports of food security (HFIAS), to the proxy TVP to assess subjectivity and consistency of households' own economic welfare. The HFIAS scale ranges from "not food insecure" to "severely food insecure". Questions that fall under "severely food insecure," signify individuals within the household that have significantly reduced number of meals per day, or have gone a whole day and night without eating. Households who are, "moderately food insecure," lack resources to access food and have typically eaten smaller meals, or foods that they did not want to eat due to lack of other options. We found that adopters of ICRAF interventions, on average, report less moderate food security, but more severe food insecurity, compared to non-adopters.

There are a couple of reasons this may be the case. First, it is plausible that efficient crop storage is a barrier to achieving food security. There are typical protocols for long-term storage of maize, where maize is mixed with pesticide and stored in pest-proof bags (Abass et al. 2017). However, these protocols may not be as readily available for pigonepea and cassava storage, or for other crops produced on-farm. Furthermore, the HFIAS scores were collected during a period when households were experiencing a poor crop season due to a late season drought. HFIAS outcomes may be bias depending on the year and month they are collected. Therefore, even though ICRAF adopter households may have produced more

agricultural product overall, there may be market failures, for example, where households were not able to sell surplus products to market, or were not able to store food efficiently. Non-adopters of ICRAF interventions may be producing a smaller variety of crops or fewer kilograms of crops overall, but may have access to better storage methods. Furthermore, if households were asked about their perceived food security when crops were flourishing pre-drought, then responses may have been significantly different.

Another potential explanation for this observation, may be that responses suffer from reporting bias. For example, social desirability bias occurs when respondents provide answers that are consistent with societal norms, or perceived viewpoints of the interviewer (Vaske 2008). Respondents may have believed they would receive future aid, or supports from ICRAF, if they reported that they are more food insecure. Furthermore, it possible that households who are extremely food insecure are likelier to adopt agroforestry practices (Afsaw 2012a). This would be an example of how selection bias can be misleading, where we may think that agroforestry adoption has made household even more food insecure, when in reality, households are likely more food secure from adopting, but are still food insecure because they are the poorer households in the population.

5.2 Alternative Strategies to Estimate Adoption Impacts

In this chapter, we aimed to assess food security outcomes for adopters of ICRAF innovations using an ESRM, and compared those outcomes to a qualitative assessment of food security. Yet, there are some alternative strategies to estimate adoption impacts that are commonly used in technology adoption literature. Some

literature uses propensity score matching (PSM) as a robustness check for ESRM using cross-sectional data (Kiyingi et al. 2015; Donkor et al. 2016). However, methods such as PSM ignore unobservable factors that affect the adoption process, and also assumes the return coefficient to characteristics to be the same for adopters and nonadopters of the technology (Khonje et al. 2015; Adego et al. 2019). It is difficult to model unobservable characteristics, such as skill and motivation of the farmer. PSM requires confoundedness where all of the variables that affect the treatment outcome must be observed, yet unobservable characteristics are unavoidable. Thus, PSM results are often bias and ESRM is generally the preferred method (Adego et al. 2019).

6. Conclusions

We estimated the effects of agroforestry adoption on subsistence farmers' food security in Tabora, Tanzania, using total market value of household agricultural production (TVP) as a proxy. Enhancing food security is fundamental to overcoming poverty in sub-Saharan Africa. Improving agricultural productivity will not be possible without cost-effective, yield increasing technologies (Afsaw et al. 2012). Agroforestry is one possible solution to meet food demands and increase the incomes of rural poor. Agroforestry is generally not a new concept to those living in Tabora, Tanzania. Yet, ICRAF provides research, education, and dissemination of improved systems to increase livelihoods.

Our results showed that adopters of ICRAF innovations can increase household food security, through increased on-farm productivity. Furthermore, households who did not adopt ICRAF innovations could have increased marginal productivity,

yet this outcome was not significant. Finally, the transitional heterogeneity effect is positive, indicating that households who did adopt have household characteristics that make them overall better adopters. These household characteristics could include motivation of farmers or other unobserved managerial skills.

Furthermore, we compare the ESRM outcomes to qualitative reports of food security. We find a discrepancy between adopter and non-adopter households, where adopter households report lower moderate food insecurity, but higher severe food insecurity than non-adopter households. This may be because there are not adequate storage methods for agroforestry crops, indicating reduced food security during a poor agricultural season. Or, the qualitative reports of food security are invalid, due to social desirability bias. Households may have purposefully incorrectly reported household food security to gain potential future aid or monetary supports.

Our results provide important insights for policy design and future research endeavors. First, inadequate local supply of seed and access to information about new cultivars are key constraints for agroforestry adoption in Tanzania (Afsaw et al. 2012). We find that households who heard of ICRAF are more likely to adopt agroforestry systems. We would encourage increased access to agroforestry information and extension services, to increase efficiency of planting and management. Moreover, mobile banking use, as well as traditional banking access, and credit access play an important role in assisting households to adopt ICRAF innovations. Access to credit and financial markets can increase ability to adopt new technologies. Mobile banking services reduce transactions costs associated

with these markets. Increasing cellular tower connectivity, as well as ensuring electricity to charge phones, may be an infrastructure barrier that increases on-farm productivity.

Future research should also explore whether some crops are more difficult to store, especially associated with agroforestry systems. This can be analyzed via tradeoffs between monocropping easily stored and marketable crops (such as maize), and more difficult crops to store and sell (potentially from agroforestry systems). Future data collection could also include qualitative perceptions of food security through both the agriculturally productive and lean seasons, over multiple agricultural seasons, to better assess the impacts of agroforestry on subjective perceptions of food security.

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CHAPTER THREE

A Qualitative Analysis of Development Aid and Path Dependence in Rural Tanzania

1. Introduction

Tanzania currently ranks 159th out of 189 countries on the Human Development Index (HDI), calculated by the United Nations Development Programme (UNDP) (HDI Value = .528). The HDI is calculated by aggregating health (life expectancy in years), education (expected years of schooling/mean years of schooling), and gross national income per capita (GNI). In Tanzania, the life expectancy is 65 years, mean years of schooling is six years, and GNI per capita is $2,805 in 2019 (UNDP 2019). Consequently, Tanzania has accepted aid for development programs from multiple organizations, including the UNDP Millennium Development Projects and the internationally funded World Agroforestry Centre (ICRAF), to improve the quality of life and food security for rural poor.

The purpose of this article is to explore the Millennium Development Projects (MDPs), and other aid organizations including the International Centre for Research in Agroforestry (ICRAF), and to a lesser extent, industrial tobacco industry, within the framework of path dependence to reflect on previous development work. Specifically, I ask the overarching question: how has prior exposure to development projects associated with farmers' willingness to participate in future aid programs? To answer this question, I seek to explore the following research questions: 1) What were the most common aid interventions, and which agency brought them? 2) Which projects were still maintained, or partially maintained at the time of the focus group? 3) What are the recommendations for future aid development? and, 4) Do participants still accept aid, based on their experiences with previous aid projects?

Path dependence explains behavior in hindsight, where small decisions made, based on sensitive dependent initial conditions, result in the final outcome (sustainability of the aid project). That outcome is fundamentally impacted by the type of resource being endowed in the project.

1.1 Technology Adoption and Path Dependence

We inherit language, customs, laws, and skills (Leibowitz & Margolis 1995). Path dependence suggests that current phenomena cannot be understood without knowledge of past events. New decisions are constrained by previous ones, even if the conditions determining previous decisions are no longer relevant (Jerneck & Olsson 2013). **Path dependence theory suggests that realizations from decisions made, in turn result in long-term consequences of how behaviors, beliefs, and policy measures carry forward into the future (Leibowitz & Margolis 1995).**

Gabre-Madhin and Haggblade (2004), conducted a survey among African agricultural specialists, to provide cases of successful improved cassava adoption. They described how many agents, including, individual farmers, private agribusiness, and nongovernmental organizations, determined cassava adoption, as well as production and marketing outcomes. They found actions or interventions taken in a given period determined the subsequent production outcomes, which altered the opportunity sets and incentives in the next period. Additionally, Ajayi et al. (2009), discussed how economic incentives, and historical deliberate planning of policy systems have shaped the development of cotton farming in Cote d'Ivoire. Further evidence from case studies support such influence of path dependence theory in explaining aid outcomes (Cowan & Gunby 1996; Jerneck & Olsson 2013).

In this chapter, I argue that an individual's assumption about the probability of failure is shaped by previous experiences, which forms individual's beliefs about how successes and failures come to be. Moreover, other neoclassical paradigms help to explain aid adoption behavior, including: risk aversion, high discount rate, and market constraints. Farmers who have historically participated in development aid, or even heard stories about successes and failures of development projects, may use that knowledge to assess their probability of failure and choose to adopt the project technology, or not. Additionally, farmers may discount future payoffs from adoption of novel technologies, thus choosing to non-adopt. Furthermore, market constraints such as inability to market novel products, may hinder sustainable adoption of novel technologies. Common pool resources, such as education, may suffer from Tragedy of the Commons (Hardin 1968), where free-riders may benefit, but do not pay. These paradigms help us to better interpret the focus group findings of this study.

To understand the influence of path dependency and initial conditions, it is important to review critical historical developments in agricultural policies implemented in Tanzania, as well as the influence of development projects. The following section provides a brief review on these factors.

2. Background

2.1 Millennium Development Projects in Rural Tanzania

Many aid organizations have tried to impact the trajectory of economic development in sub-Saharan Africa. One of the most notable, globally accepted, and highly funded of these were the Millennium Development Projects. The Millennium Declaration was unanimously adopted by 147 world leaders in September of 2000.

The Declaration committed these leaders' nations to international development objectives to be reached by 2015. The original eight goals included: (1) eradicate extreme poverty and hunger, (2) achieve universal primary education, (3) promote gender equality and empower women, (4) reduce child mortality, (5) improve maternal health, (6) combat HIV/AIDS, malaria, and other diseases, (7) ensure environmental sustainability, and (8) develop a global partnership for development. In September 2015, the Millennium Development Goals were replaced by the Sustainable Development Goals and included 17 achievements, including the eradication of poverty (United Nations)[14].

The Millennium Development Goals (MDGs) were carried out as Millennium Development Projects (MDPs) among Millennium Development Villages (MDVs). Projects that were implemented integrated agriculture, health, nutrition, education, and infrastructure. Countries were selected based on political stability of the government. Village sites were selected based on high under-nutrition of the population, and had local political acceptance. The MDPs began in 14 villages across countries, and expanded coverage in 10 sites. In the 10 scaled up sites, resources were originally concentrated to select areas, known as MV1s. The additional villages added were known as MV2s, which received less-intensive interventions than MV1s (Mitchell et al. 2018). To enhance ownership over the MDPs, governments were encouraged to incorporate the goals into their own political processes.

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[14] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

The Tanzanian Government incorporated the MDGs into national policy documents. In 2005, a National Strategy for Growth and Reduction of Poverty (NSGRP), known as "Mkukuta," aimed to achieve fast, equitable, and sustained growth. The principle of this document is that growth is necessary, but not sufficient for poverty reduction, and that equity is necessary for enhancing livelihoods. The ultimate goal of these plans was to halve absolute poverty by 2010 and eliminate poverty by 2015 (Msoka 2015). Significant strides in the agricultural sector were, and are, necessary to achieve poverty reduction.

2.2 The Agricultural Sector in Tanzania

The history of the agricultural sector continues to impact crop production and circulation today. Food security and policy in Tanzania has varied from socialism as state monopolies and cooperatives to market liberalism and privatization. Tanzania gained independence from Britain in December 1961. The time from 1962 to 1967 was the "post-independence open market period." Ujamaa policy was instated by Julius Nyerere from 1967 to 1985. Ujamaa, or African Socialism, supported collectivized agriculture in government sponsored planned settlements. Ujamaa caused agricultural decline across Tanzania, including an attempt by the state to monopolize crop marketing, lower producer prices linked to an urban industrial bias, cause parastatal inefficiency, and overvalue exchange rates, as well as neglect infrastructure such as roads (Putterman 1995).

The villagization program, adopted in 1967 as part of a national strategy for development, moved millions of rural people into villages of 250 households or more (Abdallah & Monela 2007; Chiteji et al. 2018). The goal was to facilitate distribution

of agricultural inputs such as fertilizer and improved seeds, but major environmental implications of large-scale resettlement were not fully understood prior to implementation. It is now known that the poor location of new settlements on land of inferior quality led to a sharp decline in agricultural yields, as well as an increase in deforestation (Abdallah & Monela 2007).

Tanzania again restructured in the 1980s, and transitioned to a market economy. Yet, the country has imposed periodic export bans on certain crops to secure food availability and national food security (Haug & Hella 2013). However, without policies in place, crop producers face unpredictable "rules of the game," or do not know what the export restrictions will be prior to producing. Uncertain markets leave farmers vulnerable, where they may produce crops and end up with limited buyers.

Haug and Hella (2013) assess the appropriateness of underlying factors identified by the MDGs in explaining food insecurity in Tanzania. Food insecurity continues to be a serious problem in sub-Saharan Africa, compounded by high food prices, climate change, and other uncertainties in relation to future food supply, as well as poor governance and under-investment in agricultural development. By 2011, the Government in Tanzania declared MDG1 (reduction of hunger and poverty reduced by 50%) would not be achievable. Average food prices have steadily increased in Tanzania with considerable seasonal and in-country variation. Although Tanzania has been able to secure sufficient food at the national level, the country still has a serious undernourishment problem. There has been a weak relationship between

economic growth and nutrition outcomes in Tanzania, where the agricultural sector has experienced slower growth than other sectors (Haug & Hella 2013).

Progress was made in Tanzania using the MDGs as a framework for development. Still, the Millennium goals were far-reaching, and some criticize as impractical (Easterly 2009). To continue to reduce poverty, rigorous evaluations are needed at the village-level to reflect on the successes and failures of the MDPs.

3. Methods

The Tabora region is located in the Uyui District in central Tanzania. I developed a semi-structured interview guide addressing The World Agroforestry Centre (ICRAF) projects, those conducted by the MDPs, and to a lesser extent the tobacco industry. The Millennium projects were implemented in 15 villages. I visited six of the original MDVs: Mbola, Isila, Mbiti, Msiliembe, Ibiri, and Migungumalo.

Recruitment for focus groups occurred during consent for a questionnaire, which took place during the prior two months. Each household representative who completed a questionnaire was asked by an enumerator if they would be willing to also participate in a focus group for their village. If the participant agreed, their name and telephone number were recorded for follow-up. Approximately, 74% of participants reported having at least one cellular telephone in their household. The local guides called between 10 and 15 participants one week prior to their scheduled focus group. Participants received 1 kilogram of rice as a gift for their time.

Focus groups were comprised of 10-15 participants from six villages in Tabora, for a total of 63 participants (Table 11). Each group consisted of the village chairman, two hired local guides, the translator, subsistence farmers, and the researcher. Each

focus group took between approximately 60 and 90 minutes. I asked each question from the IRB approved schedule of questions, and would ask follow up questions about interesting information offered. Data from these focus groups were audio recorded and transcribed. During focus groups a translator switched between English and Swahili. The researcher would ask the question in English, the translator would ask the focus group in Swahili, and then translate back to English for the researcher. Audio transcription is the English translation only. Typed notes were also taken as back-up documentation.

TABLE 11: Number of Focus Group Participants from Six Villages in Tabora, Tanzania

Village	Males	Females	Total Subsistence Farmers per Focus Group	Focus Group Duration
Mbola	9	1	10	1 hr 53 min
Mbiti	8	2	10	1 hr 10 min
Migungumalo	7	4	11	1 hr 12 min
Msiliembe	6	4	10	1 hr 32 min
Ibiri	10	3	13	1 hr 04 min
Isila	6	3	9	1 hr 04 min
Total Participants (N) = 63				

Focus groups were comprised of both males and females from each village, including the chief of the village, the local guides, translator, and researcher. Participants were recruited from a survey that began two months prior. Focus groups ranged from approximately one hour to almost two hours in duration.

Inter-rater reliability for qualitative coding was conducted with two trained qualitative social scientists from Oregon State University (Rater A and Rater B) (Tessema 2010). Three meetings were held with raters. The first meeting was to give a brief overview of data collection methods and the purpose of the study. Raters were asked to open-code an entire focus group each, from two separate villages independently. The second meeting, raters were asked to compare codes with the codebook that I developed. The codebook was then updated to reflect agreement on codes and definitions (Appendix C). Raters were asked to use the final codebook to re-code the same focus group. In the third meeting, raters were asked to compare coded dialogue with the applied codebook. Where codes differed, we came to complete agreement. Coding patterns revealed aid projects and their corresponding aid organization, as well as the sustainability of those projects. Other parent codes include suggestions and requests for future aid, and aid acceptance.

Krippendorff's alpha[15] was calculated based on the third meeting coded dialogue prior to complete agreement. Rater A had a pairwise percent agreement of 91% and a Krippendorff's alpha of .66. Rater B had a pairwise percent agreement of 95% and a Krippendorff's alpha of .73. The lower bound of reliability is .60, with the norm for good reliability around .80 (De Swert 2012). Using NVivo qualitative coding software and the final codebook, I explored the prevalence and interactions of codes to develop themes that arose reflecting past aid projects, their impact on the community today, and recommendations for future development. Furthermore, I

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[15] Krippendorff's alpha is a reliability coefficient, which measures the agreement among raters or coders. This method is used in qualitative content analysis to assess the observed disagreement among values assigned to units of analysis. The general form is:

$$\propto = 1 - \frac{D_0}{D_e}$$

Where D_0 is the observed disagreement among values assigned and D_e is the disagreement one would expect when the coding of units is attributable to chance, rather than to the properties of the actual units.

Where:

$$D_0 = \frac{1}{n}\sum_c \sum_k o_{ck}\delta_{ck}^2$$

And:

$$D_e = \frac{1}{n(n-1)}\sum_c \sum_k n_c n_k \delta_{ck}^2$$

Where, o_{ck}, $n_c, n_k$and n, refer to the frequencies of the values in the coincidence matrices. When observers perfectly agree $\propto = 1$. When observers agree, as if chance had produced the results, $D_0 = D_e$, and $\propto = 0$, interpreted as the absence of reliability (Krippendorff 2011).

corroborate focus group findings with The Economic and Social Research Foundation (ESRF) report, completed in August 2013, to evaluate the outcomes of the MDGs.

4. Results

Path dependence suggests that decisions result in long-term consequences of how behaviors, beliefs, and policy measures carry forward into the future. Focus group participants discussed how decisions made during aid interventions currently impact their behaviors and beliefs regarding introduced technologies. Additionally, I found that private incentives, farmer time preference, and capital assets, impacted adoption of agricultural technologies. Furthermore, common pool goods were plagued by the free rider problem, which ultimately resulted in under-provision of education, health services, and infrastructure.

According to the ESRF report (2013), the MDPs started with community training, empowerment, and identification of sectoral needs such as education, agriculture, health, environment, and infrastructure. Monitoring committees were formed, such as the health committee, education committee, and agricultural and environment committee. These committees had 557 members (45% of whom were female), whose main role it was to oversee project activities. The ESRF report found that within that 12-year period (from 2001 to 2013), achievements were made in primary school enrollment (MDG 2), infant and under five mortality (MDG 4), and reduction of malaria, HIV, and other major diseases (MDG 6). Goals that still had significant challenges were poverty reduction (MDG 1), maternal mortality (MDG 5),

empowerment of women (MDG 3), environmental goals (MDG 7), and global partnerships for development (MDG 8) (ESRF 2013).

There were several challenges reported in the ESRF report. First, there were few extension officers to conduct farmer trainings and monitor progress. Second, there was over enrollment of schools caused by preferences of students from other villages to join the MDV schools. This increased the ratio from 1 teacher per 40 students to 1 teacher to up to 65 students, which resulted in overcrowding of classrooms, insufficient desk space and books, insufficient sanitary facilities, and stressed teachers. Furthermore, students from outside the village were traveling longer distances, reducing their school performance. Third, health services became strained due to patients from other villages traveling to MDV areas for treatment. Fourth, initially it was proposed that users of water projects should pay 25 Tanzanian Shillings (TSH) per 20-liter bucket, but this became unenforceable. Fifth, unnecessary bureaucracy in administration of funds through the district council delayed implementation of activities, and disbursement of funds from UNDP. Additionally, cooperation from public and local leaders was low because the projects did not pay for direct involvement (ESRF 2013). Five years later, the issues divulged in the ESRF report were echoed during the focus group discussions.

The first and second research questions are addressed in the following sections. We explore the most common interventions by aid organizations, and use participant accounts to understand if the projects are still maintained or partially maintained. The most common interventions mentioned in the focus groups were agricultural, which included education on crop fertilization, improved crop varieties,

and spacing. Agriculture interventions were brought by Millennium, as well as ICRAF and the tobacco industry. Other interventions discussed were primarily brought by the MDPs. Often, entrepreneurship opportunities would be discussed in conjunction with agricultural intervention. Infrastructure projects were also commonly mentioned, which included road building and widening, water-wells, and improved housing. Health measures, such as the creation of a health clinic and transportation to the clinic, dissemination of medications and mosquito nets, as well as health and sanitation education were also discussed. Improved education for students through free school lunches, and monetary support to attend school were impacts of Millennium that villagers wish would have continued.

4.1 Agricultural Interventions

4.1.1 MDP Agriculture

Participants explained that productive capacity of agricultural interventions have decreased. It was common for individuals to explain that crop yields were very high when Millennium intervened during a two-year period. During this time, they saw immediate results from inorganic fertilizer use. When asked if they continued using the high yielding seeds and fertilizer as Millennium had shown them, participants would often lament that they do not have enough money to invest in these technologies. Some participants indicated that they were able to buy some fertilizer, but not enough, whereas other participants indicated they were unable to purchase any technological improvements.

> **Mbola Village**
>
> R (Researcher): Did the millennium help the productivity of the crops on your farm?

> T (Translator): He say that, actually when the productivity was…when the two years during when the millennium was here they get a good maize, because they were getting the fertilizers. But later, the production went down.

It was noted in the ESRF report (2013) that during MDV interventions, some farmers used less than half of the land for cultivation prior to aid intervention with higher crop production, which was encouraged to reduce stress on the surrounding forests. Furthermore, from 2007 to 2009, almost 6,000 famers were trained on best agricultural practices for crops such as sunflower, cotton, cassava, groundnuts, and sweet potatoes. Agricultural interventions were brought by ICRAF as well.

4.1.2 ICRAF Agriculture

ICRAF has been active in the Tabora region since 1989, at first promoting planted woodlots, and in more recent years, intercropping practices. Cassava and pigeonpea are woody perennial crops that can be left in the field for multiple years. Pigeonpea provides a non-animal source of protein and fixes nitrogen, whereas cassava grows in nutrient poor soils and is a staple food for households in times of drought. Young leaves of cassava plants are added to vegetable stews, and tubers are harvested and dried for flour or as a snack in strips. However, participants reported problems with leaving these crops in the field for multiple years.

Mbola village provided three distinct reasons why they choose not to leave cassava for multiple years. The first reason was because the improved varieties grow faster and households are able to consume what they plant in the same season. The second reason, was because participants reported a texture change in the root, which is unpleasant to eat. The third, and most commonly reported, reason is the “roots rot.”

Mbola Village

R: I heard about management of cassava and pigeonpea. I learned that sometimes they take the whole plant out every year. I want to know why they take the whole plant out…
T: Cassava, it matures, if it stays long in the soil, the roots can rot. Rotting is a problem for the cassava if it stays for more than one year. So, they take it away… He says that if the cassava stays long in the soil it becomes porous inside. It becomes like a sponge. They take away before it gets like a sponge.
R: So the older root, the texture changes and they don't like it?
T: yes.

Msiliembe and Mbiti Village also discussed the problem with roots rotting. Pathogens such as African cassava mosaic disease, cassava bacterial blight, and cassava anthracnose all impact Tanzania. In particular, cassava mosaic disease and cassava brown streak virus are spread through the whitefly (*Bemisia tabaci*). A study conducted from 2010 to 2013 found that areas in north-western Tanzania, including Tabora, were impacted by a pandemic of cassava mosaic disease (Tajebe et al. 2015). The whitefly causes leaf distortion and stunting, elongated lesions on the stems, and a corky brown necrosis of the tubers (Alabi 2011). These are all symptoms reported by participants in the region. Many organizations, particularly the International Institute of Tropical Agriculture (IITA), have worked on whitefly resistant cassava varieties. However, increasing dissemination and confidence in these varieties may be a barrier to overcome.

Village participants were asked about ICRAF interventions (pigeonpea and cassava intercropping or planting Gliricidia), in particular. If villagers did not participate in ICRAF interventions, they were asked about general intercropping practices. Some participants in Isila confirmed that they had tried planting pigeonpea, but it did not yield as expected. Households are intercropping with cassava and grounduts, and intercropping with other crops such as cowpea (black eyed peas, *vigna*

unguiculata), maize (*zea maize*), and other leguminous crops. Similarly, Ibiri participants reported planting maize and leguminous crops. Both villages reported learning about general intercropping practices from their parents and not ICRAF specifically. When asked why they preferred intercropping as opposed to monocropping, a participant in Ibiri stated that intercropping reduces labor. The mixing of leguminous crops increases soil fertility, thus potentially increasing yields on a smaller parcel of land.

Isila Village

R: And is anyone doing pigeonpea and cassava intercropping?
T: They say they planted cassava in pigeonpea but it did not perform very well. So they did not continue…
R: What crops are they intercropping?
T: Cowpeas, corn, leguminous crops
R: What about the cassava?
T: Cassava and groundnuts
R: And where did they learn that from?
T: They said some of them they get it from technicians, but others they got it from their parents…

Similarly, planting *Gliricidia sepium* can increase soil fertility. Participants in Mbola Village perceived planting Gliricidia as having a positive impact on soil fertility, but preferred not to wait for benefits. They reported that the labor time to invest in Gliricidia management outweighs the cost of waiting for potential soil benefits. Planting Gliricidia and intercropping practices were introduced to the region post-millennium projects. Therefore, households had already experienced a bumper crop from inorganic fertilizer. The wait-time it takes to see tangible benefits from agroforestry practices is outweighed by labor costs, as well as the perception of how aid interventions should perform. In other words, households experienced a bumper

crop of maize the same year inorganic fertilizer was applied during the MDPs, and households wanted to experience immediate results from Gliricidia interventions.

Mbola Village

R: But it seems like there are still many people in the village that don't take advantage of the Gliricidia… Why is that?
T: more labor …he is saying that most of the people that want to see the benefit immediately. He says the benefits from the Gliricidia takes a very long time, so other people they see that…but they know the benefits take a very long time.

4.1.3 Industrial Tobacco Production

Both ICRAF and industrial tobacco purchasers have introduced planted woodlots to the region. ICRAF introduced planted woodlots, comprised of native acacia, for erosion control and to reduce cutting trees from the surrounding woodlands. Similarly, the tobacco companies encouraged planting woodlots to prevent cutting from open-access lands, but for the primary purpose of curing tobacco and normally comprised of Australian eucalypts. Participants reported preferring the native species to the introduced eucalypts because of allelopathic effects of eucalypts, as well as reducing the surrounding water table.

Isila Village

R: Ok, so they learned from two groups, ICRAF and Tobacco companies …and is there anything that ICRAF said different than the tobacco companies? About the Woodlots?
T: He is saying that tobacco companies, they only focus on the trees for growing tobacco. But ICRAF…woodlots, soil fertility, and fodder
R: And do they prefer the acacia or the eucalyptus?
T: They prefer the acacia
R: For what reason?
T: They say because of the weather of this area…the sort of acacia they prefer them to grow in this area, because of the weather.

Focus group participants were also asked about the labor tradeoffs they make to enter the tobacco market. Participants in Ibiri, Migungumalo, and Msiliembe all

reported that tobacco companies put a quota on the amount of tobacco purchased, and were generally unclear about the industry's willingness-to-pay per kilo until selling day. Tobacco is a cash crop. For example, the reported average price per kilo is $0.58 USD for tobacco, whereas the average price per kilo for cassava is $0.12 USD. As reported by a participant in Migungumalo, if the household chooses to cultivate tobacco, it takes away land and labor that could be allocated to other crops. However, tobacco is not edible. If households are unable to sell a portion of their tobacco harvest, then the tradeoff is negative between tobacco and crops for consumption. Yet, if a household is able to sell all of their tobacco harvest, then they are able to use the profits to buy edible goods and conceivably have some left over for savings, livestock, education, or travel.

> **Migungumalo Village**
> T: …He has another point, tobacco cultivation is time consuming, so some other crops cannot be taking up (*time and labor*)
> R: So just so I know, the tobacco season is the same as all of the food crops?
> T: The tobacco, they normally start it in November. Once they start the tobacco is labor intensive, time consuming, so they can't divide themselves because maybe of the household members. That is why some of the crops are being abandoned for cultivation.
> R: And how do they see the market for tobacco? Do they see it's pretty good? Or are they thinking maybe it won't be so good in the coming years?
> T: …He is saying normally they cultivate big amounts of tobacco, but when the company comes they don't take all of the tobacco.

From Migungumalo, we may infer that there was a monopsony, where there was only one tobacco buyer, who was able to exert market power over farmers in the region. Households may base the amount of tobacco planted off previous years, guessing at the amount the tobacco industry will purchase. Yet, tobacco growing households have limited time and land to devote to crop and tree management, and

must choose what crops and interventions to continue using based on their historically perceived benefits.

4.2 MDP Projects

4.2.1 Entrepreneurship

Entrepreneurship projects were often mentioned in conjunction with agricultural aid in Mbiti Village and Mbola Village. Entrepreneurship projects were started to provide increased opportunities to generate income. Both villages were taught to process indigenous fruits into jams and wines. In Mbiti village, participants expressed that they do not have enough knowledge to continue the project, whereas those in Mbola have tried to continue the processing and are unable to find a good price at the market in Tabora Town. According to the ESRF report (2013), 316 beekeepers were trained to increase business opportunities, and 32 hives were provided.

Mbiti Village

R: And the fruit processing? Is that finished? Nobody does it?
T: No more.
R: And why not?
T: The problem with this is knowledge. They are not knowledgeable enough to continue processing fruits.

Mbola Village

T: Processing indigenous fruits, wine, jam, and also honey
R: I am wondering if anyone has anyone tried to go to town to sell the indigenous fruits and honey?
T: They take the product to the market, but it is terrible. They cannot get a good price.
R: And it's because people don't want to buy it? It's not common in the diet for people to eat it?
T: There is no proper (*market*)….so it is just a matter of going and asking, "do you need this one?" … The problem of market is very big.

There was a disconnect between Mbiti and Mbola village. Those in Mbola could help individuals in Mbiti with processing training, but they would still need help with marketing the products effectively. Furthermore, both villages mentioned honey processing as a project that has continued. There are small groups of individuals who are involved in continued beekeeping. However, both villages mentioned that a robust market to sell products is lacking. None of the participants in focus groups were involved directly in honey processing. Entrepreneurial projects generally did not meet their intended goals of increased household income.

4.2.2 Health Interventions

Villagers believed the longest lasting impacts of health interventions were education for women about pre-natal care, as well as education about bed-nets and reducing malaria.

> **Isila Village**
>
> T: He says that …reducing malaria. They give knowledge…the health officers visit the community and give knowledge. Health is number one compared to other activities.

Participants at Isila Village believed that health interventions had the longest lasting improved impact, compared to other interventions (agricultural, infrastructure, and child education programs). However, not all aspects of the health interventions are ongoing. Villagers reported that trained nurses often treat villagers for no pay. In Isila, participants stated that nurses only make small amounts of money from giving seminars, not from treating patients. Migungumalo Village reported that transportation to the clinic using bike or vehicle is no longer available, putting a large burden on the sick to travel for medical attention. The ESRF report (2013) also

corroborates that health services and testing of HIV increased. According to Msoka (2015), he prevalence of HIV for women age 15-24 declined from 24% in 2007 to 19% in 2012 due to MDP intervention.

4.2.3 Infrastructure Interventions

Infrastructure, including road building and widening, water-wells for domestic use and irrigation, and solar panels were projects that were intended to further increase agricultural production, and increase access to markets. Furthermore, computers were connected to a solar grid for schools, and cellular telephone usage significantly increased. Prior to the MDPs, the villages did not have cellular telephone towers. The ESRF report indicated that 28km of village roads were improved and another 13.4km of road was upgraded. The road infrastructure project was conducted in collaboration with AirTel to establish cell towers, which were donated to health workers to increase communication for emergency services. However, villagers reported that some roads or road widening projects were promised and not fulfilled.

Migungumalo Village

R: ok. Is there anything they believe that millennium could have done differently?
T: He says they could do, very important thing to them, infrastructure…the road. The road which was something very important for them but they did not …even electricity.
R: Did they ask for electricity, or what happened?
T: They say it was one of the plan of millennium, but it was not done.
R: Do they know why it wasn't done?
T: They don't have any idea. They say that maybe because of the time frame they had, maybe one of the reasons why

Additionally, clean drinking water is imperative for domestic use. Communal wells were constructed in every village to ease the time burden of accessing water. However, as reported by Isila Village, 10 wells were built and only one is still

functional. Focus group comments from Msiliembe, Mbola, and Mbiti echoed these sentiments, where either water wells have dried up due to poor construction and foresight, or were promised and not completed. In fact, many infrastructure projects were reported to have been promised, but not accomplished. Isila reported to have received a road widening project, which decreased their travel time to Tabora Town and local markets. Mbola and Migungumalo were similarly promised road infrastructure aid, but they did not receive these projects. Additionally, electricity or solar projects were promised in Msiliembe and Migungumalo, yet there was no follow through. When asked why these project promises were not completed, there was an overall lack of awareness or feeling of finality.

Participants from Mbola believed that once the MDP's phased out, the government should have continued the projects. Participants discussed how they are continuing to wait for electricity from the government. Ibiri was the only village, at the time, that had received an electric grid. Respondents reported that students could work at night, and their time for labor has increased because they can work into the evening. Furthermore, those with electricity can view television for leisure and education, and they can use machinery for faster food processing. Ibiri participants discussed how wealthier households pay for electricity, and are able to share with poorer individuals, especially for watching television.

4.3 Child Education

The last Millennium project that was commonly discussed was the school lunch program and student sponsorships. The School Feeding Programme, which began in 2008 increased student attendance from 60% in 2008, to 85% in 2012. The

exam pass rate increased from below 25% in 2008, to 65% in 2012. Participants from Mbiti and Isila mentioned free school lunches provided to students. Some students walk many miles to school and do not eat all day, or some students walk home for lunch, but are too tired to return to school in the afternoon. This reduces focus and overall academic performance among students.

Mbiti Village

> T: He is saying with what happened with millennium …their children... the performance was very high. Phasing out. The performance has declined.
> R: Why did it decline?
> T: Because by that time they were getting food from the schools. So, students were, there was no trouble for getting food from places. So most of the time they went to school …
> R: So now, the students they go home for lunch? And then they go back to school?
> T: Yeah. They go home to get food, and then go back to school

Additionally, Migungumalo respondents recalled that Millennium was sponsoring some students from poorer families to attend school. Once Millennium left, these projects were discontinued.

Magoti (2016) assesses Tanzania's success in implementing the MDG of achieving universal primary education. Tanzania experienced an increase in school enrollment from 2004 to 2014. Yet, the country faced challenges including drop outs due to pregnancy, death, inability to meet school basic needs, and illness. Truancy, or absenteeism, was the main cause of dropout (65%) due to the inability to meet school needs. Approximately 4% of primary school girls failed to complete primary school due to pregnancy, almost twice as much as dropouts caused by illness.

Additionally, as enrollments increased resources did not match student needs, creating ineffective learning environments. In 2014, the average pupil to classroom

ratio was 74 students per classroom. In neighboring Shinyanga, the average ratio was 141 students per classroom, and in Tabora region, the ratio was 304 students per classroom. Furthermore, teacher's basic pedagogical knowledge was lacking in pre-primary school where 53% had qualifications, and 47% had "other" qualifications. Furthermore, while the proportion of girls to boys school enrollment has been more equal, the ratio of girls to boys decreases as they get older. Additionally, by the end of the MDPs, about 72% of women were literate compared to 82% of males.

4.4 Fulfilling Requests

In this section, we investigate the third research question, what are villager recommendations for future aid development? Tanzania made it a priority to tackle poverty and food insecurity by committing to the MDPs in 2000. Although the MDGs were not successfully completed, the MDVs benefited from sustainability or partial sustainability from selected aid programs, including the cellular telephone towers, health workers, honey production, and some agricultural management education. Soliciting feedback from focus group participants about improvement for future aid, they supported three general actions: 1) increased education and capital inputs, 2) project planning inclusion, and 3) sustained infrastructure including roads, water (irrigation and water-wells), and electricity.

Each of these requests have their own difficulties to overcome. First, education must be supported and ongoing. Participants in Mbola stated that education is necessary, but not sufficient in sustaining development aid. Once aid workers leave, they take with them knowledge and advice, as well as injection of money, capital, and organization.

Mbola Village

> T: He's lamenting a lot…look the way it is. There have been many projects here. But if you see Mbola, there is not anything you can say as if …there are many projects here. People here, it is as if they don't have any education at all. So, they need actually, things to be sustainable.
> R: How does he propose that happen?
> T: The issue normally comes from top-down. When things come …it gets away…because the villagers they are not involved. If things come, and they finish…the people remain here. The decision it comes from the top. They need to be involved

Both focus group participants and the ESRF reported (2013) insufficient extension agent trainings. In fact, participants in Msiliembe village reported that the field officers did not visit their village, and they had relied on tobacco technicians for agricultural education.

Msiliembe Village

> T: They are saying there's a problem…the challenge of agricultural field officers. They don't have field officers here. They normally depend on tobacco company technicians. They only come here…he only talks about tobacco. He can't talk about any other crop than tobacco. There is no communication between them and the regional authority. Sometimes they need to plant maize or cassava and they don't have any communication with the authority to help them.

Furthermore, focus group participants yearned for more project inclusion, including what types of projects are to be conducted, as well as how those projects are disseminated. A participant in Isila believed that agricultural education was not sustainable because large groups of villagers were gathered to learn about farming practices, where too much information was given to too many people. The participant believed that if small groups were given rigorous education, then the spillover effects could be more sustainable to the rest of the village. Including the ideas of local villagers, not only the suggestions about the type of project, but how to deliver the aid, could be helpful in promoting sustainability of interventions.

Isila Village

R: What could be done in the future to make sure these types of things are continued?
T: He is saying it was not good because they were teaching so many people. It was not possible for them to grasp what was taught. He suggests that there could be a small group of people that could get the knowledge …they could become a spill-over of the technology. But they taught so many people it did not survive. They were not competent to do what was taught by millennium village.

Furthermore, capital inputs, such as improved seed varieties, go hand in hand with improved education. Once new seed varieties are disseminated, best practices on seed collection and storage could increase the sustainability of increased crop production (Afsaw 2012).

Participants frequently requested sustained infrastructure projects, including roads, electricity, and irrigation. Many respondents reported that these types of projects were planned, but not completed. When asked why the projects were promised and not fulfilled, they often reported not knowing why and would speculate about time limitations.

Migungumalo Village

R: ok. Is there anything they believe that millennium could have done differently?
T: He says they could do, very important thing to them, infrastructure…the road. The road which was something very important for them but they did not …even electricity.
R: Did they ask for electricity, or what happened?
T: They say it was one of the plan of millennium, but it was not done.
R: Do they know why it wasn't done?
T: They don't have any idea. They say that maybe because of the time frame they had, maybe one of the reasons why.

Ibiri is a good example of the poverty alleviating effects of sustained public infrastructure. Ibiri was the only village that had received an electric grid from the government at the time of the focus group.

Ibiri Village

R: Can they tell me about the change (*getting electricity*)?
T: A lot of things they are mentioning. Now they can even see TVs, some students now they can take their studies to night, time for work has increased because they can work at night, mentioned they have machines for processing, now he is saying that there are farmers who …increase in capital…for those who can pay they can get the processing.
R: So, they have to pay for it (*the electricity*). Is there sharing going on? If you're a small farmer and can't pay for electricity, do you go to a friend's house to watch TV?
T: Yes

Participants in Ibiri report faster crop processing and more labor hours during the day. Additionally, they report some resource sharing among friends. Based on discussions with focus group participants, all villages have expressed the need for basic public works such as road widening, electricity, and clean water to increase their quality of life.

4.5 Aid Acceptance

In this section we explore the fourth research question, do villagers still accept aid based on their experiences with previous aid projects? Participants from Ibiri and Isila village referred to aid workers as pests. Often said jokingly, stories have been circulated that with Millennium came "super bugs," that are now resistant to mosquito repellent. With outsiders may come difficult situations, such as the undue bureaucracy imposed, which limited the capacity of the projects.

Ibiri Village

T: They are no longer using the millennium nets, but they have nets which they got from somewhere else. It was a long time since they were given. *Laughing*. They are saying with millennium came a lot of pests.

Yet, even with potential problems, villagers expressed their acceptance of past aid and requested future aid.

Isila Village

T: He says actually, when the project came. It gave them hope. Because they were producing for two years, but later, they did not get this again…so they failed completely, because they think that maybe if they can get another project that can boost them in terms of agriculture - they would be very happy.

Participants from across villages felt hopeful that the MDPs would improve their lives. Many projects from the MDPs were not maintained, but participants reflected on the improved economic conditions while capital, cash, and education were injected to the region.

Mbiti Village

T: She is pressing that…when millennium was here. Even the economy improved. Now what they need is to make sure …the millennium should come again. It should come again to work with them so that the economy should be improved as it was before.
R: In what ways did the economy improve?
T: Actually, she is saying that when millennium was here…the knowledge they got from millennium it helped them to produce more than it was before. They get more … the food, and then they get the money. So, if it comes back…it means it will resume. As millennium was here.

A participant in Mbiti believed that if aid projects would return, then villagers could receive the same benefits as when the MDPs were actively in the region. This suggests that participants are still open to receiving aid projects, and may actually prefer aid projects to return to boost their economic well-being.

Nevertheless, participants in Mbola were aware that projects were not sustainable, and that they would have to be carried out differently in the future to ensure continuation.

Mbola Village

R: What could be done different to make sure that people really took advantage of the technology?
M: He is saying that…I think what they could need…is to get more education. About what they bring here. Millennium did not give them enough education, to make sure that whatever they do they understand. He is saying that ICRAF …they get knowledge for establishing pasture for livestock, how to get goats that

> can feed on the forage. But they had no money to buy those goats or those livestock to feed those grasses. So that knowledge was not good for them. It could be possible to get the livestock to feed those grasses that they were taught about, but there is no money.

Participants insinuate that both project capital and education must be paired to enhance sustainability. They provided an example, the MDPs left villagers with capital but a lack of education to continue using it once Millennium departed. Participants also provided a counter example, where ICRAF brought education about sustainable grazing systems, yet many people lacked the livestock to implement the technology. Participants across villages were aware that projects were not maintained, and believed that if given a second chance, could correct the mistakes made during the previous decade of failed development projects.

5. Discussion and Conclusion

5.1 Path Dependence

In the discussion section we will focus on key results from focus groups to clarify how economic incentives drive sustainability of aid interventions. Development programs can be difficult to execute when households experience negative outcomes, such as unfulfilled promises and external stressors that may not have been present prior to the development aid. The purpose of the MDPs and other aid projects was to give a big push onto a higher growth path, out of poverty. With continued education initiatives, basic infrastructure, and monetary input, villagers could have possibly sustained that development trajectory. However, once capital and aid workers left, the villages resumed a lower level of growth, as discussed in the

focus groups, where participants stated that it was as if no aid project had ever been in the village. This finding was corroborated through the ESRF report (2013).

For example, ICRAF tried to implement perennial intercropping systems, but households have experienced pests and disease. Therefore, even if they are given improved varieties, they may wish to stick with the lesser technology of harvesting perennial crops every year to reduce perceived risk. Additionally, ICRAF has tried to increase plantings of Gliricidia. Some households have been patient to receive soil nutrient benefits, whereas others expected to see crop increases within the same year. Some households, who may have a higher discount rate (or time preference for benefits today), may have an expectation that fertilizer application should take a short amount of time before seeing benefits. This could be influenced by the expectation through the MDPs, who pushed for inorganic fertilizer application. Had the MDPs chosen to introduce organic fertilization methods, or pushed for a mixed methods approach (organic and inorganic fertilizer methods), then perhaps expectations of crop management may have been different. The results of projects, across aid organizations, may set expectations for future project outcomes.

Agricultural activities were the most common entrepreneurial endeavor mentioned by participants. The ESRF reported (2013) insufficient agricultural extension training and monitoring, yet 6,000 farmers were taught improved farming techniques. The ESRF also indicated that groups from within the village were formed to oversee progress on the MDGs. It may be the case that Millennium recruited local leaders and participants to maintain the projects, and to transition to local governance once MDP left. However, a primary issue was the low collaborative effort of local

leaders, indicating a lack of agency. According to the ESRF, local leaders were not paid for their involvement, reducing their participation overall. Furthermore, ideas from participants may have been overlooked or not solicited to the full extent. Pressures may have been felt by aid workers on the ground to appease donors and secure funding through the bureaucracy imposed, limiting capacity to improve projects.

Poor experiences with development agencies may lead to future reluctance to accept aid. However, this was not necessarily the case in this case study. Even though focus group participants reported many unfulfilled promises and discontentment with discontinuation of projects, they continued to appear accepting of future aid. Some participants even reported feelings of failure that the projects were not sustainable. It is likely that even though the level of poverty reduction desired was not achieved, the new growth trajectory is likely higher than their previous pre-MDP growth path on aggregate. For example, the nurse station was still partially functional, and those farmers who benefited from agricultural education could continue to use that knowledge to improve their farms. In fact, participants reveal to be open to having development projects return to re-gain a high level of donor-funded capital inputs.

Mitchell et al. (2018) conducted a retro-active exploration of the MDVs, with the aim to evaluate: (1) the project's effects on outcomes of interest within MV1s, (2) if the project-specific targets were met within MV1s, and (3) how much was spent by site, stakeholder, sector, and year within MV1s as of the year 2015 across MDP countries. Using econometric methods, they discovered similarities to our findings. Their results indicate that substantial impacts occurred in agriculture and health, with

less conclusive results from poverty, nutrition, and education outcomes. Had aid workers been aware of incentives based on resource type, sustained poverty alleviation may have been more achievable across aid projects in Tabora.

5.2 The Free Rider Problem: Common Pool Resources

The MDPs increased common pool goods that could have benefitted from being privatized or rationed in some other way, including infrastructure projects, education, and health care. Perhaps, due to the combination of geology and equipment, aid workers were unable to dig the water-wells deeper. Each additional bucket of water taken from the well reduces the next person's consumption capability. Millennium tried to impose a payment strategy to more sustainably extract the resource. However, the strategy was ultimately unenforceable, creating a tragedy of the commons situation (Hardin 1968).

The tragedy of the commons problem was also evident for schooling, where increased enrollment from students from outside villages reduced education quality and resources for MDV students. This problem was similarly accounted for with the health clinic, where emergency services were in higher demand from non-MDVs, reducing overall functionality. According to Libecap (2008), overexploitation or under provision of public goods arises from incompletely defined and enforced property rights. Libecap (2008) explores options for mitigating losses from open access or common pool goods.

One suggestion, for water-wells, would be to create an enforceable permitting system, where the titles for water allocations could be adjusted in response to climate change and technological changes. Households could then buy or sell permits

depending on how much water they need (Libecap 2008). Creating ownership over the water resources may reduce stealing or free riding.

However, solutions for education and health services can be even more complicated. According to Wells et al. (2007) the full cost of health care is often not charged to patients. Focus group participants reported that nurses are not being paid for upholding their position, and only make some money from seminars about health practices. Suggestions from Wells et al. (2007) include preventative health care measures or potentially a more efficient insurance program, where a small fee is paid over-time to prepare for a catastrophic event. However, they note that distribution of services that are both fair and equitable is a problem extremely difficult to solve, and any solution is bound to have some problems. Health care is similar to under provision of education, where excluding students from obtaining an education by creating a permit or payment program could result in efficient classroom sizes, yet may not be equitable.

5.3 Private Goods: Agriculture and Entrepreneurship

Private goods are owned by their user, and can be bought and sold due to their relative scarcity. ICRAF, the tobacco industry, and Millennium all incentivized increased production of private goods, mainly in the form of increased agricultural production. The main challenges expressed by focus group participants were related to incomplete markets, and risk aversion. Leaving perennial crops for multiple years, and selling other introduced agro-business products (jams, jellies, and honey), posed serious risk due to potential pests, disease, and lack of market for products, respectively. Therefore, activities, such as agroforestry and new technologies or

entrepreneurial activities, promoted to increase household production, in reality may require more capital, labor, and time allocation for potentially reduced production, if not managed optimally.

5.4 Conclusion

Fifteen villages in Tabora, Tanzania received development aid from multiple organizations, including the UNDP Millennium Development Projects, ICRAF, and tobacco industry. I visited six of the original 15 villages to explore the impact of prior exposure to aid projects and how that influenced farmers' willingness to participate in future aid programs. Soliciting feedback from six focus groups (n = 63 participants) in Tabora, we found that participants lamented many of the poor outcomes from the MDPs, but were still receptive to future aid. This may be because some individuals still partially use some of the resources previously brought by the aid agencies. Furthermore, participants indicate that when aid agencies are in the village the programs can be very helpful at, for example, increasing crop yields. It is only when the agency fully leaves that programs become more dysfunctional. Of the projects introduced, I found that health aid, and to a lesser extent agricultural aid had the most longevity.

Furthermore, I argue that had aid workers been aware of the incentives posed by the free rider problem and the interactions between organizations, they may have made different decisions on how to promote development. Path dependent outcomes are dictated by the type of good or aid program introduced. Households behaved differently depending on whether the program was common pool or privatized, due to differing incentives, which can determine the course of adoption behavior and

sustainability of aid programs. Finally, this research has opened a dialogue to identify potential improvements that future development projects can achieve.

Much of the research that retrospectively examines project efficacy, particularly with the MDPs, is conducted at a macro-scale. Furthermore, there is limited ex-ante research exploring post-MDP interventions. This research is the first of its kind in Tabora. I focus on the village-level beliefs that were formed though project experiences, and suggestions from participants, which will enable future aid development to meet the needs of specific community goals. I suggest that further micro-level studies be conducted to assess aid project efficacy.

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GENERAL CONCLUSION

Is development aid effective? This question has intrigued many social scientists since the inception of widespread global aid programs, and was the impetus to my curiosity and this dissertation. When someone is suffering, it is only natural to want to reach a helping hand. But, is it possible that we are doing more harm than good? Economists have explored the topic of aid intervention and technology adoption through case studies using a variety of methods (Feder and Slade 1984; Jaeger and Matlon 1990; Easterly 2006; Banerjee and Duflo 2011). Yet, there is still not widespread consensus, and we continue to search for a universal truth - if there even is one.

Using a mixed methods approach in this dissertation I was able to collect rich, contextual accounts of the impact of development aid in Tabora, Tanzania. This cite was particularly fascinating, because multiple aid organizations had left a mark on the region, creating a complex story of technology adoption behavior. Typically, case studies tend to look at one aid intervention at a time, has the technology been adopted or not? Simply, this way of thinking overlooks partial adoption and changes to the technology made by households. Furthermore, when measuring aid intervention benchmarks, such as, “how many students are enrolled in school?”, or “how many farmers were at the training session?” we are not accurately measure aid efficacy, and we forgo perceptions of individuals receiving the interventions. In a small way, this dissertation aims to fill those gaps.

FINDINGS

The first chapter explores household characteristics that impact adoption of agroforestry using multinomial logistic methods. The method chosen purposefully breaks agroforestry into multiple types of adoption – treed and perennial cropping systems. Those groups were further broken into their component parts, adoption of the full intercropping system, partial adoption of the intercropping system, or monoculture; as well as Gliricidia adoption, planted woodlot adoption, or a combination of both. Findings suggest that short-term illness is statistically significant and negatively impacts the likelihood of adopting planted woodlots, while long-term illness is significant and positively influences the likelihood of adopting planted woodlots. Furthermore, access to a health clinic is statistically significant and positively influences the relative odds of adopting partial intercropping systems, as well as planted woodlots; yet, negatively influences plantings of *Gliricidia sepium*. Furthermore, credit access is statistically significant and positively related to the relative odds of adopting treed systems. We also explore the use of mobile-banking, which significantly increases the relative odds of adopting *Gliricidia sepium* and the combination of *Gliricidia sepium* and woodlots. We assert that once treed systems are established they need little maintenance to accrue benefits, which may explain the direction of health indices. Furthermore, Access to banking and credit services may increase households' ability to manage savings, purchase novel seed varieties, or hire labor. These insights can assist aid agencies when pursuing households for new projects, understanding that across the board assumptions about credit and health access have different implications depending on the type of land management system.

Chapter two more directly addresses the question, is agroforestry adoption having the intended outcome of increased food security? I focus on the aid package, adoption of Gliricidia and/or pigonepea and cassava intercropping, introduced by ICRAF. Furthermore, I use total market value of household agricultural production (TVP) of the farm from the agricultural season in 2019 as a proxy for food security. Using endogenous switching regression methods (ESRM), I am able to account for unobserved heterogeneity in adoption behavior and measure the effect of agroforestry adoption on households' food security. I found that households who did adopt agroforestry systems can expect a higher TVP than if they had not adopted in the counterfactual scenario. This valuable insight suggests that agroforestry does have significant positive impacts for adopter households.

Chapter three explores how the history of development aid in the region has impacted communities through the lens of path dependence. Additionally, I explore how we can meet the needs of the Tabora community in the future. This chapter incorporates discussions about the Millennium Development Projects, as well as ICRAF and the tobacco industry, to better understanding the impacts and sustainability of aid projects. Participants from focus groups were asked to discuss and compare aid projects. Notably, they expressed discontentment with tobacco industry tree species, and greater preference toward ICRAF trees. Tobacco industry introduced non-native eucalypt species that require large quantities of water resources, as compared to native species supported by ICRAF. Unique to this study is the qualitative use of the path dependence theory, and how fundamentally the explanation of path dependence for aid adoption is influenced by the type of resource

category that the aid falls under. In practical use, this chapter looks backward at what has been done in Tabora, which can help future aid agencies to meet the desired goals of the community.

MIXED METHODS APPROACH

The underlying theme of this dissertation is development aid project efficacy. I first explored what household characteristics influence agroforestry adoption decisions, and then investigated whether those who had adopted are more food secure. The final chapter emphasizes that adoption decisions are predicated on past experiences.

The aid organizations, presumably, introduced novel technologies to improve the lives of those living in Tabora. Using a mixed-method approach, I was able to hear personal accounts of project successes and failures, as well as compare findings to the quantitative survey data. The process of writing this dissertation was iterative, where qualitative results informed quantitative results, and vice versa. For example, through focus groups I learned that some households had not heard of ICRAF before. This encouraged me to explore the variable, "heard of ICRAF," further to specify the adoption decision within the multinomial logistic regressions and ESRM. Furthermore, the qualitative methods allowed for a more exploratory third chapter, because the efficacy of the MDPs had not been investigated in the Tabora region since they ended in the mid-2000s.

Additionally, each organization had their own projects, way of disseminating information, and longevity in-situ. ICRAF has been working in the Tabora region since 1989, at first disseminating information on planted woodlots, and more recently

promoting intercropping and plantings of *Gliricidia sepium*. ICRAF is primarily a research organization that aims to provide education and assistance about perennial agriculture. This differs significantly from the tobacco industry, who has also promoted planted woodlots, but for the primary purpose of growing trees quickly, to cure tobacco products. Through focus groups I was able to learn about tobacco industry goals, and ensure that ICRAF Interventions (Chapter Two) did not include woodlots, because I was unable to decipher between those who learned about planted woodlots from ICRAF or tobacco industry via the survey instrument.

Furthermore, I was able to learn about detailed accounts of agricultural interventions brought by MDP as compared to ICRAF. Both agencies have promoted optimal spacing and use of hybrid seed varieties, but MDP more forcefully promoted use of inorganic fertilizers, which may have impacted perceptions and beliefs on how fertilizer trees, such as Gliricidia, enhance soils. This finding improved my understanding of agroforestry adoption decisions (Chapter One), as well as how past aid experiences influence future aid adoption (Chapter Three).

UN-EXPECTED FINDINGS

As with all research, I stumbled upon some un-expected findings. First, even though introduced agroforestry systems are perennial, households prefer to harvest food crops every year. This is likely due to experiences with pests and disease, as well as the changed texture of the cassava tuber. Additionally, it may be that households are reliant on the harvest of these crops to sustain them through the dry season. Future research can better answer the questions: Why do some households harvest perennial crops every year, and what can aid agencies do to ensure full

benefits of perennial agroforestry systems? Are agroforestry crops more difficult to store through the lean season? What plant diseases, if any, are causing households to harvest perennial crops every year? Furthermore, planted woodlots have been promoted to substitute for collecting fuelwood from the commons. Future research can better address this substitution query, and explore why agroforestry is not acting as a good substitute currently.

Second, I was surprised to learn that agricultural education is provided from multiple sources. The earliest education comes in grade school, where children take farming classes as part of the traditional curriculum. For adults, there are government extension agents that provide workshops and educational test plots, as well as government provided radio shows about agriculture advice; educators from the local Agricultural University conduct genetic tests and disseminate hybrid seed varieties; entrepreneurs from the tobacco industry primarily focus on tobacco growth and yield, yet teach about appropriate spacing, and fertilization, as well as planted woodlots; ICRAF promotes agroforestry, and the Millennium Project aid workers provided extensive agricultural education. These findings further necessitated the use of mixed methods to accurately convey the experiences of households in Tabora. The focus groups assisted me, the outsider, in better understanding the impact of each of these organizations in turn.

CLOSING REMARKS

Looking back at what has been done is the best way to make improvements for the future. On the onset, my intention was to look solely at ICRAF and agroforestry interventions. But, when I learned that many other education and aid

programs were interwoven into the fabric of these villages, I knew that telling that story in a rigorous manner will help us, the aid providers, to better assist communities in the future. Few studies have been conducted post-2015 to see if Millennium projects were sustainable. Perhaps, one reason that ICRAF projects are successful is that there is continued collaboration and education provided to communities, whereas when Millennium left the flow of education and monetary support stopped. My hope is that future development aid research prioritizes longitudinal studies that measure the impact of development aid for intended outcomes in collaboration with participants. In doing so, we can get a little closer to ensuring development aid is effective.

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APPENDIX A: MAPS OF TANZANIA

FIGURE 1 (Appendix A): Original Map of Millennium Cities Initiative in Tabora Tanzania, via Columbia University (2013) - *Reference: Millennium Cities Initiative Invest in Tanzania: Focus on Tabora (2013) Earth Institute, Columbia University.*

FIGURE 2 (Appendix A): Tabora, Tanzania is located at 1,190m (3,904ft).

FIGURE 3 (Appendix A): Village's relative location to Tabora Town. Mbola is quite large. The two points labeled Mbola represent the outer boundaries of the village. Furthermore, Isila is also quite large and is distinctly represented by Isila Pulu and Isila Ibasa. Data was combined for both sides of Mbola and Isila Village for analysis.

APPENDIX B: Recruitment and Consent Guides and Scripts in English for Questionnaire Participants

I. Recruitment Guide for Survey

My name is XXX. I am working with Sonia Bruck, a student from the United States of America. I am doing research about a farming program created by the World Agroforestry Centre's (ICRAF) that is being used in the Mbola region. For the study, I need to talk to farmers, and I am inviting you to participate because you live in Mbola and farm some or all of your own food. The study is called, "Adoption of Agroforestry in Mbola Region Tanzania: Pigeon Pea & Cassava Intercropping with Gliricida sepium." This study is being conducted by Sonia Bruck, Dr. Troy Hall, and Dr. Badege Bishaw at Oregon State University, with the partnership of Dr. Anthony Kimaro at ICRAF. The funding for this project is from the United States Government and ICRAF.

I am asking farmers about their farm and whether or not they do intercropping. I will be interviewing farmers individually at their homes or another place that they choose. I will also be having small group discussions with a small number of farmers. The interview takes about 45 minutes, and the small group discussions will last about an hour. So if you participate in both the interview and focus group, it will take approximately 2 hours.

If you have questions prior to your participation – you can go to Dr. Matata or your Local Guide (name of individualized local guide), who will be located at (individualized location). Sonia Bruck will be residing at the catholic church in Tabora Town if you would like to ask her questions.

II. Consent Guide for Survey

My name is XXX. I am a student from ARI-Tumbi and I am doing research about farming pigeon pea and cassava and using trees on farms. The purpose of the research is to help the World Agroforestry Centre learn more about the farmers in this region, why some people choose to adopt agroforestry and others do not, how agroforestry has changed the farming practices of some households, and how agroforestry has affected the food available to households.

You are one of approximately 600 farmers that have been randomly chosen to be included in our study. We will be asking you questions about your farming experiences, household goods, distances to markets, reasons for adopting new farming practices, health, and food availability. It should take about 45 minutes. The interview will take place in your home or at another location you prefer.

The study is voluntary – you are not required to participate. And, if you do agree, you may stop at any time or choose not to answer questions you don't want to answer. There is no penalty for not participating. There is no payment for being in the study.

Although there is no direct benefit to you from participation, we expect that the community will benefit by helping us learn more about your experiences farming.

Some of the questions ask about personal topics, like health and savings; some people find these questions make them uncomfortable. What you tell us in the questionnaire is confidential, meaning no one else in the community or anyone who reads the research will be able to identify that you participated. I will not be recording your name on the interview. However, it is possible that other people in your household might overhear your responses, unless you prefer to talk with me in a private location.

As part of the information we collect, we will include the approximate location of your home (for example, the street you live on), but we will not record your exact address. This information will be used to find the distance to market, major roads, and major cities.

The findings from this study will be written in a book and be available through the computer. The information collected from you for this study will be available to other researchers in Tanzania at ICRAF, in the United States, and other researchers in the future. Because we do not know the studies that may be done in the future, we would like her permission now to share your information with other researchers without having to ask you again the future. The information we share will not include your name or address or any other way to directly identify you. If you do not consent to the future use of your information, you should not participate in this study.

This study is paid for by the United States government and the World Agroforestry Center (ICRAF). If you have questions prior to your participation – you can go to Dr. Matata or your Local Guide (name of individualized local guide), who will be located at (individualized location). Sonia Bruck will be residing at the Catholic Church in Tabora Town if you would like to ask her questions.

In the event that you decide to withdraw from the study prior to data analysis your data will be discarded. If the data has been collected and is processed for analysis your data may be used.

Assessment of comprehension.

o Do you have any questions?

o So that I know you understand what the study involves, would you please tell me what you think we are asking you to do?

Do you consent for the questionnaire? ***YES/NO Recorded in Qualtrics***

APPENDIX C: Survey Instrument in English and Swahili

Start of Block: Block 1: Consent, Village, Willingness to Adopt

Q1 What is your Enumerator ID?

- *Redacted for Privacy of Enumerators*

Page Break

Q2 **Instructions for Enumerator: Full consent script to be read now**
Do you consent to take this survey?

- Yes (Ndiyo)
- No (Hapana)

Skip To: End of Survey If Instructions for Enumerator: Full consent script to be read now Do you consent to take this survey? = No (Hapana)

Q3 **Instructions for Enumerator: Record the Village**

- Mbola
- Isila
- Msiliembe
- Mbiti
- Ibiri
- Migungumalo

Q4 The next questions ask about your opinions on farming practices. Farming practices include using crops, fertilizers, tools such as shovels, and oxen. For each statement, I'd like you to say if you agree or disagree, or if you don't have any opinion. (Maswali ijayo yanauliza maoni yako juu ya mbinu bora za kilimo. Mbinu hizi ni pamoja na kutumia mazao, mbolea, zana kama vile jembe, na maksai. Kwa kila sentensi, napenda unasema ikiwa unakubali au haukubaliani, au ikiwa huna maoni yoyote.)
Instructions for Enumerator: If interviewee "agrees" ask "moderately agree" or "strongly agree"; If they "disagree" ask "moderately disagree" or "strongly disagree"

Q5 I am eager to be the first to try new farming practices. (Ninashauku ya kuwa wa kwanza kujaribu mbinu mpya za kilimo.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q6 I influenced others in my community to adopt new farming practices. (Niliwashawishi wengine katika jamii yangu kutumia mbinu moya za kilimo mpya.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q7 I am willing to follow others who adopt new farming practices. (Nina nia ya kufuata wengine wanaotumia mbinu mpya za kilimo.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q8 I need to be convinced of the advantage of new farming practices by others in my community before trying the practices myself. (Ninahitaji kuhakikishiwa na faida ya mbinu mpya za kilimo na wengine katika jamii yangu kabla ya kuanza kuzitumia.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q9 I am suspicious of new farming practices. (Ninamashaka na mbinu mapya za kilimo.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q10 My opinion about new farming practices is respected by others in my community. (Maoni yangu kuhusu mbinu mpya za kilimo yanaheshimiwa na wengine katika jamii yangu.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q11 I will adopt new farming practices but will not attempt to influence others to do so. (Nitatutumia mbinu mpya za kilimo lakini sijaribu kuwashawishi wengine kufanya hivyo.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q12 I am resistant to trying new farming practices. (Sikotayari kutumia mbinu mpya za kilimo.)

- ○ Strongly Agree (Nakubaliana kabisa)
- ○ Moderately Agree (Naukubaliana kiasi)
- ○ Neither Agree nor Disagree (Sina maoni)
- ○ Moderately Disagree (Sikubaliana kiasi)
- ○ Strongly Disagree (Sikubaliani sana)

Q13 I try new farming practices out of necessity. (Ninajaribu mbinu mpya za kilimo bila ya lazima.)

- Strongly Agree (Nakubaliana kabisa)
- Moderately Agree (Naukubaliana kiasi)
- Neither Agree nor Disagree (Sina maoni)
- Moderately Disagree (Sikubaliana kiasi)
- Strongly Disagree (Sikubaliani sana)

Q14 Do you purposefully plant or leave indigenous trees on your farmland? Unapanda ama kuacha miti ya asili shambani kwako?

- Yes (Ndiyo)
- No (Hapana)
- Not Sure (Si Uhakika)

Q15 Have you planted Gliricidia sepium on your farm? Umeshawahi kupanda Mglirisidia shambani kwako?

- Yes (Ndiyo)
- No (Hapana)
- Not Sure (Si Uhakika)

Skip To: Q18 If Have you planted Gliricidia sepium on your farm? Umeshawahi kupanda Mglirisidia shambani kwako? = No (Hapana)

*

Q16 How many Gliricidia sepium trees have you ever planted? (Ni miti ngapi ya mgliricidia ambayo umewahi kupanda?)

_____

*

Q17 What year did you first plant Gliricidia sepium?
Kwenye mkwaka gani umepanda Mglirisidia mara ya kwanza?

_____

Q18 Intercropping for this study means purposefully planting pigeon peas and cassava together on the same land. Do you practice intercropping?
Katika jaribio hilo mchanganyiko wa mazao ni mbaazi pamoja na mihogo kupanda kwa wakati moja. Umetumia mfumo huu wa mchanganyiko wa mazao (mbaazi na mihogo)?

- Yes (Ndiyo) (1)
- No (Hapana) (2)
- Not Sure (Si Uhakika) (3)

Q19 Do you plant cassava with another crop (not pigeon pea)?
Umeshawahi kupanda mihogo pamoja na mazao mengine (isiyo mbaazi)?

- Yes (Ndiyo)
- No (Hapana)
- Not Sure (Si Uhakika)

Q20 If yes, what other crop do you plant with cassava?
Kama ndio, mazao gani unapanda pamoja na mihogo?

_____

Q21 Do you plant cassava on your land? (not intercropped)(Je, umepanda mihogo shambani kwako?)

- Yes (Ndiyo)
- No (Hapana)
- Not Sure (Si Uhakika)

*

Q22 What year did you first plant cassava? (Je, mwaka gani ulianza kupanda mkoba?)

_____

Q23 Do you plant pigeon pea with another crop (not cassava)?
Je, umeshawahi kupanda mbaazi pamoja na mazao mengine (isiyo mihogo)?

- Yes (Ndiyo)
- No (Hapana)
- Not Sure (Si Uhakika)

Q24 If yes, what other crops do you plant with pigeon pea?
Kama ndio, mazao yapi mengine unapanda pamoja na mbaazi?

_____

Q25 Do you plant pigeon peas on your land? (Not Intercropped)(Je, unapanda mbaazi kwenye shamba lako?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

*

Q26 What year did you first plant pigeon peas?(Mwaka gani ulianza kupanda mbaazi?)

_____

Q27 Do you have a planted woodlot? (Faidherbia Albida, Acacia, or trees for fuelwood)
Umeshawahi kupanda miti kwenye woodlot? (Faidherbia Albida, Acacia, ama miti ya kuni)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Skip To: Q30 If Do you have a planted woodlot? (Faidherbia Albida, Acacia, or trees for fuelwood) Umeshawahi kupa... = No (Hapana)

*

Q28 If yes, what year did you plant your woodlot?
Kama ndio, katika mwaka gani umepanda woodlot yako?

_____

Q29 If yes, do you use your planted woodlot to cure tobacco?
Kama ndio, unatumia kuni ya woodlot yako kwa ajili ya kukausha tumbaku?

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q30 Did you try any of the following agricultural practices but chose to stop?
Umeshawahi kujaribu kutumia mbinu za kilimo zifuatazo lakini umeacha?

- ○ intercropping with pigeon pea and cassava (mchanganyiko wa mazao ya mbaazi na mihogo)
- ○ intercropping with just pigeon pea (mchanganyiko wa zao la mbaazi pekee)
- ○ intercropping with just cassava (mchanganyiko wa zao la mihogo pekee)
- ○ planted woodlots (woodlots ambazo umepanda)

End of Block: Block 1: Consent, Village, Willingness to Adopt

Start of Block: Block 2: Planting Practices

Q31 Have you heard about the International Centre for Agroforestry (ICRAF)? (Je, umesikia kuhusu International Centre for Agroforestry (ICRAF)?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q32 From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo cha mbaazi au mihogo?)

- ○ Mr. Peter Matata (Ari-Tumbi)
- ○ Extension Agent (Asifa Ugani)
- ○ Neighbor who is not family (Jirani ambaye si ndugu)
- ○ Family member (Familia)
- ○ Someone from outside the community (Mtu kutoka nje ya kijiji)
- ○ ICRAF (World Agroforestry Centre)
- ○ Other (Mwingine)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = Mr. Peter Matata (Ari-Tumbi)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = Extension Agent (Asifa Ugani)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = Neighbor who is not family (Jirani ambaye si ndugu)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = Family member (Familia)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = Someone from outside the community (Mtu kutoka nje ya kijiji)

Skip To: Q34 If From whom did you learn about pigeon pea or cassava planting? (Umejifunza kutoka kwa nani kilimo... = ICRAF (World Agroforestry Centre)

Q33 If other, who? (Ikiwa mwingine, ni nani?)

_____

Q34 From whom did you learn about tree planting with Gliricidia sepium? (Umejifunza kutoka kwa nani kupanda miti ya migliricidia?)

- ○ Mr. Peter Matata (Ari-Tumbi)
- ○ Extension Agent (Asifa Ugani)
- ○ Neighbor who is not family (Jirani ambaye si ndugu)
- ○ Family member (Familia)
- ○ Someone from outside the community (Mtu kutoka nje ya kijiji)
- ○ ICRAF (World Agroforestry Centre)
- ○ Other (Mwingine)

Skip To: Inst If From whom did you learn about tree planting with Gliricidia sepium? (Umejifunza kutoka kwa nani k... = Mr. Peter Matata (Ari-Tumbi)

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Skip To: Inst If From whom did you learn about tree planting with Gliricidia sepium? (Umejifunza kutoka kwa nani k... = ICRAF (World Agroforestry Centre)

Q35 If other, who?(Ikiwa mwingine, ni nani?)

_____

Inst **Enumerator Instructions: Read to Interviewee**

"Agroforestry for this project is defined as plantings of pigeon peas, cassava, and Gliricidia sepium. Please respond to the following questions to the best of your ability about agroforestry."

"(Neno Kilimo msitu (mseto) katika mradi huu maana yake ni kuchangaya mbaazi, mihogo na mtiti ya migliricidia. Tafadhali jibu maswali yafuatayo kwa kwa jinsi unavyoelewa Kilimo msitu/mseto.)"

Q36 **Instructions for Enumerator: Slide the bar to record the number**

	0 10 20 30 40 50 60 70 80 90 100
How many times, if at all, did ICRAF or an extension agent discuss agroforestry with you in the past four weeks? (Katika wiki nne zilizopita, ni mara ngapi wataalam wa ICRAF au afisa ugani wamejadili na wewe kuhusu Kilimo Msitu?)	
About how many times, if at all, did ICRAF or an extension agent discuss agroforestry with you in the past 12 months? (Katika miezi kumi na mbili iliyopita, ni mara ngapi wataalam wa ICRAF au afisa ugani wamejadili na wewe kuhusu Kilimo Msitu?)	

Q37 What tools does your household use to manage your farm? (Je, ni zana gani za kilimo mnazotumia katika kaya yako?)

- [ ] Hand hoe (Jembe)
- [ ] Fencing (Uzio)
- [ ] Plow (Jembe la kukokota kwa Ng'ombe)
- [ ] Livestock/Oxen (Mifugo/Ng'ombe)
- [ ] Hand Weeding (Kupalilia kwa mikono)
- [ ] Hired Workers (Kibarua)
- [ ] Ox Cart (Gari la kukokota na ng'ombe)
- [ ] Machete (Panga)
- [ ] Axe (Shoka)
- [ ] Other (Nyingine)

Q38 If other, what?(Ikiwa mwingine, ni nini?)

_____

End of Block: Block 2: Planting Practices

Start of Block: Block 3: Prices and Labor Hours

Q39 Do you own, rent your land or is it under communal ownership? (Je! unamiliki shamba lako mwenyewe, unakodisha shamba lako au unalima shamba linalomilikiwa na Kijiji au jamii?)

- Own (Mwenyewe)
- Rent (Nakodisha)
- Communal Ownership (Umiliki wa jamii)

Q40 **Instructions for Enumerator: Slide the bar to record the number**

0 20 40 60 80 100 120 140 160 180 200

About how many acres does your household farm? (Kwa wastani ni ekari ngapi unalima kila mwaka?)	

Q41 About how much of land has your household tried intercropping pigeon peas or cassava? This means intercropping pigeon peas or cassava with any crop such as corn or cow pea (Je! Ni kiasi gani cha shamba lako mmepanda kilomo mseto cha mbaazi au mihogo)

Instructions for Enumerator: 0/10 = none, 5/10 = half, 10/10 = all. Use the values in between to indicate less than half or more than half.

0 (0)
1 (1)
2 (2)
3 (3)
4 (4)
5 (5)
6 (6)
7 (7)
8 (8)
9 (9)
10 (10)

Q42 How many kilos of each crop did your household produce in the last agricultural season? (Je! Kaya yako ilazaa kilo ngapi katika msimu wa kilimo uliopita?)

Q43 Does your household sell the following foods to market?
(Je! Kaya yako inauza vyakula vifuatavyo kwa soko?)

	Yes, Tabora Town (Ndiyo, Tabora mjini) (1)	Yes, Local Market - market in village or neighbors - (Ndiyo, Soko la Kijiji) (2)	Yes, outside Tabora region (Ndiyo, nje ya Mkoa wa Tabora) (3)	No (Hapana) (4)
Cassava (Mihogo)	○	○	○	○
Pigeon Pea (Mbaazi)	○	○	○	○
Corn (Mahindi)	○	○	○	○
Rice (Mpunga)	○	○	○	○
Millett (Uwele)	○	○	○	○
Yams (Viazi vitamu)	○	○	○	○
Green Vegetables (Mboga Mboga)	○	○	○	○
Tree Fruits (Matunda ya mti)	○	○	○	○
Watermelon (Tikiti Maji)	○	○	○	○
Sunflower (Alizet)	○	○	○	○
Tobacco (Tumbaku)	○	○	○	○
Cow Pea (Kunde)	○	○	○	○
Bambaranut (Njugu Mawe)	○	○	○	○

Peanut (Karanga)	○	○	○	○
Squash (butternut)	○	○	○	○
Tomato (Nyanya)	○	○	○	○

Q44 If you sell any foods to market how much do you sell them for? TSH per Kilogram.
(Ikiwa unauza vyakula vyovyote kwa soko unauza vipi? TSH kwa Kilogramu.)

Instructions for Enumerators: Enter amount in TSH (10,000 = 10,000 Shillings)

(	200	400	600	800	100	120	140	160	180	200
	0	0	0	0	00	00	00	00	00	00

Cassava (Mihogo)	
Pigeon Pea (Mbaazi)	
Corn (Mahindi)	
Rice (Mpunga)	
Millett (Uwele)	
Yams (Viazi vitamu)	
Green Vegetables (Mboga Mboga)	
Tree Fruits (Matunda ya mti)	
Watermelon (TikitiMaji)	
Sunflower (Alizet)	
Tobacco (tumbaku)	
Cow Pea (Kunde)	
Bambaranut (Njugu Mawe)	
Peanut (Karanga)	
Squash(Butternut)	
Tomato(Nyanya)	

*

Q45 Has your household used chemical fertilizer on your farm before? If yes, how many **months** ago? Chemical fertilizer is usually in a liquid or powder form. It is used to feed the plant to help it grow larger. (Je! Kaya yako imeshatumia mbolea za viwandani kwenye shamba? Ikiwa ndiyo, ni lini ulitumia mbolea za

viwandania kwa mara ya mwisho? Mbolea hapa humaanisha zile zinazotengenezwa kiwandania na hutumiwa kupandia au kukuzia mazao.)

_____

*

Q46 If you hire workers, how much do you usually pay each individual per day in TZ shillings during the farming season? (Ikiwa unajiri vibarua kwa kilimo, je unalipia kiasi gani kwa siku kwa fedha za kitanzania?)

_____

*

Q47 How many workers did you hire in the last agricultural season?
Umeajiri watu wangapi kwenye msimu wa kilimo uliyopita?

_____

*

Q48 How many days on average did each hired worker work in the last agricultural season?
Taja, kila kibarua amefanya kazi kwa siku ngapi kwenye msimu wa kilimo uliyopita?

_____

End of Block: Block 3: Prices and Labor Hours

Start of Block: Block 4: Labor Time

Q49 What does your household typically use to cook meals? (Je, familia yako hutumia nini kupikia chakula?)

- ○ Firewood (Kuni)
- ○ Improved Charcoal Cookstove (Jiko la banifu la Mkaa)
- ○ Improved Firewood Cookstove (Jiko la banifu la kuni)
- ○ Gas Cookstove (jiko la gesi)
- ○ Solar Cookstove (jiko la jua)
- ○ Kerosine cookstove (jiko la mafuta ya taa)

*

Q50 How much firewood does your household usually collect per week? (In Loads/Bundles)
(Ni kiasi gani cha kuni ambacho familia yako hukusanya kila wiki?)

_____

Q51 Be sure to answer the following questions for total hours of everyone in the household, not just one individual.
(Maswali yafuatato yanahusu kaya na sio mtu mmoja tu. Hivyo jibu lako liwe linatoa taarifa ya kile Kaya inachofanya au muda kaya inaotumia.)

Instructions for Enumerator: If unsure leave blank

0 10 20 30 40 50 60 70 80 90 100

How many hours does it take your household to collect fuelwood per week? (Je! Kaya yako hutumia masaa mangapi kukusanya kuni kwa kila wiki?)	
How many hours does it take your household to collect water per week? (Je! Kaya yako hutumia masaa mangapi kuchota maji kwa wiki?)	
How many hours does your household typically spend doing non-farm, wage earning work per week? (Je! Kwa kawaida kaya yako hutumia masaa mangapi kwa wiki kufanya kazi zingike za kuingiza kipato ukiacha kilimo?)	
How many hours does your household typically spend farming per week? (Je, kawaida kaya yako hutumia masaa mangapi kwa kilimo kwa wiki?)	
How many hours does it take to reach your local market per week? (Je! Unatumia masaa mangapi kwenda soko la hapa kijijini kwenu kwa wiki?) Instructions for Enumerator: The time it takes to get there and back home	
How many hours does it take you to reach Tabora? (Je! unatumia masaa mangapi kufikia Tabora mjini?) Instructions for Enumerator: The time it takes to get there and back home	
How many hours does your household typically spend helping your friends or neighbors with their farm work per week? (Je! Kwa kawaida kaya yako hutumia masaa mangapi kusaidia marafiki au majirani zako na kazi zao za shamba kwa wiki?)	

How many hours does your household spend taking care of children per week? (Kaya yako hutumia masaa mangapi kutunza watoto kwa wiki?)	
How many hours does your household typically spend taking care of sick family members per week? (Je, familia yako hutumia masaa mangapi kwa wiki kuuguza mwafamilia aliyemgonjwa?)	
How many hours does your household typically spend cooking meals per week? (Je! Kwa kawaida kaya yako hutumia masaa mangapi kwa wiki kupika chakula?)	
How many hours does your household typically spend cleaning around the house per week? (Je, kawaida kaya yako hutumia masaa mangapi kwa wiki kusafisha mazingira ya myumbani?)	
On average, how much time does it take your household to plant 10 trees? Kwa wastani, kaya yako humutia muda gani kupanda miti 10?	
How many hours does your household spend taking care of Gliricidia sepium trees per week? (pruning, cutting, watering, protecting) (Je! Kaka yako hutumia masaa mangapi kutunza miti kila wiki? (kupogolea, kukata, kumwagilia, kulinda))	
How many hours does your household spend taking care of any trees per week? (Soil enhancing trees, fruit trees, shade trees, any other trees) INSTRUCTIONS FOR ENUMERATOR: NOT INCLUDING GLIRICIDIA	

How many hours does your household spend managing pigeon peas per week? (weeding, pest control, watering, thinning) (Kwa kawaida kaya yako hutumia masaa mingapi ya kutunza mbaazi kwa wiki? (kupalilia, kupiga dawa ya wadudu, kumwagilia, kung'olea)	
How many hours does your household spend managing cassava per week? (Weeding, watering, thinning) (Kwa kawaida kaya yako hutumia masaa mangapi kutunza mihogo kwa wiki? (kupalilia, kumwagilia, kung'olea)	

Q52 From where does your household usually collect firewood? (Check all that apply) (Kwa kawaid, kaya yako inakusanya kuni kutoka wapi?)

- [ ] My land (Ardhi yangu)
- [ ] Farmland (Ardhi yangu)
- [ ] Fallowed land (Shamba liloachwa kulima ili kurudisha rutuba)
- [ ] Planted woodlot (Shamba la kuni)
- [ ] Woodlands (Misitu)
- [ ] Purchase from local market (kukunua kutoka sokoni)
- [ ] Other (nyingine)

Q53 If other, from where does your household usually collect firewood? (Ikiwa ni nyingine, kwa kawaida kaya yako hukusanya kuni kutoka wapi?)

_____

Q54 Do men or women in the household typically plant the trees? (choose all that apply) (Je! Kwa kawaida ni wanaume au wanawake katika kaya wanaopanda miti?)

- ☐ Men (Wanaume)
- ☐ Women (Wanawake)
- ☐ Children (Watoto)

Q55 Do men or women in the household typically manage the trees? (choose all that apply) (Je! Kwa kawaida katika kaya ni wanaume au wanawake hutunza miti?)

- ☐ Men (Wanaume)
- ☐ Women (Wanawake)
- ☐ Children (Watoto)

Q56 Out of all of the crops on your farm, which one takes the most time to plant? (Kati ya mazao yote kwenye shamba lako, ni zao lipi huchukua muda mwingi kupanda?)

_____

Q57 Out of all of the crops on your farm, which one takes the most time to manage? (Kati ya mazao yote kwenye shamba lako, ni zao lipi huchukua muda mwingi wa kutunza?)

_____

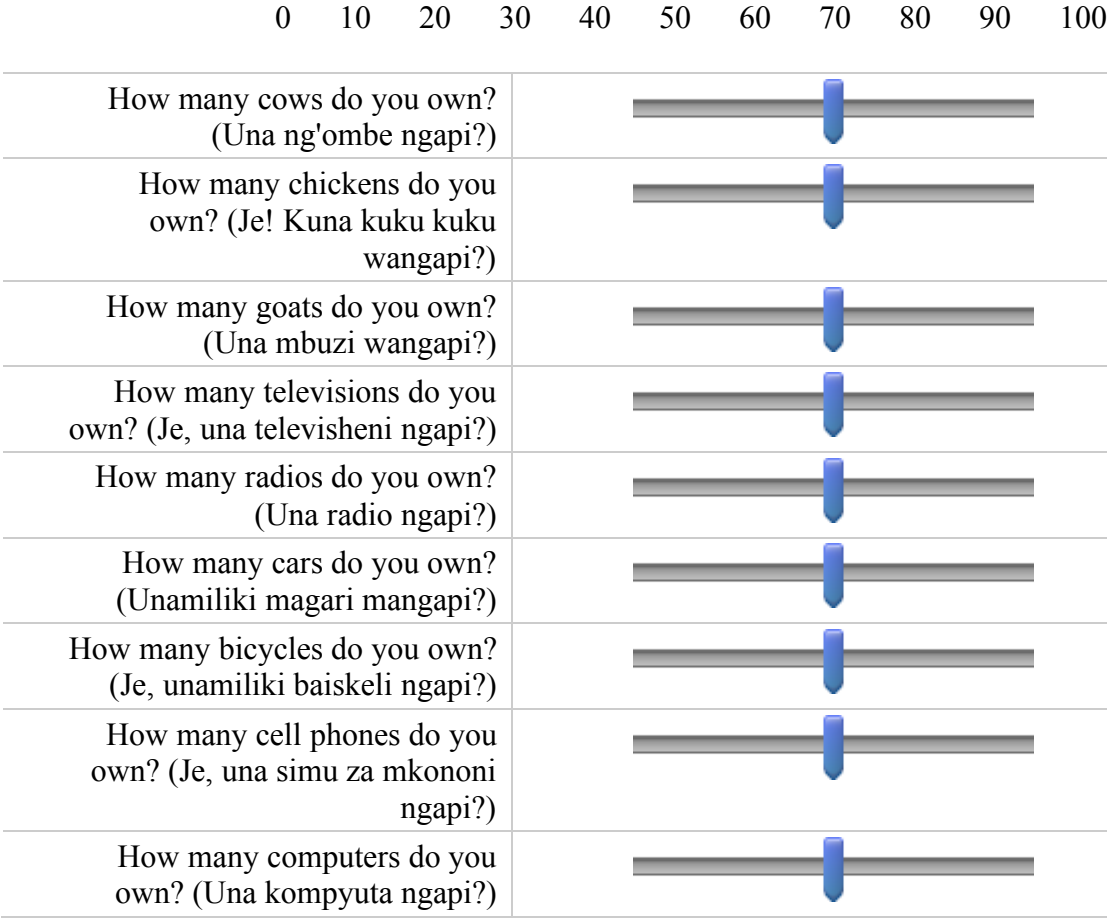
End of Block: Block 4: Labor Time

Start of Block: Block 5: Recall and Millennium Development

Q58 Please indicate whether you own the following in your household: (Check all that apply) (Tafadhali onyesha ikiwa unamiliki zifuatazo katika kaya yako:)

- [ ] Metal Roofing (Paa lililoezekwa kwa mabati)
- [ ] Cows (ng'ombe)
- [ ] Chickens (Kuku)
- [ ] Goats (Mbuzi)
- [ ] Television (Luninga/Televisheni)
- [ ] Radio (Radio)
- [ ] Car (Gari)
- [ ] Bicycle (Baiskeli)
- [ ] Gas Cook Stove (Jiko la Gesi)
- [ ] Water Well (Kisima cha Maji)
- [ ] Cement Flooring (Sakafu ya saruji)
- [ ] Wood Flooring (sakafu ya kuni)
- [ ] Cell Phone (simu ya mkononi)
- [ ] Computer (kompyuta)

Q59 **Enumerator Instructions: Ask interviewees how many of each they own**



Q60 Did you know about the Millennium Development Projects? (Je, unajua kuhusu Miradi ya Maendeleo ya Milenia?)

- ○ Yes (Ndiyo) (Yes)
- ○ No (Hapana)

Skip To: Q64 If Did you know about the Millennium Development Projects? (Je, unajua kuhusu Miradi ya Maendeleo ya... = No (Hapana)

Q61 Did you find the Millennium Development Projects to be helpful in increasing your household's farm crop yields? (Je, unadhani Miradi ya Maendeleo ya Milenia ina manufaa katika kuongeza mavuno yako ya mazao ya kilimo?)

- Strongly Agree (Nakubaliana kabisa)
- Moderately Agree (Naukubaliana kiasi)
- Neither Agree nor Disagree (Sina maoni)
- Moderately Disagree (Sikubaliana kiasi)
- Strongly Disagree (Sikubaliani sana)

Q62 Did you enjoy working with the people from the Millennium Development Projects? (Je! Ulifurahia kufanya kazi na watu kutoka Miradi ya Maendeleo ya Milenia?)

- Strongly Agree (Nakubaliana kabisa)
- Moderately Agree (Naukubaliana kiasi)
- Neither Agree nor Disagree (Sina maoni)
- Moderately Disagree (Sikubaliana kiasi)
- Strongly Disagree (Sikubaliani sana)

Q63 Has your household continued to use the technology introduced to you from the Millennium Development Projects? This includes seed varieties, bug nets, sanitation, or education.
(Umeendelea kutumia teknolojia zilizotolewa kwako kutoka Miradi ya Maendeleo

ya Milenia? Hii inajumuisha aina za mbegu, neti za mbu, usafi wa mazingira, au elimu.)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q64 Do you have access to a community bank? (Je, unanufaika na huduma ya benki ya jumuiya hapa?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q65 Do you have access to a government bank? (Je, unanufaika na huduma za benki ya serejali?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q66 Do you have access to credit for agriculture? (Je, unanufaika na upatikanaji wa mikopo ya kilimo?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q67 Do you use TigoPesa, AirTel, or another phone payment service? (Umeshawahi kutumia mfumo wa M-Pesa ama TigoPesa, Airtel Money n.k.)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: End of Block If Do you use TigoPesa, AirTel, or another phone payment service? (Umeshawahi kutumia mfumo wa M-Pes... = No (Hapana)

Q68 If yes, how often?
(Mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

End of Block: Block 5: Recall and Millennium Development

Start of Block: Block 6: Preferences, Community, and Self Efficacy

*

Q69 How many children between the ages of 1 day and 14 years live in your home? (Je, ni watoto wangapi kati ya umri wa siku 1 na miaka 14 wanaishi nyumbani kwako?)

_____

Q70 How many of your household members have moved to an urban area? (Ni wangapi wanachama wa kaya wako wamehamia eneo la mjini?)

_____

Q71 What community groups do you belong to? (Check all that apply) (Je! Wewe ni mwajumuiya ipi?)

- [ ] Church (Kanisa)
- [ ] Mosque (Msikiti)
- [ ] Tree Planting (Kupanda miti)
- [ ] Women's Group (Kikundi cha Wanawake)
- [ ] Men's Group (Kikundi cha Wanaume)
- [ ] Music Group (Kundi la Muziki)
- [ ] Art Group (Kundi la Sanaa)
- [ ] School Group (Kikundi cha Shule)
- [ ] Other Group (Makundi mengine)
- [ ] Do not belong to any group (Usio wa kikundi chochote)

Q72 Have you talked about agroforestry in any of these groups? (Je! Umeshawahi kungumzia kuhusu kilimo misitu katika makundi haya?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q73 Please answer the following questions to the best of your ability from "Agree" to “Disagree" or “neither agree nor disagree.” (Tafadhali jibu maswali yafuatayo kwa ufasaha kutoka "Kukubaliana kabisa" hadi "Haukubali sana".)

Instructions to Enumerator: If interviewee chooses “agree,” ask “moderately agree” or “strongly agree”; if interviewee chooses “disagree” ask “moderately disagree” or “strongly disagree.”

	Strongly Disagree (Sikubaliani sana) (1)	Moderately Disagree (Sikubaliana kiasi) (2)	Neither Agree nor Disagree (Sina maoni) (3)	Moderately Agree (Naukubaliana kiasi) (4)	Strongly Agree (Nakubaliana kabisa) (5)
I have the ability to manage pigeon peas, cassava, and Gliricidia sepium. (Nina uwezo wa kusimamia mbaazi , mhogo, na Mgliricidia)	○	○	○	○	○
I look to my neighbor's experiences managing pigeon peas, cassava, and Gliricidia sepium in order to make my farming decisions. (Huwa nachukua uzoefu kwa jirani yangu kusimamia mbaazi , mhogo, na Mgliricidia ili kufanya maamuzi yangu ya kilimo.)	○	○	○	○	○

Access to seed makes it difficult to plant pigeon peas (Je! Unakubaliana au haukukubaliani na maneno yafuatayo: Upatikanaji wa mbegu hufanya vigumu kupanda mbaazi)	○	○	○	○	○
Access to seed makes it difficult to plant cassava. (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Upatikanaji wa mbegu hufanya vigumu kupanda mhogo.)	○	○	○	○	○

Weather patterns are too hard to predict to plant cassava or pigeon peas. (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Ni vigumu sana kutabiri mwelekeo wa hali ya hewa ili kupanda mihogo au mbaazi.)	○	○	○	○	○
Pigeon peas or cassava are too hard to grow. (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Ni vigumu sana kwa mbaazi au mhogo kukua)	○	○	○	○	○

Q74 Please answer the following questions to the best of your ability from "Agree" to “Disagree" or “neither agree nor disagree.” (Tafadhali jibu maswali yafuatayo kwa ufasaha kutoka "Kukubaliana kabisa" hadi "Haukubali sana".)
Instructions to Enumerator: If interviewee chooses “agree”, ask “moderately

agree" or "strongly agree"; if interviewee chooses "disagree" ask "moderately disagree" or "strongly disagree."

	Strongly Disagree (Sikubaliani sana) (2)	Moderately Disagree (Sikubaliana na kiasi) (3)	Neither Agree nor Disagree (Sina maoni) (4)	Moderately Agree (Naukubaliana na kiasi) (5)	Strongly Agree (Nakubaliana na kabisa) (6)
It is too hard to sell pigeon peas or cassava (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Ni vigumu sana kuuza mbaazi au mhogo)	○	○	○	○	○
It is too hard to gain access to fertilizer to grow pigeon peas or cassava (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Upatikanaji wa mbolea ili kukuzia mbaazi au mhogo ni mgumu sana)	○	○	○	○	○
There are not enough people to help me plant pigeon peas, cassava, or Gliricidia sepium (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Hakuna watu wa kutosha wa kunisaidia kupanda mimea ya mbaazi, mhogo, au Mgliricidia)	○	○	○	○	○

There are not enough people to help me manage (weeding, pest control, watering, thinning) pigeon peas, cassava, or Gliricidia sepium (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Hakuna watu wa kutosha kunisaidia kusimamia (kupalilia, kupiga dawa ya wadudu, kumwagilia, kung'olea) mbaazi , mhogo, au mgliricidia)	○	○	○	○	○
It is too hard for me to transport pigeon peas, or cassava to markets (Je! Unakubaliana au haukubaliani na maneno yafuatayo: Ni ngumu sana kwangu kusafirisha sokini mbaazi , au mhogo)	○	○	○	○	○

End of Block: Block 6: Preferences, Community, and Self Efficacy

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Start of Block: Block 7: Health

Q75 Have any household members experienced illness or injury during the last agricultural season that impacted their ability to work on the farm?
(Je, msimu wa kilimo uliopita kuna mwanachama wa familia aliyepata ugonjwa au majeraha na kupelekea kuathiri uwezo wa kufanya kazi kwenye shamba?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Skip To: Q77 If Have any household members experienced illness or injury during the last agricultural season that... = No (Hapana)

Q76 How many days did household members have to rest due to illness or injuries during the last agricultural season? (Siku ngapi wanakaya wa familia walipaswa kupumzika kutokana na ugonjwa wakati wa msimu wa kilimo wa mwisho?) **Instructions for Enumerator: Make sure this is total number of days!**

_____

Q77 Have any household members experienced long-term illness or injury spanning several agricultural seasons that have impacted their ability to work on farm? (Je, wanachama wa familia wanapata magonjwa ya muda mrefu au kuumia wakati wa msimu wa kilimo ambapo imeathiri uwezo wao wa kufanya kazi kwenye shamba?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q78 Have any household members experienced illness or injury that has impacted their ability to work off-farm? (taxi driver, sell goods to market, work in a store) (Je, kuna wanakaya wowote waliyopata magonjwa au madhara ambayo yameathiri uwezo wao wa kufanya kazi nje ya kazi za shamba?(derava wa taxi, kuuza bidhaa sokoni, kufanya kazi ya stoo))

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q79 Who usually takes care of sick family members? (Check all that apply) (Ni nani anayewatunza wagonjwa kwenye kaya yako?)

- ☐ Men - Father, Husband (Wanaume - baba, mume)
- ☐ Women - Mother, Wife (Wanawake - Mama, Mke)
- ☐ Children (Watoto)
- ☐ Friend not from family (male) (Rafiki si kutoka kwa kiume wa kiume)
- ☐ Friend not from family (female) (Rafiki si kutoka kwa kike wa kike)

Q80 Does your household have access to a health clinic when household members are sick? (Je! Kaya yako ina uwezo wa kupata huduma za kliniki wakati wanakaya anapokuwa mgonjwa?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

Q81 Does your household make use of homemade or local medicines? (Not western medicine) (Je! Kaya yako hutumia dawa zilizotengenezwa nyumbani au dawa za kienyeji?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)
- ○ Not Sure (Si Uhakika)

End of Block: Block 7: Health

Start of Block: Block 8: HFIAS

Q82 In the past four weeks did you ever worry that your household would not have enough food? (Katika wiki nne zilizopita umewahi kuwa na wasiwasi kwamba familia yako haitakuwa na chakula cha kutosha?)

- Yes (Ndiyo)
- No (Hapana)

Skip To: Q84 If In the past four weeks did you ever worry that your household would not have enough food? (Katika... = No (Hapana)

Q83 How often did this happen? (Je! Hii ilitokea mara ngapi?)

- Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q84 In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food? (Katika wiki nne zilizopita, je, wewe au mwanakaya yeyote wa kaya alikula vyakula ambavyo hakutaka kula kwa sababu ya ukosefu wa rasilimali?)

- Yes (Ndiyo)
- No (Hapana)

Skip To: Q86 If In the past four weeks, did you or any household member have to eat some foods that you really di... = No (Hapana)

Q85 How often did this happen? (Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q86 In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food? (Katika wiki nne zilizopita, je, wewe au mwanakaya yeyote wa nyumbani alikula chakula kidogo kuliko ulivyohisi anahitaji kula kwa sababu hakuwa na chakula cha kutosha?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q88 If In the past four weeks, did you or any household member have to eat a smaller meal than you felt... = No (Hapana)

Q87 How often did this happen?(Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q88 In the past four weeks did you or any other household member have to eat fewer meals in a day because there was not enough food? (Katika wiki nne

zilizopita je, wewe au mshiriki mwingine wa kaya alikula chakula kichache kwa siku kwa sababu hakuwa na chakula cha kutosha?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q90 If In the past four weeks did you or any other household member have to eat fewer meals in a day bec... = No (Hapana)

Q89 How often did this happen? (Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q90 In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food? (Katika wiki nne zilizopita, kulishatokea hata kidogo kutokuwa na chakula cha aina yoyote katika kaya yako kwa sababu ya ukosefu wa rasilimali za kupata chakula?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q92 If In the past four weeks, was there ever no food to eat of any kind in your household because of la... = No (Hapana)

Q91 How often did this happen?(Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q92 In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food? (Katika wiki nne zilizopita, je, wewe au mwanakayayeyote wa nyumbani alilala bila kula kwa sababu hakuwa na chakula cha kutosha?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q94 If In the past four weeks, did you or any household member go to sleep at night hungry because there... = No (Hapana)

Q93 How often did this happen?(Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q94 In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?

(Katika wiki nne zilizopita, je, wewe au mwanakayayeyote aliyekaa siku nzima na usiku bila kula kitu chochote kwa sababu hakuwa na chakula cha kutosha?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q96 If In the past four weeks, did you or any household member go a whole day and night without eating a... = No (Hapana)

Q95 How often did this happen? (Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q96 In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?
Katika wiki nne zilizopita, wewe ama mtu kwenye nyumba yako amelazimishwa kula chakula cha aina moja (si vyakula mbalimbali) kwa sababu ya hali duni?

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q98 If In the past four weeks, did you or any household member have to eat a limited variety of foods du... = No (Hapana)

Q97 How often did this happen?(Je! Hii ilitokea mara ngapi?)

- ○ Rarely (once or twice in the past four weeks) (Mara kwa mara (mara moja au mara mbili katika wiki nne zilizopita)
- ○ Sometimes (three to ten times in the past four weeks) (Wakati mwingine (mara tatu hadi kumi katika wiki nne zilizopita)
- ○ Often (more than ten times in the past four weeks) (Mara nyingi (zaidi ya mara kumi katika wiki nne zilizopita)

Q98 During an average year, do you or any household member have a lack of food during any month? (Check all that apply) (Kwa wastani kwa mwaka, wewe au mwanakaya yeyote wa kaya ashawahi kukosa chakula mwezi wowote?)

- ☐ None (Hakuna)
- ☐ January (Januari)
- ☐ February (Februari)
- ☐ March (Machi)
- ☐ April (Aprili)
- ☐ May (Mei)
- ☐ June (Juni)
- ☐ July (Julai)
- ☐ August (Agosti)
- ☐ September (Septemba)
- ☐ October (Oktoba)
- ☐ November (Novemba)
- ☐ December (Desemba)

End of Block: Block 8: HFIAS

Start of Block: Block 9: Final Questions

Q99 What is your age? (Je! Una miaka mingapi?)

_____

Q100 What is the highest education of the head of the home? (Je, mkuu wa kaya ana elimu kiasi gani?)

- ○ Pre-Grade 1 (Kabla ya Daraja la 1)
- ○ Pre-Grade 2 (Kabla ya Daraja la 2)
- ○ Grade 1 (Darasa la 1)
- ○ Grade 2 (Darasa la 2)
- ○ Grade 3 (Darasa la 3)
- ○ Grade 4 (Darasa la 4)
- ○ Grade 5 (Darasa la 5)
- ○ Grade 6 (Darasa la 6)
- ○ Grade 7 (Darasa la 7)
- ○ Form 1 (Kidato cha kwanza)
- ○ Form 2 (Kidato cha pili)
- ○ Form 3 (Kidato cha tatu)
- ○ Form 4 (Kidato cha nne)
- ○ Form 5 (Kidato cha tano)
- ○ Form 6 (Kidato cha sita)
- ○ Bachelor's (Shahada)
- ○ Post Graduate Diploma (Chapisha Diploma ya Uzamili)
- ○ Master's (Shahada ya uzamili)
- ○ PhD (Shahada ya uzamivi)
- ○ Medical Doctor (Daktari wa Matibabu)

- ○ Law Degree (Shahada ya Sheria)
- ○ Engineering Degree (Shahada ya uhandisi)

*

Q101 How many adult males live in your household? (Wanaume wangapi wanaishi katika nyumba yako?)

_____

*

Q102 How many adult females live in your household? (Ni wanawake wangapi wanaoishi katika nyumba yako?)

_____

Q103 Were you born in this village? (Ulizaliwa katika kijiji hiki?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Skip To: Q105 If Were you born in this village? (Ulizaliwa katika kijiji hiki?) = Yes (Ndiyo)

Q104 If no, from where did you move from? (Ikiwa hapana, umetoka wapi?)

_____

Q105 Are you the head of the household? (Je, wewe ni mkuu wa nyumba?)

- ○ Yes (Ndiyo)
- ○ No (Hapana)

Q106 Thank you so much for taking this survey. It will help ICRAF know how agroforestry is helping your community. (Asante sana kwa kushiriki utafiti huu. Itasaidia ICRAF kujua jinsi kilimo misitu kinavyo saidia jamii yako.)
Would you like to say anything else about pigeon peas, cassava, Gliricidia sepium, health, weather patterns, or food preferences?
(Je! Ungependa kusema kitu kingine chochote kuhusu mbaazi , mhogo, mgliricidia , afya, hali ya hewa, au machaguo ya chakula?)

_____

_____

_____

_____

_____

Q107 **Instructions for Enumerator: Record participant gender**

- ○ Male
- ○ Female

Q108 We will be conducting small group discussions with farmers later in this study. These discussions will give us more information about farmers' experiences. Participation in a discussion is voluntary. Would you be willing to participate in a small group discussion with other farmers from your village? Tutafanya tena majadiliano na wakulima kwenye vikundi hapo baadae. Ushiriki wa hayo majadiliano yatakuwa ya hiari na yatatupa taarifa zaadi juu ya uzoefu wa wakulima. Je ungependa kushiriki kwenye majadiliano ya vikundi na wakulima kutoka kijijini kwako? If yes, Thank you. I will add your name to the list of possible participants. We will let

you know if you are selected for a focus group, and we will provide more information at that time. Kama hapana, nashukuru kwa ushiriki wako. Kama ndiyo, nashukuru sana na nitaongeza jina lako kwenye listi ya wanaotarajiwa kushiriki kwenye majadiliano ya makundi, na tutakupa taarifa zaidi baadae.

Instructions for Enumerator: IF YES RECORD NAME AND LOCATION IN DESIGNATED NOTEBOOK TO REACH FOR FOCUS GROUPS!

- ○ Yes (Ndiyo)
- ○ No (Hapana)

End of Block: Block 9: Final Questions

APPENDIX D: Qualitative Codebook

Coding Patterns: Please code full sentences. Aim to code the question (R - Researcher) with answers (T - Translator). For example, (R) may ask, "what crops have changed due to climate change?" - when a sentence with sorghum is mentioned code the entire sentence as Sorghum & Millet. If the question is asked, and the answer does not correspond, do not code the question with the answer. Please code ICRAF Intervention with any time that Pigeonpea, Cassava, or Gliricidia is mentioned. Mention of these crops are all ICRAF-related project discussions. Implementation of woodlots may be coded in either ICRAF interventions or in Tobacco Company Interventions. Please use context clues to decide if the discussion is about ICRAF fertilizer trees or Tobacco Company interventions. There may be times when both are discussed at the same time, in this case, please use both parent codes ICRAF Interventions and Tobacco Company Interventions.

Table 1 (Appendix D): Qualitative Codebook

Parent Codes	Child Codes	Grandchild Codes	Code Description	Example Text
Aid Intervention			General code for Aid Intervention Projects can be coded here (If it is not clear what program the aid is from)	S: And how are they storing their food? M: They normally store it in bags.
	ICRAF Interventions		General code for ICRAF Interventions	S: So, my first question is who here has heard of ICRAF before I came here?
		Gliricidia	Gliricidia inteventions, perspections of fertilizer trees.	S: So that was my next question.... since you're not using the chemical fertilizer often, are you taking advantage of the gliricidia? Are there other ways that you're trying to improve the soil? M: Initially they were thinking that the gliricidia could improve their soil fertility, after using the gliricidia sepium they saw there was a difference. They saw the difference between those who were using and not using the maize.
		Cassava	Management of cassava plants or intercropping experiences with cassava	S: I have a management about cassava and pigeonpea. I learned that sometimes they take the whole plant out every year. I want to know why they take the whole plant out...like the cassava can be left for many years and be eaten for many years.

			M: Cassava…it matures…if it stays long in the soil, the roots…can rot. Rotting is a problem for the cassava if it stays for more than one year. So they take it away.
	Pigeonpea	Management of pigeonpea plants or intercropping experiences with pigeonpea	S: And are they leaving the pigeonpea for many years, or are they taking it out every year? M: They say that every year, they harvest
	Non-Adoption	Non-adoption of icraf interventions	S: Is anyone planting Gliricidia? Has anyone heard of that tree before? M: They haven't planted.
	Farming Groups	Farming groups created by ICRAF to disseminate knowledge	M: …ICRAF has created some groups. Farming groups. From that farming groups it was easier from them to get knowledge…from the groups. Even the millennium villages when they came….all the groups were formed by ICRAF. From the groups which were formed by ICRAF, when it came, it helped them which was informed by ICRAF. ICRAF was the base of other projects which came here. So ICRAF was not only planting trees, it brought some knowledge of establishing forage for livestock. He said that ICRAF, they had money, compared to millennium.
	Woodlots	May be cross-over between tobacco company and ICRAF, but if clear that ICRAF code under ICRAF-Woodlots	S: Ok, so they learned from two groups, ICRAF and Tobacco companies …and is there anything that ICRAF said different than the tobacco companies? About the Woodlots? M: He is saying that tobacco companies, they only focus on the trees for growing tobacco. But ICRAF…woodlots, soil fertility, and fodder
Miombo Project (UNDP)		The Miombo Project funded by UNDP to increase education about environemnt and forest conservation	S: What's the Miombo Project? M: Miombo project, it belonged to the ministry of forestry- it was a project which was funded by UNDP
Tobacco Company Interventions		Tobacco aid interventions, including tree planting	S: Ok, so the tobacco company, did they recommend any trees to plant? M: The tobacco company, they brought trees like…Acacia, they

			brought species of trees which they brought.
MDP		Millennium Development Projects	*MDP should fall under a child code.*
	Project Types (General List)	General listing of MDPs in the village	S: Can they tell me the activities they did with Millennium? M: They say it was about agriculture, and capacity building, and environment.
	Entrepreneurship	Entrepreneurship projects, including textiles, sales, and business start-up	S: What kind of entrepreneurship? M: Processing indigenous fruits, wine, jam, and also honey
	Not-Continuing Projects	Projects that were started during MDP but not continued to present day	S: Can they tell me more about the things that are not continuing, the projects that are not continuing? M: They have said a lot of things, the most important things which they have said is the things about children. When millennium was here, the students they normally get food, but now-a-days that service is no longer existing.
	Bank	Banking projects	M: They said also it opened a bank (Sacos), so they put money in the bank…. S: Are there any indigenous fruits that are preferred that they gather?
	Indigenous Fruits	Indigenous fruit preserve projects	M: yes yes. S: Ok, what indigenous fruits? M: There are so many, Tonga.
	Recommendation for Improvement	Village recommendations for improvement that can be made for the future, what could have been done better	S: What do you think that millennium projects did well and what could they have improved on? M: He is saying the good things which millennium did for them is education, which they got for conserving the environment, their natural forests, and also stove….and also there was another activity of giving food to students at the school, and health. Which is still existing. Normally they got rice and maize for students so it was enjoyable for students who could sort of …food. And also he is saying another good thing, was to use proper methods of cultivation,

			even keeping of chickens which was also given by millennium.
	Difficulty Marketing	Difficulty marketing new entrepreneurship goals	S: I am wondering if anyone has anyone tried to go to town to sell the indigenous fruits and honey? M: They take the product to the market, but it is terrible. They cannot get a good price.
	Agriculture	General agricultural interventions brought by MDP	S: Can they tell me what kind of projects millennium did? M: They say they focused on agriculture fertility of maize and sunflower. S: And can I know more about the agriculture projects they did?
	Fertilizer	Fertilizer policy effect on continuing MDP	M: What they did…is they brought seeds…also they brought …inaudible…brought technicians to help them for the farmers. Fertilizers were given to the farmer.
	Crop Surplus	Crop surpluses during MDP and continuation, if at all.	M: He says actually, when the project came. It gave them hope. Because they were producing for two years, but later, they did not get this again…so they failed completely, because they think that maybe if they can get another project that can boost them in terms of agriculture they would be very happy.
	Un-fulfilled Promises	Promises made by MDP but not fulfilled	S: Did they ask for electricity, or what happened? M: They say it was one of the plan of millennium, but it was not done.
	Food Storage	Food storage education and changes due to MDP	S: How are they storing their maize? M: Now-a-days they normally buy pesticides. They buy pesticides and they store in the bags.
	Conservation	Education about conservation practices under MDP	S: Ok, can they tell me more about what they learned about environment? M: He says that they were taught not to set fire in the forest.

Government Intervention			Government interventions that have been conducted (or planned to be conducted), or requested government intervention	S: In terms of the electricity…have they spoken with the government about that? Is the government providing that? They've promised to come with that or are they still waiting? M: They were promised to get electricity, that was the government promise. But initially it is somewhere in another village…once they are finished they will come here. In the future the government….
	Savings and Banking		Ways of saving money earned. Why many people do not have a bank account (poverty or distance to government banking services).	S: Alright, so …say they earn a lot of money, are they putting that money in the bank? M: They normally put in the bank
	Police Protection & Safety		Police, saftey, and trust in police	S: What happens if they catch someone? M: They say if someone is caught, of that kind, they get arrested.
		Crop Protection	Crop protection conducted by the household during harvest season - related to police protection and safety	S: I do want to ask about land security, and if they have any problems with people stealing food. So, if they have a fruit tree in their front yard…do they seem to have any issues with people taking fruit or maize from their field…or they feel comfortable? M: Yes, I am not sure they answered your question…they are saying there are people who are stealing the fruits and crops, there are so many.
		Land Rights	Land rights, land ownership, and sale of land. Protection of property.	S: So, someone in the village can sell land, to someone that wants to move? M: Yes, yes.
Aid Acceptance			Open-ness to outsiders and aid intervention	S: Do they still use the nets? M: They are no longer using the millennium nets, but they have nets which they got from somewhere else. It was a long time since they were given. *Laughing.* They are saying with millennium came a lot of pests.

	Supportive of Aid	If the tone sounds supportive of new aid intervntion, or positive emotions about previous aid intervention	S: I guess, knowing that some projects worked and some projects didn't work, are they still open to having people come and help or are they more like….oh I don't know, some stuff worked and some stuff didn't work M: They think if another project would come …(someone else starts talking) He is saying that they are very accepting, because they want to learn more, to gain knowledge from the aid
	Not Supportive of Aid	If the tone sounds not supportive of new aid intervention, or not supportive of previous aid intervention	M: They are saying they were not happy about millennium…bringing fertilizer phosphate. S: Why weren't they happy? M: It takes some one to two years to be solved in this way. You use for just one year you can't see the effect, you use for some years you can see the effect.
Requests		How aid can be improved in the future. Requests that were made, or are made for future aid.	*Requests should fall under a child or grandchild code*
	Education Requests	Requests for more education, or education that they would like to continue from the past aid encounters.	S: Can anyone tell me if they're using organic fertilizer, like cow dung or leaves from the trees, or leguminous crops? M: They normally use cow dung, if there is not chemical fertilizer they use cow dung. They say that to use tree fertilizer they don't have education, they are not trained about that.
	Agriculture Requests	Requests for more agricultural aid, including fertilizers, or improved seed.	M: If you could come in the future…they would like to get a better variety of maize, sorghum, sorghum…so they can improve their food security. It could help them.
	Project Inclusion Requests	Requests to be included in project planning and discussion.	S: So, when millennium came, did they sit down and have a meeting and ask what the communities wanted? How did that work? M: They say there are two reasons…one they say that it was participatory, the farmers were involved – they said what they wanted. But the other things

				which came directly from the project.
	Infrastructure Requests		Requests for infrastrucure, including housing, roads, or solar.	M: He says they could do, very important thing to them, infrastructure…the road. The road which was something very important for them but they did not …even electricity.
		Irrigation Request	Requests for irrigation infrastructure	M: Yes, with the government … They are insisting of getting the irrigation system S: What about the water? Did they build wells here? M: Yes, they did them.
		Water Request	Requests for water wells, or clean water for drinking	S: And are they still functional? M: …inaudible…only one is functional S: In ten wells only one is functioning.
		Electricity Request	Requests for electricity	M: yes. S: Did they ask for electricity, or what happened? M: They say it was one of the plan of millennium, but it was not done.
		Road Request	Requests for road infrastructure	S: Do they know why the road infrastructure was not completed? M: They don't know…they don't know the reason
Gender Disparity			Use pronouns when possible to highlight potential gender disparities.	S: Ok, so once they sell the tobacco the loan is immediately paid back from the money they made? M: Yeah yeah, paid back… She is saying that here, there are two groups. They normally get loan, others do not get loan. Particularly that lady. She doesn't get loan from tobacco.
Climate Change			Climate change impacts on community	*Climate change should fall under child code.*
	Pests		Pest impacts on agriculture relating to climate change	S: So the pests are easier to get into the traditional cow paddies silo? Why does the weather change that they're not using the cow paddy silo like their parents did? M: The change of technology has

		allowed them to leave the silos, they are more expensive, and they can control the pests.
Food Changes	Food changes due to climate change	S: OK, so now-a-days their eating oranges, lemons, and passionfruit ...and that was not eaten before? M: Yeah.
Millet & Sorghum	Milet and sorghum metioned - two most common crops mentioned not planted due to climate change	M: Sorghum is not planted now-a-days. Simsim…you know the crop which you gave me? M: They say even the livestock is fewer….
Livestock	Livestock management changes due to climate change	S: Why is there less livestock? M: They are saying, weather. Due to climate variability so most of the things have disappeared S: Can I ask how the climate has changed, in what way that they see?
Weather Changes	Weather changes due to climate change	M: They are saying that the weather has changed because of the high temperature, and decline of rainfall... So many people now-a-days…
Soil Fertility	Soil fertility changes due to climate change	Even the soil fertility is another problem. S: And is she getting a good yield, is she able to have enough food all year?
Food Yield	Food yield changes due to climate change	M: She says it depends on the weather, if the weather is good she can get more yield, if the weather is bad she can get bad yield.