Challenges of Adopting Sustainable Agricultural Methods in Contrasting Tropical Environments

Food Crops in Toliara, Madagascar
&
Coffee in Cauca, Colombia

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Abstract

This paper addresses the reasons why farmers show varying adoption rates of methods promoted by agricultural extension. It analyzes the context-specific obstacles that prevent farmers from adopting certain methods. This study looks at the effects of three types of factors on method adoption in two tropical environments: Toliara, Madagascar (semi-arid flat) and Cauca, Colombia (humid mountainous).

The factors analyzed were biophysical differences between farms, personal differences between farmers, and attributes of method promotion by extension. Data was collected primarily through farmer interviews. Biophysical factors such as slope, livestock, and farm size were negatively or positively correlated with method adoption depending on the environment. Livestock and farm size had opposite effects on method adoption in each of the sites. Personal factors such as parents' methods, trauma, religion, and risk aversion also impacted method adoption. Crop diversity and food security were correlated with greater method adoption in both sites. Attributes of extension correlated with adoption included method's testability, rapid and visual response, cost, and the degree to which a method addresses the overarching system constraint.

Recommendations for how extension can account for diverse constraints within target populations include increased emphasis on local capacity-building, less emphasis on reportable rates of adoption of donor-selected methods, and community-supported, sequential adoption to hedge individual risk. This need for sensitivity and adaptability to farmers' diverse and changing constraints will only increase as future factors such as climatic and technological change become reflected in the evolution of constraints and strategies employed by farmers across the tropics.

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1. Introduction

This paper seeks to analyze and address limitations to the adoptability of certain agricultural methods promoted by agricultural extension in the tropics. First and foremost, this paper is an analysis of obstacles faced by smallholder farmers in adopting sustainable methods and how these obstacles manifest across contrasting climatic, topographic, geographic, cultural, and economic conditions within two distinctly characterized tropical contexts. Secondly, it is a critique of the ways in which agricultural extension interacts with these constraints in tropical, smallholder farming systems. The application of this research will be recommendations for what agricultural extension could do to overcome the specific challenges to adoption presented across the diversity of the tropics, where agricultural knowledge is in high demand but is often inaccessible to smallholder farmers.

Agricultural extension is a powerful tool for conveying new ideas and approaches to farmers. It can lead to improved livelihoods, resilience, and overall sustainable development. Agricultural extension can be defined as "the application of scientific research and knowledge to agricultural practices through farmer education," or the "delivery of information inputs to farmers" (Anderson, 2007). Much of agricultural extension's role as it exists today was formed and popularized in the 1960's and 1970's during the peak of the Green Revolution, a time when technologies such as high-yielding varieties, fertilizers, and irrigation provided the basis for a "quantum leap forward in food production" (FAO, 1996). These technologies were made available and useful to target farmers through the transfer-of-technology (TOT) model in which scientists determined research priorities, developed technologies under controlled conditions, and then had agricultural extension agents transfer the technologies to farmers (Chambers, 1987). The increases in yield, however, were disproportionately enjoyed by farmers in certain regions (e.g. Asia) and generally by farmers who were relatively resource-rich in terms of capital or infrastructure, and were thus more secure than resource-poor farmers and therefore less risk-averse. The disparity in the benefits reaped from this era of agricultural extension can be attributed to a lack of focus on the needs and constraints of resource-poor farmers who, for example, could not afford to rely on seeds that had to be bought each year and the associated inputs designed for them (FAO, 1996).

By the mid-1980's, the greatest challenge facing agriculture was no longer how to increase production overall but how to enable resource-poor farmers to produce more (Chambers, 1987). In response, the TOT model was adapted to be more sensitive to their specific constraints, and thus the "who" at which extension was aimed shifted to smallholder farmers. This was done through farming systems research (FSR), an approach in which information obtained from farmers is analyzed by scientists in order to identify possible solutions. However, this approach ultimately retains "power in the hands of scientists" because while farmers are asked to identify their problems, the problem-solving and solution-creating processes are still dominated by an external actor (Chambers, 1987). Still missing from extension theory was the essentiality of encouraging and enabling resource-poor farmers to self-organize and to determine not only *what* they needed but also *how* they were going to achieve their goals and with which methods. Therefore, while it is important that a solution promoted by agricultural extension addresses a farmer-identified need or constraint, the solutions themselves must be deemed feasible, attractive, and effective by farmers or else they will fail to be adopted or useful.

Successful agricultural research has exceptionally high rates of return when the beneficiaries are resource-rich farmers (Chambers, 1987). Increases in productivity, the original motivation for agricultural extension, have been observed most dramatically in extremely resource-rich areas such as North America and Western Europe as well as relatively-resource rich areas such as the Indian state of Punjab. Infrastructure and capital are not the only factors at play in creating this pattern; each of these large areas has relatively uniform environments. The plains and deltas of South and Southeast Asia, where the Green Revolution found much of its success, are largely uniform in terms of physical conditions such as soils as well as social and cultural conditions (Chambers, 1987). This uniformity allows innovations to be more widely applicable and easily extended. However, the top down process of traditional agricultural extension can be lacking in concern for interpersonal and environmental variation among farmers and their farms (Vanclay, 1994). During this time, socioeconomic distinctions between farmers were discussed in a global sense (resource-rich vs. resource-poor). Meanwhile, the concept of environmental uniformity was applied across large regions, with uniformity characterized as relatively uniform access to irrigation, distance to bodies of water, precipitation patterns, soil type, and topography. By the late-1990's, agricultural extension moved away from this focus on large-scale environmental uniformity and the resource-rich vs. resource-poor dichotomy and towards an approach that addresses variations on a smaller scale. These smaller-scale variations (e.g. between farmers in the same region) were addressed with the introduction of FSAR (Farming Systems Adaptive Research), the new name given to FSR in the late 1980's (Collinson, 1987).

FSAR involved identifying "target groups" within larger farmer populations, which were composed of farmers operating under fairly homogenous local circumstances and who could be expected to have similar problems as well as opportunities for method adoption (Collinson, 1987). Target groups were further divided into "recommendation domains" to account for minor but important variations within the same local system. These variations were characterized as "geographical" or "hierarchical," which correspond with Chamber's differences in environment and resource-endowments. Furthermore, Collinson emphasized that conditions at the research stations where technologies were developed needed to be representative of the farmers for which they were intended. The reasons for this are especially apparent in dry systems, as farmers in dry systems typically obtain less than half the yields that research stations operating under similar conditions can achieve (FAO, 1996). This is due to research stations' controlled and constant access to irrigation, improved seeds, fertilizer, pesticides, and constant labor, all of which cannot be ensured on real farms. One of the ways to overcome this obstacle of variable conditions in extension is to conduct experiments in farmers' fields. This is one of the tenets of FSAR and is used to account not only for differences between research stations and farmers' fields, but also variation amongst farmers' fields. This attention to small-scale variation amongst farmers was unprecedented. With these modifications made to agricultural extension, the locations of "where" research was being conducted better-suited farmers.

By the late 1990's, the "what" being tested rose to equal importance with the emergence of PVS (Participatory Varietal Selection). PVS trials include formal steps in which farmers express their preferences concerning crop varieties under evaluation (Paris, 2011). Farmers' opinions are sought using parameters that emphasize the traits important to them and are thus very useful in predicting whether or not farmers are likely to adopt a variety (Paris, 2011). While this farmer-centered approach was of utmost importance to plant breeders and their extension programs, it was followed by PR&E (Participatory Research and Extension), an extension process involving farmer prioritization of issues and methods.

Extension agents oftentimes saw farmers who failed to adopt introduced methods as "recalcitrant and irrational" (Vanclay, 1994). In the 1990's, farmers' attitudes and lack of knowledge were considered to be the main barriers to adoption. Research done at this time revealed that farmers' resistance to changing their methods oftentimes had a rational basis, including unattractive trade-offs, risk, contradictory information, costs of implementation, incompatibility with other aspects of farm management, or personal objectives and perceptions (Vanclay, 1994). PR&E sought to adjust for these farmer-identified barriers by emphasizing the problem-solving skills of farmers over the problem-solving skills of scientists, thus adding a much-needed participatory aspect to the "how" of extension and research (Ton, 2005).

PR&E called upon farmers to not only identify and prioritize their problems, but to also select methods that they wanted to develop, learn, and ultimately utilize. These decisions – though based on technical information provided by extension agents – were not made by the extension agents. A key role in PR&E is that of the facilitator, the link between the scientists and the participating farmers. The facilitator is responsible for the clear transfer of information, ideas, and learning strategies between these two groups (Ton, 2005). An important distinction between PR&E and historical extension processes is that farmers become active participants in the research process towards solutions, not just identifiers of problems as they were under FSR. Under PR&E, the principal task of extension workers is not to transfer agricultural knowledge or technology to farmers but to facilitate an analysis with the farmers (Ton, 2005). This is best done at the start of the relationship between extension agents and the community so that once the farmers have become aware of what causes their problems and have prioritized them accordingly, they can incorporate extension agents' technical knowledge into their solutions. The term "participatory" is essential as it means that farmers are the principal decision-makers in defining their goals, planning their tests, implementing their methods, and evaluating the impacts (Ton, 2005).

The lessons learned from the ever-shifting paradigm of agricultural extension include that farmers need technologies and methods that not only address problems identified by them, but that do so in a way they find feasible, appropriate, efficient, and attractive. The problems faced by subsistence farmers and the solutions they perceive to be most effective will vary not only across climates and world regions, but also within certain areas, especially if the environment lacks uniformity.

Based on my experience, the enduring problem in the current context of agricultural extension is that farmers cultivating under similar climatic and social conditions still exhibit varying rates of adoption of agricultural methods that are promoted by extension agents. During the summer of 2014, I interned at the sub-regional FAO Office for Central Africa based in Libreville, Gabon, working on a project concerning the FAO's agricultural extension activities with several banana and plantain cooperatives in the rainforest. During my first mission to the field I visited each of the involved cooperatives and conducted interviews with their leaders (who were almost all women). I was surprised to see that despite their proximity to each other, the cooperatives differed greatly in their approaches to plantain production and their receptiveness to the methods promoted by the FAO.

Between stretches of the dense, tall, and humbling forest lay variously sized plots of plantain trees oftentimes intercropped with cassava, taro, and sweet potato. The FAO was promoting a suite of methods, including the use of horizontally-growing sweet potato vines as a cover crop, orderly row spacing of the plantain trees, and chicken manure as fertilizer. The FAO also encouraged the cooperatives to jointly invest in hiring seasonal laborers who used chainsaws to clear new plots or to control the bush in existing plots. This mechanical clearing of land, though costly, was promoted by the FAO as being far more sustainable than the traditional method of clearing forested land, i.e. slash-and-burn.

I expected each of the cooperatives to show similar levels of interest or disinterest in the FAO's methods, as well as comparable levels of adoption. This was not the case. One cooperative was still using slash-and-burn to clear vast plots, another was clearing smaller plots by hand with the use of only a machete, another was using only chicken manure in their fields, and yet another was so highly interested in the potential of synthetic pesticides that they had invited a representative from the national agrochemical company to come and make a presentation to their cooperative. I distinctly remember the arrival of this representative. He was wearing a neon orange jumpsuit and brought a projector for a PowerPoint presentation that he delivered within the wood-planked walls of one of the few homes with electricity. The FAO team and I peeked in through the windows, noticing the apparent interest in the farmers' faces upon hearing the promises of the chemical company's products. Whatever problem he was offering to solve, it was clearly a priority. It surprised me that farmers who grew the same crops, lived under seemingly identical environmental, cultural, and economic conditions, and were presented with the same methods by the same agricultural extension agents could have entirely different rates of adoption and success with these methods.

Chambers argued in the 1980's that the greatest challenge facing agriculture was helping resource-poor farmers produce more, especially through the development of technologies with increased farmer participation. I would add that while production is still the major constraint for most smallholder and subsistence farmers, the greatest challenge facing agriculture today is producing more or maintaining yields in the face of unprecedentedly variable climatic conditions and without further degrading the already changing environment. Furthermore, interrelated constraints such as income and livelihood, access to markets, and nutrition are still of great importance to subsistence farmers. However, I consider increasing seasonal variability and environmental degradation the most important constraint in this era because it affects every other constraint. Under unpredictable environmental (and economic) conditions, micro-variations between farmers and farms in the same area are of utmost importance in determining if a method will be adopted. Small-scale variations in factors such as farm slope, the presence of windbreaks, or degree of crop diversity can be the deciding factor in determining if a farming household will be resilient and withstand a shock event, let alone if they will decide to undertake the risk of adopting a new method. Therefore, micro-variations between farmers and farms in the same area have never been of such great importance to agricultural extension as they are now and must be emphasized and studied further.

There exist three identifiable factors that have always influenced the success of agricultural extension: 1) environmental variation in the face of a "one size fits all" fallacy; 2) economic and personal differences between farmers with varying resource-endowments, life experiences, and associated levels of risk aversion; and 3) the approach of the extension itself regarding both how and if it addresses the overarching constraint of farmers and from whom the solutions are sourced.

The beginnings of my research question were conceived during my semester abroad in Madagascar during which I saw countless faded signs or frayed banners that had been left behind by a slew of international development organizations. FAO, WFP, USAID, WHH, and EU were only some of the many names plastered up on abandoned project sites. The deep southwestern limits of the island, encompassing the regions of Androy and Atsimo-Andrefana, were referred to by some as a "graveyard of development projects." I wondered why these projects had failed, particularly those concerning agricultural extension, and what impact they had left on the farmers who now re-used empty WFP sacks to store their own corn and cassava. I was reminded of the varying rates of adoption amongst farmers in the very different yet seemingly homogenous rainforest system in Gabon.

I argue that biophysical variation within a single farm (e.g. slope, soil texture across slope, size, location, presence of livestock, crop diversity) and personal differences that are not always linked to resources or capital (e.g. life experiences, parents' methods, risk aversion) are at play when varying method adoption is observed in the same community or area. Of similar importance is the degree to which an extension service addresses a farmer-identified constraint and enables the farmer to produce locally adapted solutions. This study seeks to answer why differences in method adoption and extension success exist between farmers within the same region. I answer this question by analyzing what micro-variations exist amongst these farmers and how their subsequent obstacles to adoption differ in two distinct tropical environments. The outcomes of this research should help agricultural extension understand and account for differences within their target population, subsequent differences in obstacles to adoption, and thereby improve their ultimate impact by enhancing the accessibility of their activities to smallholder farmers in diverse, tropical environments.

2. Research Questions

The primary purpose of this research is to analyze how context-specific obstacles prevent farmers from adopting sustainable methods that are promoted by agricultural extension. The application of this research is to provide recommendations for how agricultural extension and related NGOs can understand and better address these context-specific obstacles in their interventions.

> Problem: Farmers cultivating under similar climatic and social conditions exhibit varying rates of adoption of agricultural methods that are promoted by extension agents.
>
> Main Hypothesis: Variation in method adoption within the same area can be attributed to 1) biophysical differences between farms, 2) personal differences between farmers, and 3) the ways in which methods are introduced and promoted by extension agents. This is because each of these factors influences farmers' perception of the feasibility and pay-off of the proposed method.

During the in-field component of this research, I depended on the following list of factors to determine whether or not they were correlated with famers' management decisions and ultimate willingness or ability to adopt a proposed method. I studied the correlation of these factors with management decisions in two distinct tropical environments, as the manifestation of these factors as obstacles or motivations for adoption varies across different environments. The two environments referred to in this paper are semi-arid flat (Toliara, Madagascar) and humid mountainous (Cauca, Colombia) environments, which contrast in precipitation and topography.

I have divided the following factors into the three categories referred to in my hypothesis. These factors can serve either as obstacles or motivations to adoption, depending not only on the case study but also on the farmer in question.

1) **Biophysical differences between farms**

A. Topographical differences between individual farms' landforms can impact adoption of methods.
B. The presence of livestock can influence adoption of methods.
C. The size of the area under cultivation influences adoption of methods.

2) **Personal differences between farmers**

A. The methods used by farmers' parents have a strong impact on the methods a farmer is willing to adopt.
B. Personal beliefs about ecology and community (e.g. soil health, role of livestock, role of agrochemicals, relationship to other farmers) strongly influences farmers' priorities and choice of methods.
C. Economic stability, financial capital, and overall food security of the farmer impacts likelihood of adoption.
D. Risk-aversion of the individual farmers influences adoption. Risk-aversion can be influenced by the preceding factors.

3) **Extension's introduction and promotion of methods**

A. A method that is a portrayed as addressing a need explicitly identified by farmers is more likely to be adopted.
B. A method that can be tested in a trial plot and shown to have positive results is more likely to be adopted.
C. Short waiting time to pay-off renders a method more likely to be adopted, particularly in subsistence systems.
D. Visually obvious or measurable pay-offs render a method more likely to be adopted.
E. Improved access to agricultural credit (if available) can help farmers undertake the financial risk of adopting a new method.

F. Cost of method impacts rate of adoption, especially amongst resource-constrained and subsistence farmers.
G. Methods promoted through an organization or agent that shares ethnic, linguistic, or socioeconomic identities with the target farmer population will be more readily accepted, particularly in a divided, heterogeneous region.
H. Methods introduced to the appropriate actors within the community (with concern for gender, age, household roles), in appropriate settings, and at the right time, will be considered more favorably for adoption.

In the following section, I describe how I measured the importance of these factors in influencing method adoption in the two case studies that serve as the basis for this paper.

3. Methods:

3.1. Justification and System Characterization

Toliara, Madagascar and Cauca, Colombia exist in two different tropical environments that contrast in many ways. These two locations and the agricultural systems within them differ in climate, topography, precipitation patterns, soil type, major crops, pests, and other biophysical aspects. They also differ in language, dominant socioeconomic status and religion, world region, non-agricultural livelihoods, and political history. Both regions host various types of organizations working in the fields of agricultural extension, food security, and development.

Figures 1 and 2: (Left) Map of Madagascar with Toliara highlighted by a pin. (Right) Map of Colombia with Popayán (capital of Cauca) highlighted by a pin. Maps not to scale. Image Sources: Google Maps, 2017.

Toliara, Madagascar

Location

Toliara is a coastal city in southwestern Madagascar and the capital of Atsimo-Andrefana, the largest of the country's 22 regions, covering 66,236 square kilometers with a population of 1.4 million. The city of Toliara is quite small, with an area of 16 square kilometers and a population just under 160,000 people (Institut National de la Statistique, Antananarivo, 2014). It is located at 23°21′S and 43°40′E, and the Tropic of Capricorn runs slightly north of the city. The area surrounding Toliara is classified as deciduous thicket and is considered a "globally distinctive ecoregion" for its endemic plant and animal species (WWF, 2017). For example, six of the world's eight species of baobab are found only in this region of Madagascar (Platt, 2013). While this ecoregion is an important hub of biodiversity conserve, it is also home to people who etch their food and livelihoods out of the earth mostly with handheld tools, beating sun, strong winds, and low rainfall.

Livelihoods and Traditional Cropping System

The major sources of livelihoods in the surrounding Toliara area are agriculture, fishing, shipping, and the informal charcoal industry. Most farmers cultivate maize, cassava, squash, sweet potatoes, and a variety of beans, unlike the majority of Madagascar which cultivates paddy rice. Prior to major cyclones in 1968 and 1978, the region was more similar to the rest of the country in that it produced rice, but the cyclones left the region's rice fields covered in sand (Goodman and Benstead, 2003). After these major and destructive weather events, cassava and maize rose to their current importance as staples, with 99% of farmers cultivating cassava, making it the region's most prevalent crop for its ability to resist dry spells and locust invasions (Neudert, et al. 2014). The major cash crops of the region are sisal and cotton. Farmers rely heavily on livestock, *zebu* (Malagasy cattle) in particular, which hold a degree of religious importance in the traditional belief system (followed by 55% of Malagasy people) (Library of Congress, 1994).

Traditional agricultural methods include monoculture of most staples, especially cassava. Tillage is most often done with handheld tools, though use of a *zebu*-drawn plow is increasing (Goodman and Benstead, 2003). Farmers who own *zebu* supplement the generally insufficient pastureland by diverting excess biomass as fodder and leaving soil bare between harvests. There are few traditional pest control methods, and conventional methods involve unregulated pesticides promoted and sold by the Chinese textile company, Tianli. Slash-and-burn, or *tavy*, is practiced further inland in Atsimo-Andrefena. Common crop storage methods include drying for maize, application of chili pepper to tuberous plants, or application of neem seed oil.

Climate

Climatic factors are heavily influential in determining which crops and livestock have grown to be most important and widespread in the region. Normally precipitation is lowest in July, with a monthly average of 4 mm. Precipitation and temperature peak in January, with an average monthly rainfall of 76 mm and maximum temperatures of 36°C (Climate Data, 2012 and World Weather Online, 2016).

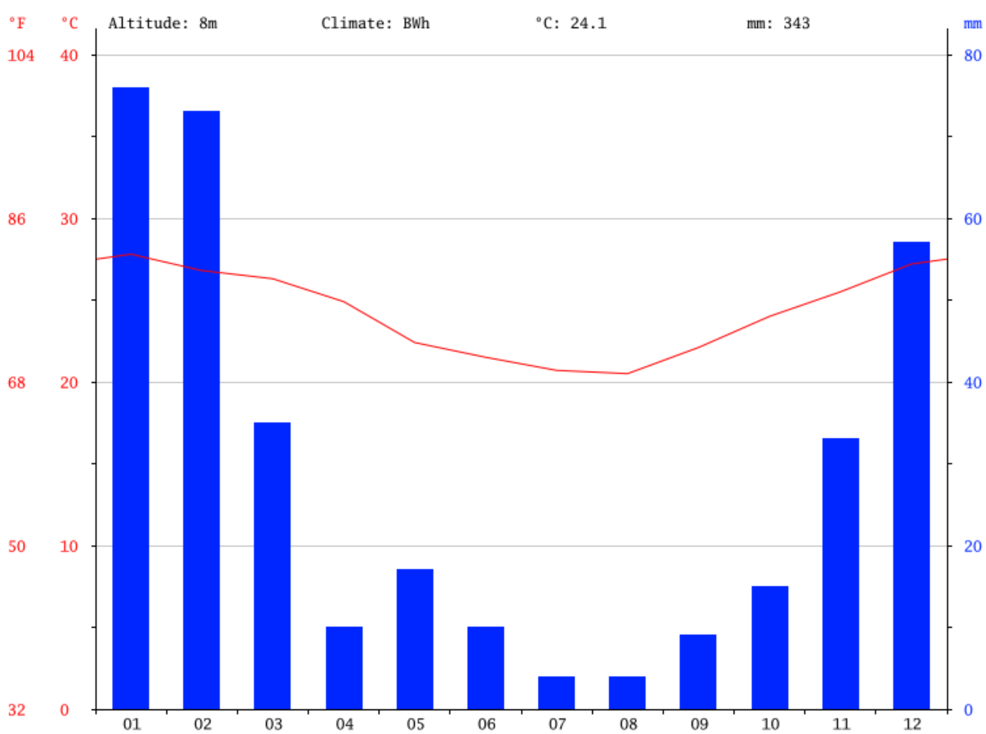


Figure 3. Annual precipitation and temperature patterns in Toliara. Source: Climate Data, 2012.

In the semi-arid region including and surrounding Toliara, 500 mm is considered to be normal annual precipitation, though the timing and intensity of rainfall has become increasingly unpredictable. Rainfall has always been erratic, with the region receiving as little as <200 mm and as much as 700 mm per year in the 1950's (Battistini, 1964). Total seasonal rainfall between 1995 and 2009 varied by 40% (coefficient of variation) in the south and southwestern parts of the country, making it the region in Madagascar with the highest inter-annual rainfall variability (WFP and Unicef, 2011). Furthermore, the region has the fewest rainy days of any region on the island, with less than 75 rainy days per year considered normal (Rasambainarivo, 2003).

The soils in this region are Calcisols and Aridisols, clay and sand-dominated, have sedimentary limestone for parent material, and are considered ferruginous (containing rust and iron-oxides) (Rasambainarivo, 2003). Alluvial soils can be found along the region's two major rivers (the Fiherenana and Onilahy rivers), which flank the city of Toliara (Rasambainarivo, 2003).

Constraints

The region's primary constraint to agriculture is water scarcity, which is exacerbated by increasingly erratic and unpredictable rainfall. Apart from extreme climatic conditions (e.g. destructive cyclones and cyclic droughts), the region suffers from migratory locust invasions from *Locusta migratoria* and *Nomatacis* (Goodman and Benstead, 2003). The only benefit of these is that they can be consumed by local people as a source of high quality and dense protein. Other pests and fungus include mealybugs, borers, caterpillar worms, *Striga grandica* on maize, and mosaic fungus. Poor storage facilities render stored crops susceptible to rotting and rats.

The increasing climatic variability and seasonal unpredictability has been largely attributed to deforestation, with some controversy surrounding the topic. Many scholars agree that Madagascar was once covered in forest, yet with the pressures of the relatively recent arrival of humans (2000 years ago around the start of the current era), the forest has been cut back to less than a fifth of its previous size (Library of Congress, 1994; Rakotovao, 1998). This region in particular has seen a 45% reduction in forest due to cropland expansion in the last four decades (Hansich, 2015). One of the main causes for this increasing rate of deforestation is the slash-and-burn cropping system, known in Madagascar as *tavy*. Despite legal restrictions on slash-and-burn especially near national parks, it continues to be the preferred method of clearing land in this shifting agricultural system in comparison to more labor-intensive methods or stationary, intensive cultivation, which requires investments in long-term soil health (Rollin, 1997). However, the percentage of farmers practicing slash-and-burn is difficult to assess because of fears over sanctions by conservation and national park authorities (Guerra, 2014). Furthermore, traditional customary law is the prevailing land rights system, with >96% of fields lacking a formal land title (Hanisch, 2015).

A second major cause for deforestation is the demand for charcoal used to heat kitchen stoves. This second cause is more relevant to the areas immediately surrounding Toliara, as urban areas have a high, concentrated demand for forest-sourced charcoal. Often it is the landless poor who gather wood from the forest to sell in the city as charcoal. This practice has pushed the forest further inland, negatively impacting many factors including groundwater sources, soil health and susceptibility to erosion, and the region's two major river systems. Coupled with the vegetation loss due to deforestation, strong prevailing winds from the south contribute to significant wind erosion of these fine and often dry soils. Relatively flat and low-lying topography (<300 meters) exacerbates the erosive effects of these winds (Rasambainarivo, 2003).

These major irrigation, weather, pest, and soil erosion constraints are coupled with farmers' limited access to education, training, proper storage facilities for surplus produce, poor transport for produce, and reliance on unjust intermediary system. These intermediary systems are the result of poor transportation infrastructure for produce traveling long distances, and involve intermediary transporters buying farmers' produce for a fraction of the market price. Therefore, the farmer does not have to transport produce, but receives a below-market price. Furthermore, the market suffers from seasonal saturation, as most food crops are grown and consumed within the region and harvested at the same time.

Demographics and Food Security

The climatic variability and generalized water scarcity of the region have had negative impacts on food security and nutrition. Up to 54% of households in the region report that their own crop production is never enough for food subsistence, 41% report that it production is only sufficient in years with lots of rain, and only 5% report production as sufficient to feed all household members (USAID, 2013). Consequently, childhood stunting is prevalent in 60% of children in of Atsimo-Andrefana and the percentage of children meeting minimum dietary diversity is a mere 37% as opposed to a maximum of 80% observed in other regions of the country (USAID, 2013).

It is important to understand the economic peculiarities of Toliara. The city runs on calories derived mostly from imported rice. The streets are lined with stacked bags of rice from Turkey, Brazil, Pakistan, India, and Madagascar, all with varying prices attached to them. The majority of rice consumed in Toliara comes from Pakistan, and much of it is considered "animal feed grade" and not intended for human consumption, as indicated on the bag itself. Because the majority of Malagasy rice (grown further inland and to the north) is considered high quality, it is exported and sold at higher prices internationally. Meanwhile, most Malagasy people eat cheap South Asian rice that can be imported at low prices.

The primary form of transportation in Toliara is the cyclo-pousse or pousse-pousse, a rickshaw bicycle with a carriage attached to the back. The pousse-pousse drivers are all young to middle-aged men who come to the city from mostly rural areas seeking to work as transporters for many hours a day and for meager pay. The pousse-pousse market is saturated in that there are far more pousse-pousses available at any given time than there are people who are willing to pay to ride them. A pousse-pousse driver can end the day with as little as 5,000 Ariary ($1.55) in his pocket. These men represent a fraction of rural to urban migration in the region. Other forms of migration include interregional migration. Over the past few decades, intraregional migration from inland and interregional migration from the country's southernmost regions has tipped the urban and peri-urban population in favor of ethnic groups such as the Mahafaly and Antandroy (instead of the indigenous Vezo, a seminomadic fishing ethnic group). Now more than half of Toliara is populated by migrants from other regions who have brought with them different agricultural methods. It should be noted that all groups in the country speak Malagasy, yet with large differences in regional dialects and vernacular. French is spoken in cities amongst the educated middle and upper classes, but most farmers do not speak French.

Institutions and Methods Promoted

There are many institutions, both local and international, working on the ground in and around Toliara in agricultural extension or food security. Local institutions include but are not limited to the following: SOMONTSOY, a Malagasy NGO working to improve the services of international organizations by researching the needs of local communities; La Maison des Paysans (La MdP), a Malagasy rural rights and livelihoods advocacy group with a target population of 3,700 peasant farmers; Betanimena (Big Red Earth), an agroecological research station working with La MdP in agricultural extension; Centre National Anticridien (CNA), a state-led operation for monitoring and controlling locusts; and FOFIFA, a state-run agricultural research station experimenting with cropping techniques and improved varieties. Le Ministere de l'Agriculture et du Developpment Rurale is the main state apparatus through which smaller state programs are organized.

International institutions include but are not limited to the following: Welt Hunger Hilfe (WHH), a German food security organization; Land O' Lakes, an American food company doing humanitarian work with USAID; and the Deutsche Gesellschaft für Internationale Zusammenarbeit, better known as GIZ, a German environmental organization working with La MdP.

Methods Promoted in Toliara, Madagascar
• Permanent organic soil cover (including covercrops and mulch) to increase soil moisture, organic matter, and prevent erosion • Intercropping mutually beneficial crops (e.g. maize, *taboira* squash, *dolic* beans), and legumes with maize to suppress *Striga grandica.* • Composting (secondary to use of biomass as soil cover) • Use of livestock manure as fertilizer • Controlled use of pesticides calibrated to pest reproductive cycles • Some NGOs: agroforestry in buffer areas around biosphere reserve areas that are open for use but maintain a degree of protection.

Cauca, Colombia

Location

Cauca is a department (equivalent to a state) in southwestern Colombia with an area of 30,000 square kilometers and a population of 1.36 million people (Martinez, 2015). Cauca is located between 2.7°N and 76.8°W, close to the equator on its northern side. The region is mountainous and humid, as it encompasses the beginnings of the Andean mountain range called the Colombian Massif. The city of Popayán is the capital with a population of 250,000 and an elevation of 1,760 meters (SA-Colombia, 2017). As much as 80% of the department is considered mountainous, placing most of the existing agriculture on sloped land (Colombia-SA, 2017).

Livelihoods and Traditional Cropping System

The economy of Cauca is based mainly on agriculture, livestock, and logging. Industrialized agriculture exists in the north of the department where sugar cane, plantains, maize (traditional and improved varieties), cacao, and peanuts are just some of the region's commercially produced crops (Martinez, 2015). Cauca also has mining industries for gold, silver, platinum, talc, gypsum, and charcoal along the Pacific coast (Martinez, 2015).

Colombia is a major producer of high quality coffee; third in the world after Brazil and Vietnam, but first in production of *Arabica* beans (International Coffee Organization, 2014). Colombia's coffee industry suffered in 2008 and 2011 from coffee leaf rust, but is has since had successful tree replanting programs (International Coffee Organization, 2014). Cauca, however, is not one of Colombia's top coffee producing regions, contributing only 7% of the nation's output (Reuters, 2010). Small cooperative and family-owned coffee farms compose Cauca's contribution to Colombian coffee production, and differ in production methods from the industrial coffee plantations further north.

On these small farms a multitude of crops are grown, including maize, cassava, plantains, avocado, and various citrus fruit trees. Keeping small livestock such as chickens is not uncommon, though the main cash crop is coffee. Many farmers in the region have access to relatively affordable synthetic inputs, including pesticides, fertilizer, and lime.

Climate

The areas around and including Popayán have tropical monsoon climates and subtropical highland climates with significant rainfall for most of the year and a dry season from June to August (Instituto de Hidrologia, Meteorologia y Estudios Ambientales, 1999). Rainfall peaks at 330 mm for the month of November on average, but can be as low as 50 mm per month from June to August (World Climates, 2017). Total annual precipitation equals approximately 2 meters, and temperatures range from 10°C to 20°C throughout the region without much seasonal variation (World Climates, 2017).

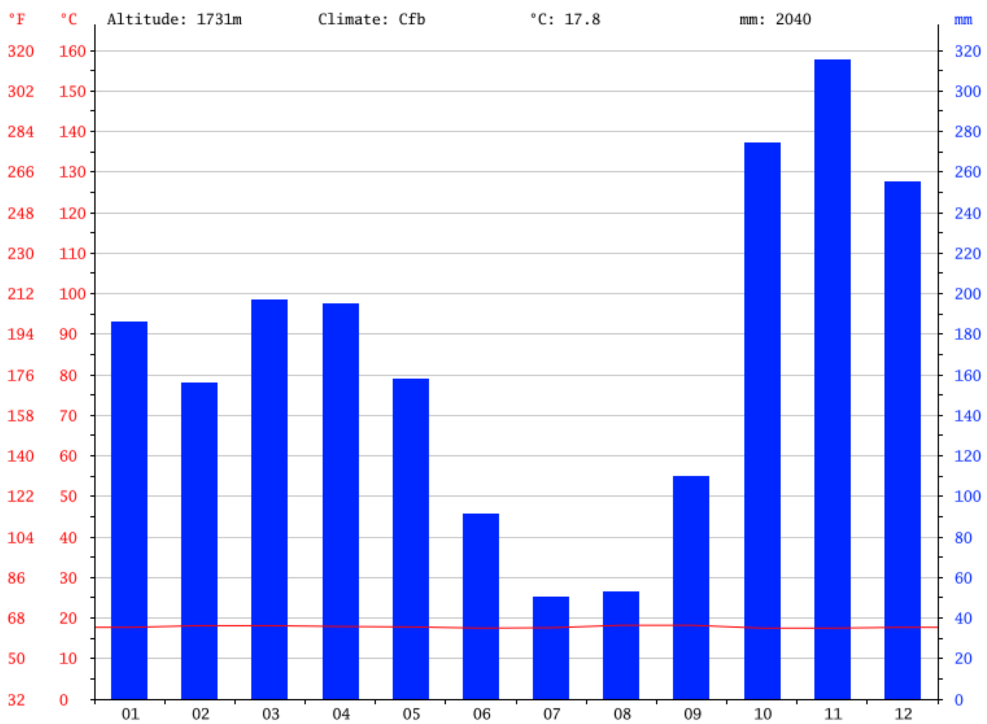


Figure 4. Annual precipitation and temperature patterns in Popayán. Source: Climate Data, 2012.

Recently, Mocoa (in Putumayo, Cauca's southern neighboring department) has experienced exceedingly rare and intense rain events during which up to a third of a month's expected rainfall occurs in one night (BBC, 2017). These changes in precipitation patterns have been attributed to climate change, and may also be observed in Cauca.

The soils at higher elevations in the region are dominated by Andisols and are volcanic in nature. The soil of this region is high in organic matter has the potential to be "exceptionally productive if protected from erosion" (Encyclopedia Britannica, 2017).

Constraints

The primary constraints to coffee growing in Cauca are disease pressures from coffee leaf rust and pest pressures from the coffee cherry borer. The coffee cherry borer (*Hypothenemus hampei*) is a small beetle that bores into the coffee cherries and lays its eggs inside, leaving a hole in the cherry and causing its insides to rot. Coffee leaf rust (*Hemileia vastatrix*) is a fungus that defoliates coffee trees, reduces cherry production, and in severe cases prevents production. Coffee leaf rust has affected farmers across the world in nearly every coffee growing region (Avelino et al. 2006). It reached epidemic levels in Latin America from 2008 to 2012, with farmers in Cauca experiencing a 69% reduction in production at this time (ICO, 2016; Cerna, et al. 2016). Coffee leaf rust spreads by contact and wind, and is more likely to spread under wet, warm conditions (Rayner, 1961).

Climatic factors such as heat spells and major rain events can have negative impacts on farmers' coffee yields, partially because they contribute to ideal conditions for the spread of coffee leaf rust. The region's undulating and often steep topography in conjunction with its high level of precipitation render the soil prone to water erosion if not vegetated. This topography contributes to high labor requirements and labor constraints, especially on steep slopes where the coffee trees must be tended to individually and each cherry is harvested by hand. The price of hiring outside labor and buying equipment and inputs are also constraints.

Water scarcity is not a constraint and there is no need for irrigation since the rainfall is plentiful. The FCC provides controlled storage facilities that minimize post-harvest and post-processing losses. The market for specialty coffee is international and unsaturated, and therefore provides constant demand.

Demographics and Conflict

The people of Cauca, known as *Caucanos*, are some of the most ethnically diverse in the country, as Cauca has a larger indigenous population than many other departments in Colombia (Martinez, 2015). Just over half of *Caucanos* are racially mixed white and indigenous people, who make up the majority of the population in and Popayán. Indigenous populations living in Native communities close to Popayán and farther east constitute one fifth of the department's population (SA-Colombia, 2017). Though indigenous languages are spoken in certain communities, Spanish is spoken and understood widely, and is usually the first language of someone from the region.

The most mountainous and forested parts of Cauca have been heavily affected over the past five decades by the internal conflict in Colombia, in part due to their heavily indigenous demographics. This is because fighting between the government, paramilitary forces, and leftist anti-government guerrilla forces (e.g. FARC) is generally concentrated in areas populated by indigenous peoples, who live disproportionately in Cauca as compared to other regions of Colombia. The impacts of this conflict in Cauca include high levels of internal displacement and loss of land. People have begun to return to their original homes in recent years, and the beginnings of the peace process in 2016 indicate a more politically stable future for this region.

Institutions and Methods Promoted

Multiple institutions operate within Cauca in the spheres of rural development and agricultural extension. Organizations pertaining to coffee production in particular include the Federación Campesina del Cauca (FCC) and the Cooperativa de Caficultores del Cauca, or simply Caficauca, which provides a suite of services to Cauca's coffee growers, including agrochemicals, technical training, and help with bank loans (Caficauca, 2017). Because the United Nations prioritizes resolving the political conflict and removing the region's associated landmines as the main area of intervention, food security and agriculture initiatives are limited.

The FCC is an association of coffee growers that functions much like a large coffee cooperative. It was founded in 1971 by community organizers who sought to improve land rights and livelihoods for peasant farmers, or *campesinos*. The FCC has both environmental and social missions; their environmental mission is to protect their environment from pesticides and other agrochemicals, while their social mission is to improve livelihoods and invest organic premiums into the communities of organic farmers. Currently the FCC focuses its efforts on supporting farmers in the production of specialty coffee intended for export to the U.S. and Europe. The FCC was certified Fair Trade in 2004 and is now promoting USDA organic certification amongst its target farmer population. This farmer population includes 700 organization members spread out across six municipalities within Cauca, 29% of whom are women (Virality Coffee, 2017). Each of these municipalities has a local association that operates under the FCC umbrella.

Organic certification is lengthy process with stringent regulations including full farm full transition to organic, obtaining new de-shelling and roasting equipment, and a complete ban on synthetic fertilizers and pesticides. The FCC has helped 30 of their member farmers achieve organic certification, while many others are undergoing or contemplating the transition from conventional production to organic. Apart from conducting coffee quality tests and packaging the coffee for export, the FCC's major activities include producing and selling affordable organic agricultural inputs, including compost-based fertilizers and organic pesticides. The FCC makes these inputs at their composing plant, *Agroempresa FCC*, which was completed in 2014. The technicians at the composting plant also provide technical guidance to farmers seeking to use composting and vermicomposting methods on their farm.

Methods Promoted in Cauca, Colombia
• Reliance on <u>organic</u> pesticides and fertilizers (provided at low prices by extension), as well as achieving organic certification* • <u>Composting</u> (vermicompost) • Enhancing <u>natural pest enemies</u> (intercropping cassava with coffee to enhance the presence of a beneficial fungus that repels borers) • <u>Less dense</u> spacing of trees (2,500 trees per hectare in organic production as opposed to 4,000 trees per hectare in conventional) • <u>Intercropping</u> with woody trees for shade, leguminous *Inga feuillei* trees ("guamo" colloquially) for increased nitrogen availability, plantain trees (for increased phosphorus return to soil via leaf litter, shade, and food for potential bird pests)

• Raising livestock (e.g. chickens, guinea pigs, rabbits, and cattle) for manure-based fertilizer

*Organic certification (USDA) is achieved by following a set of legally defined practices including full farm adoption of organic methods, replacement of equipment used for conventional cultivation, no synthetic pesticides or fertilizers, and a transition period of 2-3 years before certification during which USDA agents inspect the farm and check farm records.

Economic and Development Differences

Country	Madagascar	Colombia
GDP	$10.6 billion	$380 billion
GDP per capita	$463	$7,800
HDI ranking:	158th	95th
GINI index	47.5	53.5
GINI index rating	26th	11th
Currency to $1 USD	3,200 Ariary	2,900 Pesos
Literacy Rate	65%	95%

Table 1: Comparison of economic and human development indicators. Sources: UNDP 2016, CIA World Factbook 2012, CIA World Factbook 2001, CIA World Factbook 2015, World Bank 2013

According to the HDI (which measures three factors related to health, education, and economics), Colombia is considered to have a high level of development and Madagascar is considered to have a low level of development (out of four categories: low, medium, high, and very high) (UNDP, 2016). Regional differences must be emphasized here as well; not a single country in South America falls into the same category as Madagascar (low development), whereas in Africa only two countries in North Africa fall into the same category as Colombia (high development). All countries in sub-Saharan Africa have a rating of medium or low development.

Madagascar is consistently ranked as one of the world's poorest countries, falling almost always in the bottom ten countries globally (Rasambainarivo, 2003). It is often the only country on the list to have never engaged in a civil or international war (the 2009 coup never escalated to what was considered civil war). Meanwhile, Colombia has struggled through the longest war in the western hemisphere (Walker, 2016).

The challenges presenting these nations are therefore grand in scale but also very different in nature. The same applies more specifically to their challenges in agriculture. Both regions face agricultural constraints including pests and erosion, yet the types of pests and the causes for erosion differ greatly. I chose to answer my research questions in the context of these two locations precisely because they differ so much biophysically and socioeconomically. Furthermore, the organizations working within these two regions not only face completely different sets of constraints, but they also have very different goals; in Madagascar the goal is to improve food security and soil health while in Colombia the goal is to enable more farmers to achieve organic certification and reap the associated economic benefits for improved livelihoods.

3.2. Data Collection

The main method of data collection in both cases was structured interviews with farmers and extension agents and other stakeholders. The interview-based research conducted in Colombia was complimented by a soil health component.

Research Methods Implemented in Toliara, Madagascar

The data collection period for the following methods was April 4-28, 2016. The data was collected as part of an Independent Study Project with the School of International Training[1] during the Spring 2016 semester of their Madagascar study abroad program in Biodiversity and Natural Resource Management. During this three-week period, 14 interviews were conducted with a total of 20 participants. Transect walks, and participant observation supplemented these interviews. The types of interviews conducted varied depending on the place, interviewee, and subject matter. A key difference between the methods employed in these two components is that in Toliara I did not interview farmers explicitly affected by NGOs or agricultural extension, but rather those cultivating within walking distance of the agroecological research station Betanimena.

The following list of methods describes these distinctions in detail:

[1] School of International Training (SIT), a Brattleboro, Vermont-based graduate institute and international education institution that offers accredited study abroad programs in Madagascar.

1) Structured interviews with farmers cultivating land on the outskirts of Toliara in the communes of Miary, Antaravay, and Maninday. The farmers were selected by my local guide. Interviews took place in or next to the farmers' fields, generally between 8:00 AM and 11:00 AM. A total of 6 farmer group interviews were conducted with a total of 10 farmer participants. All participants were Malagasy men. These interviews were conducted in Malagasy and interpreted into English by my local guide. The following information was collected:

i. Demographic information: region of origin, how long the participant had been a farmer, how long they had farmed in this region.
ii. Basic farm information: size of farm in terms of number of plots, crops grown and livestock ownership.
iii. Management decisions: use of *tavy* (illegal in Toliara due to proximity to multiple national parks), fertilizer use and type, pesticide use and type, tillage use and tool, irrigation source, reliance and description of farmers' traditional methods, intercropping practices, covercropping practices, mulching practices, and motivations, obstacles, and skepticism regarding these methods.
iv. Harvest and yield indicators: harvests per year and proportion of yield stored, consumed, and sold. Issues with storage and methods taken to prevent food loss in storage.
v. Sensitivity to climate change: observations on frequency, intensity, and predictability of the rains, heat spells, locust invasions, etc.
vi. Perception of NGOs and reliance on or knowledge of their activities.
vii. Major constraints to agriculture and what NGOs or the government should do to address these, including improved seeds, inputs, better hand-held watering and pesticide application tools, agrochemicals, technical training, irrigation access, regulation of market prices, etc.

2) Semi-structured interviews with agricultural experts and technicians. Interviews took place at the agroecological research station Betanimena on several mornings. Two separate interviews were conducted with two agricultural scientists, one local man and one foreign woman. The questions asked to these experts were also asked to third set of participants (stakeholders and NGO representatives), and can be fond below. These interviews were conducted in French.

3) Semi-structured interviews with stakeholders and representatives of various local and international NGOs. Interviews took place in the offices of the organizations, generally in the afternoon, and only one per day. Interviews were done mostly by scheduled appointment. A total of 6 interviews were conducted with 8 Malagasy participants, both men and women. These interviews were conducted mostly in French.

i. Personal information: time working for current organization and any past work.

ii. Organization information: organization base (local or international), mission statement, funding sources, size of staff in Toliara, past and current programs, past and current extension activities, size and demographics of target population, existing or past partnerships with other related organizations.

   a. If an agricultural extension organization, what methods are promoted by your organization? In what locations, for how long, and to whom? How do they compare (e.g. complement, conflict) with the traditional methods of the target population?

   b. If not an agricultural extension organization, what are your organization's programs and activities in the realm of food security, food aid, or environmental protection?

   c. Degree to which agroecological methods are perceived as furthering the mission of the organization.

iii. Organization efficacy: reported or perceived levels of community participation in activities, perception of organization by target community, examples of failed projects and success stories, and reasons for success or failure.

iv. Sensitivity to constraints: current and future challenges of the target population and activities or services intended to address these challenges.

4) Participant observation, transect walks, and unstructured interviews with actors not directly related to agriculture, such as representatives of Indian and Egyptian shipping companies, local university students, and acquaintances in local government. No direct questions were asked to participants in this group, but information gathered through conversations about their daily jobs, personal frustrations, and professional plans helped to clarify and form a better understanding of the local atmosphere surrounding agriculture, trade of foodstuffs, and the role of universities and

government in farmers' and city dwellers' lives. These conversations happened in English and French, and were not recorded or noted.

Data Analysis

The information collected during these interviews was recorded by hand with a notepad and paper, and was transcribed to a computer within 24-hours of the interview. Individual answers to questions were organized in spreadsheets where all information from farmers was compiled and analyzed. First, farmers were divided into three groups depending on their degree of method use (e.g. farmers using 1/3 of the main methods promoted by extension (mulching, covercropping, and intercropping), 2/3 of the methods, or 3/3 of the methods). Then, responses to other questions were overlaid with rates of adoption to highlight trends. Qualitative data was checked for consistency, and any differences or inconsistencies between farmers' and stakeholders' anecdotal information were noted.

Research Methods Implemented in Cauca, Colombia

The data collection period took place over January 9-21, 2017. This data collection was undertaken as part of the in-country component of Cornell University's SMART[2] project in Cauca, Colombia. The 2017 data collection period was the third installment of an ongoing project between Cornell SMART researchers and the FCC.

During this two-week period, 17 farmers were interviewed on a total of 16 farms. These 16 farms were pre-selected by the FCC and represented four of the FCC's six municipalities of influence surrounding their headquarters in Popayán. These interviewees included several community leaders or heads of their community's coffee associations. Therefore, this interview pool may have been more educated, wealthy, or successful than the average coffee producer in each village. All farmers interviewed were members of the FCC.

[2] Student Multidisciplinary Applied Research Team (SMART), is a program under CIIFAD, the Cornell International Institute for Food, Agriculture and Development, that sends small teams of students to multiple countries each January.

All interviews with all participants were conducted in Spanish. Two team members will full Spanish language ability asked and recorded answers to questions. Three other team members alternated with each other in the roles of keeping a third record of interview responses for later cross-referencing, recording farm observations such as slope, and collecting soil samples.

Of these 16 farms, 7 were organic, 5 were conventional, and 4 were in the process of transitioning to organic production. All of the farmers interviewed operated small farms of less than 3 hectares. In addition to interviews and farm observations, multiple soil samples were taken from each of the 16 farms for off-farm testing.

1) Structured interviews with farmers sought both quantitative and qualitative data. Questions regarding demographics and personal information, basic farm information, and sensitivity to climate change were mostly common to all farms regardless of farm type, whereas questions pertaining to management decisions varied depending on the classification of the farm as organic, transitioning, or conventional. These questions were designed in order understand the rationale and decision-making processes behind farmers' management practices. The following information was collected:

i. <u>Demographic information</u>: time as a farmer, time farming coffee, time farming coffee using this management type (organic, conventional, or transitioning).

ii. <u>General Farm information</u>:

   a. Size of farm in hectares, number of plots, number of trees in each plot, production information
   b. Coffee variety grown in each plot, number of trees of each variety
   c. Presence and type of livestock, other non-coffee crops cultivated, proportion of non-coffee crops intended for consumption vs. sale.

iii. <u>Management Decisions and Costs</u>: type and cost of fertilizer used, type and cost of pesticides used, use of lime, use and methods of composting, application schedules for all inputs, costs of hired labor when applicable, degree to which records (agronomic and financial) were kept.

   a. For farmers in transition, what expected costs are there in transitioning to organic and achieving certification?

b. Primary motivation for current type of management (e.g. monetary, personal, environmental). Primary concerns or disincentives for not using an alternate management type.

iv. Pest and Disease Pressures:

a. Fungal and insect-related pests, times of year for outbreaks, or correlations with certain weather events.

v. Sensitivity to Climate Change: observations on seasonal variations, disruptions in patterns, major weather events (e.g. flooding or dry spells), and how these have changed over their entire careers as coffee-growers.

2) Additional observations on the following biophysical factors:

i. Intensity of slope on a scale from 1-4 (1 as flattest, 4 as the steepest)

ii. Spatial relations between coffee and other crops, such as proximity of cassava, plantain, or maize plants to coffee trees and the planting patterns on the farm.

3) Soil tests:

i. Active Carbon (AC) has been found to predict overall soil health with 67% accuracy and is therefore the best rapid, inexpensive test that can be conducted in the field (Rekik, 2016). As AC represents the most labile fraction of soil carbon, its levels respond the greatest and fastest to changes in soil management. AC comprises the base of microbial food web. Following the protocol developed by Weil et al. (2003), each soil sample was air-dried for a period of several days before testing.

ii. Soil pH measures soil acidity, which affects the chemical availability of nutrients for plant uptake. Soil pH was measured using a Low Range (4.0-6.2) pH Test Kit and air-dried soil samples.

iii. Soil texture by feel is a subjective but standardized measurement of the proportions of sand, silt, and clay within a soil sample. Soil texture influences soil properties such as structure, water retention, infiltration, percolation, root penetration, and cation exchange capacity (Weil and Brady, 2017). Using the "Guide to Soil Texture by Feel," each soil sample was tested for texture.

4) Unstructured interviews with FCC agricultural technicians and participant observation.

   i. FCC representatives, leadership, and technicians provided educational materials, demonstrations, and tours of their office and organic fertilizer production plant. Through these activities, the history, activities, individual opinions, and mission of the FCC was better elucidated.

Data Analysis

The information collected during interviews, in the field, and off-farm was recorded using notepads. All data was collected in Cauca but all data analysis was completed in Ithaca, NY. All data was transcribed to a spreadsheet.

Qualitative data on motivations, obstacles, and anecdotal information was transcribed and organized into categories. Differences in opinions and inconsistences in anecdotes were noted. Quantitative data sets were calculated for means and ranges, and when applicable were run through statistical tests to look for significant correlations. These calculated figures and other quantitative and qualitative data sets were merged, overlaid for trends, and graphed when necessary.

4. Results:

4.1 Toliara, Madagascar Results

Farmer Group	**1**	**2**	**3**	**4**	**5**	**6**	
# Interviewed	*2*	*1*	*1*	*3*	*2*	*1*	
Method Usage							
Covercropping	No	No	Yes	Yes	Yes	No	50%
Mulching	No	Yes	No	Yes	Yes	No	50%
Intercropping	Yes	Yes	No	Yes	Yes	Yes	83%
Total Usage:	1/3	2/3	1/3	3/3	3/3	1/3	
Degree and Details of Method Usage							
Covercropping	-	-	Yes//		grasses	-	
Mulching	-	uprooted weeds	-	Yes//	uprooted grasses	-	
Intercropping	Maize + squash	Maize + squash	-	Maize + cucumber	Maize + squash	Maize + beans	
Supplemental Irrigation							
Irrigation Source	*Jirama* well	Self-dug lined well with generator	Self-dug unlined well	Self-dug unlined well	None	Channel from river	
Other Management Decisions							
Burning	No	No	No	Yes	No	No	
Tillage	Hoe	Tractor	Hoe	Hoe	*Zebu*-drawn plough, hoeing	*Zebu*-drawn plough, hoeing	
Fertilizer Type	No	Chemical, when affordable	*Zebu* + chicken manure	*Zebu* manure	No	No	
Pesticides	No	1x per year	No	4x per week	No	Every 2 days	
Farm Size							
Classification	Small (<0.5 ha)	Large (>1 ha)	Small (<0.5 ha)	Medium (0.5<X<1 ha)	Large (>1 ha)	Medium (0.5<X<1 ha)	
Proportion of Crops Consumed, Sold or Stored							
Consumed	**75%**	5%	5%	20%	25%	**50%**	
Sold	20%	**75%**	**90%**	**75%**	**50%**	25%	
Stored	5%	20%	5%	5%	25%	25%	
Majority:	Consumed	Sold	Sold	Sold	Sold	Consumed	
Crop Diversity							
# of crops	4	3	14	12	9	3	

Table 2. Summarizes the findings from the surveys of the farmers in Toliara.

METHOD USE: All of the interviewed farmers were utilizing at least one of the methods promoted by the NGOs. No farmer was using any of the promoted methods to the fullest, ideal extent. For example, covercrops were not used consistently throughout a field, mulching involved some dried biomass atop mostly bare soil, and the maximum number of crops intercropped was two, never three. Overall method-use was as follows: 50% of farmers used only one method, 17% used two methods, and 33% used all three promoted methods. Amongst farmers using only one of the three methods, 66% were using intercropping as their only method, which was the most popular method and used by 83% of all surveyed farmers. Mulching was never used by a farmer using only one method. The degree to which this method use could be attributed to extension was difficult to assess because the farmers interviewed were not in the target populations of most of the NGOs interviewed.

PARENTS' METHODS AND ORIGIN: Farmers' place of origin or their parents' place of origin influenced their use of methods. Farmers indicated that they followed their parents' or "fathers'" methods of production; if their parents used a method, they were more likely to use it. No farmers with parents from dry south or southwest regions (Androy or Atsimo-Andrefana) intercropped maize with a legume. Farmer 6, with origins on the eastern coast of Madagascar, did intercrop maize and kidney beans.

PROPORTIONS: The majority (67%) of farmers who sold most of their produce showed higher rates of method adoption (≥2 out of 3 methods), with the exception of a vegetable farmer. All of the farmers who consumed most of their produce showed low rates of method adoption (1 out of 3 methods).

IRRIGATION: To supplement rainfall, most farmer groups (83%) used supplementary irrigation. One farmer group used a well provided by the national water and electricity company, *Jirama*. Others used self-dug wells, channels from rivers, or no irrigation. One farmer group that had no irrigation facility mentioned a channel that used to flow off of a nearby river, but the channel had since dried up due to lack of rain.

HARVESTS: Most farmer groups reported two harvests each year. However, they expressed concern that they would only reap one harvest due to the late rains of that year. By mid-April, farmers who had planted in December expecting rains by March anticipated losing their crop.

MANAGEMENT: Only one farmer group reported burning their fields, but they did so only in an effort to control caterpillars and not to clear new fields. Farmer group 3 explained that burning was practiced in the countryside, but the peri-urban farmers surveyed by this study did not burn because it was illegal. All farmers tilled their soil, most with hand-held hoes, and a smaller number with *zebu*-drawn ploughs or tractors. When *zebu* were present on the farm, farmers reported uprooting maize and using biomass and crop residues to feed their livestock.

FERTILIZER: Fertilizer-use for food crops was low, with 33% of the farmer groups using manure-based fertilizers. Farmers reported that the price of fertilizer was not proportionate to the increase in yield from the fertilizer. Some farmers blamed this on high prices demanded by foreign fertilizer companies combined with low local market prices for their produce.

PESTICIDES: Pesticide use was split, with 50% of farmer groups using no pesticides and the other half applying as rarely as once a year to as frequently as four times a week. Those who applied pesticides frequently did so in order to control caterpillars and mealybugs, which were perceived as being non-native to the region and recently introduced. There was confusion and controversy on the topic of the origin of these pests and the efficacy of the pesticides. Many farmers insisted that the caterpillars and mealybugs first appeared in their fields after the textile company Tianli arrived in the region and promoted contract farming of cotton. Tianli also promoted pesticides to combat caterpillars and mealybugs, yet farmers were experiencing pesticide resistance and inefficacy when using the pesticides. Farmers expressed frustration that they were given no clear instructions on how and when to use the pesticides, no safe application tools, and were sometimes sold expired pesticides (especially to illiterate farmers).

FARM SIZE: Farmers with large to medium farms (0.5 ha to >1 ha) were more likely to use two or three methods. Farmers with smaller fields (less than 0.5 ha) tended not to use multiple methods.

CROP DIVERSITY: Farmer groups that reported a greater number of crops on their farms (Mean 10.5 crops) also the highest rates of adoption (3 out of 3 methods). Farmer groups that reported a lower number of crops on their farm (Mean 6 crops) had lower rates of adoption (1 out of 3 methods), with the exception of the vegetable farmer in Farmer Group 3 who grew 11 crops that were mostly vegetables and leafy greens intended for sale. Without Farmer Group 3, the Mean drops to 3.5 crops for farmers using only one method.

RELIGION: Extension agents asserted that according to the traditional belief system in the region, it is considered disrespectful and taboo to take active measures to improve soil fertility because it implies that the farmer does not have faith that the earth will deliver enough for sustenance. Furthermore, since *zebu* are spiritually important, diversion of biomass as fodder for *zebu* is common and logical not only from a livestock perspective but also a religious perspective. No data on religious beliefs or practices was collected during farmer interviews. Previous studies have shown that 39% of households have no livestock (poorest), 47% own 6 zebu and 13 small ruminants on average, and the top 14% of wealthiest farmers own herd sizes of 42 zebu and 57 small ruminants on average (Neudert et al. 2014).

Motivations for Adoption

The primary cited motivations for adopting the promoted methods were increasing yields and increasing soil moisture. Extension agents said that increased in yields were expected to be achieved by protecting soil from various types of erosion, increasing soil fertility, or improving synergistic relationships between crops. Farmers using mulching and covercrops noted that these methods improved moisture retention of their fields and prevented soil sealing.

However, when asked all farmers cited pests and unpredictable rains (and resulting water scarcity) as their primary constraints to production. The methods promoted by extension did not explicitly address these constraints.

Obstacles to Adoption

One of the main obstacles to adopting covercropping or mulching was the diversion of biomass as fodder for *zebu*. Another obstacle was the long waiting time to pay-off of these methods. While soil moisture and soil organic matter may improve over time and yield will increase, the immediate need for biomass as fodder outweights long-term investments in soil health.

Climatic variability also affected farmers' ability to use the promoted methods because when the rains are significantly late, little to nothing grows and so farmers reap little to no biomass and low yields. The limited biomass available is diverted to *zebu*, which act as a bank of wealth particularly in drought times. During these times the pastureland for *zebu* that complements biomass as fodder is also negatively impacted by late rains.

Extension agencies reported farmers implementing methods but not to the extent that was considered full or correct adoption, such as mulching as a dusting of straw over a mostly bare field or intercropping of maize and squash but very little intercropping of maize and legumes, which would help to control *Striga grandica*. Stakeholders and NGO representatives stated that reasons for this partial adoption included 1) farmers not getting enough biomass from the soil to support mulching or covercropping, 2) living under conditions of low food security and associated high levels of risk aversion, 3) inability to invest in soil health if doing so would mean cutting back on crop consumption (by the household or by *zebu*) with no finances to buy food or fodder alternatives.

Pests were the constraint that farmers spoke about the most and extension addressed the least. The three methods promoted widely by NGOs addressed soil health, but no NGOs or agricultural extension groups were addressing pest control (with the exception of emergency government spraying against locust invasions in some high-risk areas). Consequently, farmers were buying unknown pesticides from Tianli and using them without instructions.

Figures 5 and 6: Biomass availability was a limiting factor for farmers in Toliara. Research stations in Toliara had greater access to irrigation and inputs than most farmers. (Top) The biomass observed at the FOFIFA state-led research station in Toliara. (Bottom) The biomass observed in the fields of Farmer Group 5. Addressing differences in conditions and yields between research stations and farmer's fields was emphasized by FSAR in the late 1980's (Collinson, 1987). These differences are considered to be particularly noticeable in dry systems (FAO, 1996).

4.2. Cauca, Colombia Results

A total of 30 out of 700 FCC member farmers are certified organic. In 2016 there were 39 farmers who were considered to be in transition, which includes those who lacked certification but were organic in practice (Cerna, et al. 2016). However, the interviewed farmers were chosen by the FCC to equally represent all farm types. Therefore, the breakdown of the interviewed farmers' farm types is not proportional to the ratio of farm types in the area.

Farm Type	Organic	Transitioning	Conventional
# Interviewed *Total 16*	7	4	5
Other Non-Coffee Crops			
Mean	6.3	4.3	3.6
Range	5 – 9	1 – 7	1 – 6
Standard Deviation	1.6	2.8	2.1
Consumption vs. sale of non-coffee crops			
% of farms reporting most sold	**71%**	-	40%
% of farms reporting most consumed	29%	-	**60%**
Presence of Livestock			
% of farms with chickens	57%	0%	20%
% of farms with cows	14%	25%	0%
% of farms with rabbits	14%	0%	0%
Total % of farms with livestock	57%	25%	20%
Fertilizer			
No use	**100%**	**50%**	0%
Chemical (Urea)	0%	25%	**80%**
Chemical 4-24-7	0%	0%	20%
Homemade Formula	0%	25%	0%
Pesticides			
No use	29%	50%	**60%**
Sulfocalcio synthetic (organic)	**42%**	**50%**	0%
Fungicide	0%	0%	40%
Homemade Formula (soap-based)	29%	0%	0%

Table 3. Summarizes the findings from farmer interviews in Cauca concerning management decisions.

CROP DIVERSITY: Organic farmers had more crop diversity in their farms. The most common non-coffee crops were: plantain trees, cassava, maize, leguminous *Inga feuillei* trees, and woody fruit trees (especially avocado and citrus). These crops were generally intercropped with coffee.

Farmers indicated that they thought that plantain trees improved potassium in the soil through their leaf litter, *Inga feuillei* improved nitrogen availability, and cassava promoted the growth of a beneficial fungus that prevented coffee cherry borer. It was visually observed that organic farmers more likely to intercrop plantains, cassava, and *Inga feuillei* with coffee whereas conventional farmers were more likely to intercrop maize with coffee.

PROPORTIONS: Farmers who reported that only a small amount of their non-coffee products were for consumption and the majority was for sale were more likely to be organic. Conversely, farmers who reported that large proportions of their non-coffee products (especially maize) were intended for consumption were more likely to be conventional.

LIVESTOCK: Farmers who owned livestock and thus had on-farm access to manure were more likely to be organic farmers. More than half (57%) of organic farmers reported having on-farm livestock whereas only 20% of conventional farmers had on-farm livestock. Farmer who owned livestock reported using manure from on-farm chickens, cows, and rabbits in their composting heaps, as well as egg shells.

PARENTS' METHODS: Farmers whose parents cultivated organically were more likely to be organic. While only 29% of organic farmers said that their parents also cultivated organic coffee, 100% of farmers who said that their parents cultivated organic coffee were organic farmers themselves and were therefore continuing their parents' methods.

BORER AND RUST: Every farm showed some degree of existing damage from both coffee cherry borer and coffee leaf rust. However, many farmers reported not having issues with pests or disease despite visible signs of rust on leaves and borer holes on coffee cherries. It seemed that there was a certain threshold of damage that had to be reached before a farmer would recognize pests or disease as a problem, but this threshold was undefined inconsistent from farm to farm. It was observed that visible damage from rust was oftentimes concentrated and much more severe at the bottom of the slope. Additionally, farmers reported that if their neighbors who were cultivating in fields adjacent to theirs noticed issues with the coffee cherry borer or coffee leaf rust, they would notice the same issues in their fields shortly thereafter.

PESTICIDES: Most organic farmers relied on organic pesticides made at home from soap or supplied by the FCC (e.g. "sulfocalcio"). The majority of conventional farmers (60%) did not use any form of pesticide, with 40% using a fungicide.

FERTILIZER: All conventional farmers reported using chemical fertilizers, including urea and a 4-24-7 N:P:K fertilizer. No organic farmer used chemical fertilizer. All organic farmers reported using only organic fertilizers. All organic farmers had an on-farm area dedicated to composting. The most common materials used in home composting: coffee pulp, maize husks, eggshells, bones, chicken and rabbit manure, plantain tree stalks, household food waste. No conventional farmers engaged in on-farm composting. Some farmers in transition had on-farm composting areas, but supplemented compost with chemical or homemade fertilizers.

Farm Type	**Organic**	**Transitioning**		**Conventional**
# Interviewed *Total: 16*	7	4		5
Area Under Coffee Cultivation				
Average size in hectares	1.4	1.2		1.7
Range	0.8 – 3.0	0.6 – 2.0		1 – 3.0
Standard Deviation	0.8	0.6		1.0
Tree Density and Production		*Org. in Practice/Transitioning**		
Mean tree density (trees per ha)	2,550	3,274	4,542	4,250
Mean production (kgs per tree)	0.96	0.72	0.32	0.96
Mean production (kgs per ha)	2,258	1,896	1,353	4,292
Slope				
Average slope rating*	1.6	2.6		3.0
Soil pH				
Mean pH	5.6	5.6		5.6
Mean pH range of the 3 samples taken from individual farms	0.37	0.36		0.60
Prices		*Org. in Practice/Transitioning**		
Baseline price	$2.41/kg	$1.09/kg		$1.09/kg
Fair Trade Premium	$0.09/kg	$0.09/kg		$0.09/kg
Organic Premium	$0.135/kg	-		-
Full price	$2.635/kg	$1.18/kg		$1.18/kg
Gross income per hectare	**$5,949.83**	$2,237.28	$1,596.54	**$5,064.56**
Gross income per Farm	$8,328.60	$2,684.74	$1,915.85	$8,609.75

Table 4. Summarizes the findings from farmer interviews and farm observations in Cauca concerning coffee production, price, and farm observations.

*Org. in Practice/Transitioning: The left-hand figures show data for transitioning farms that were organic in practice but had not yet been certified. The right-hand figures show data for farms that were still changing their management practices to reflect organic requirements.

PRODUCTION: Coffee trees on organic farms were much less densely spaced than on conventional farms. This resulted in organic farms having lower yields per hectare. However, production per tree was identical for organic and conventional farms, and significantly lower for farms in transition.

COSTS AND GROSS INCOME: Organic farms earned more gross income per hectare than conventional farms. Despite having nearly half the average tree density of conventional farms and therefore significantly lower production per hectare coupled with lower average number of hectares under cultivation, organic production brought in more revenue by nearly 15%. This was because of the higher baseline prices and the organic premiums earned by organic coffee. Since conventional farms are larger on average (have more hectares under cultivation), they earn similar total farm revenues to organic farms of smaller size. Therefore, organic farms can cultivate on less land but earn gross income that is similar to that of conventional farms. To calculate profits, each farm would have to take into account labor and input prices. According to the findings of the first installment of the SMART research team in 2015, due to these additional costs of production on conventional farms, conventional farms have higher overall production costs and therefore make less net income, or profits. It was determined that for these reasons it was more profitable to be an organic farmer (Avila, et al. 2015). It should be noted that transitioning farmers experience a significant dip in gross income, especially in the beginning before they are organic in practice. This may be due to the coffee trees adjusting to new management and the added economic strain of certification costs (e.g. buying new equipment).

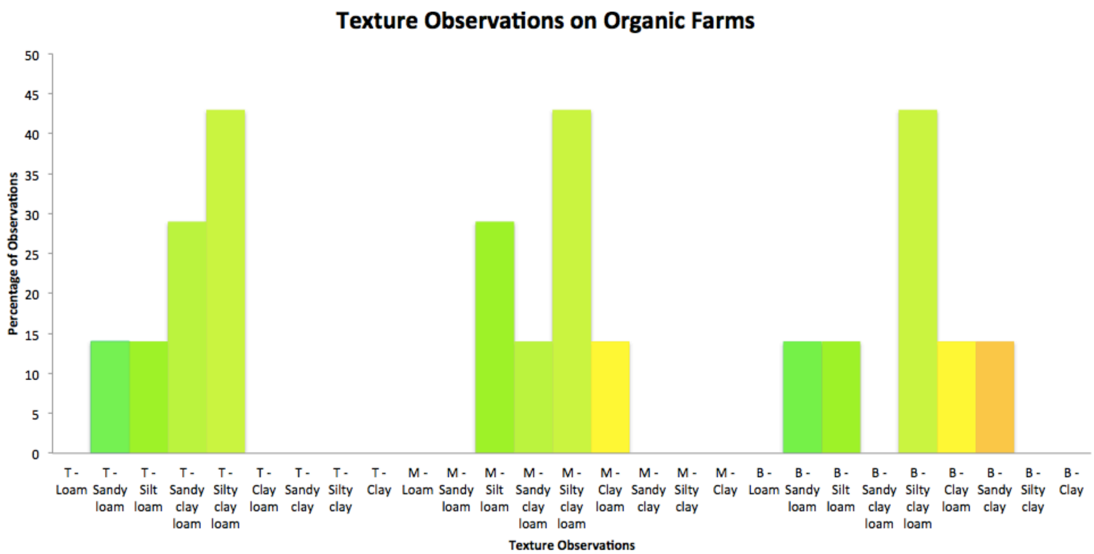
RECORDKEEPING: Farmers had a consistently good or approximate sense of their farm structure and production levels. However, many farmers displayed aversion or apathy towards keeping meticulous written records of management decisions and annual differences in production. It was observed that this attitude was more prevalent in conventional farmers. One conventional farmer remarked that he liked being a coffee farmer, but if he kept records he might notice that in some years he loses money. He said that knowing about his economic losses may convince him to return to his old job as a construction worker, which he did not enjoy as much as coffee farming. Contrastingly, organic and transitioning farmers had an incentive to keep written records to gain certification and prove their organic management. However, standardized recordkeeping skills were lacking throughout all farmers regardless of management type.

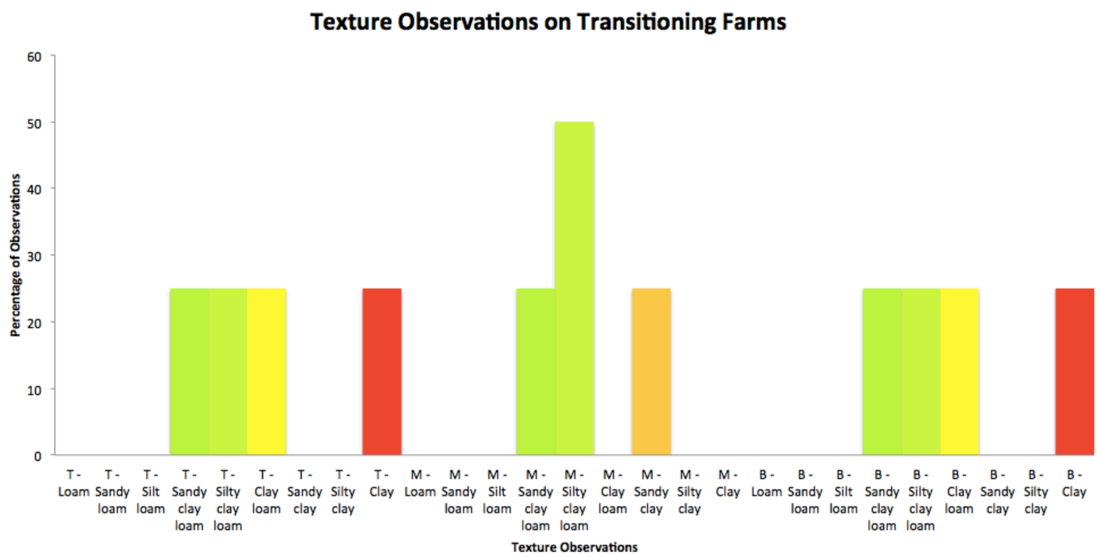
SLOPE: Farmers on more gradual slopes tended to be organic farmers whereas farmers on steeper slopes tended to be conventional. *Slope ratings were subjectively determined and given on a scale from 1 to 4 (1 flattest, 4 steepest). The ratings correspond to the following approximate ranges in angle degrees: 1: 0°-20°, 2: 20°-40°, 3: 40°-60°, 4: 60°-80°

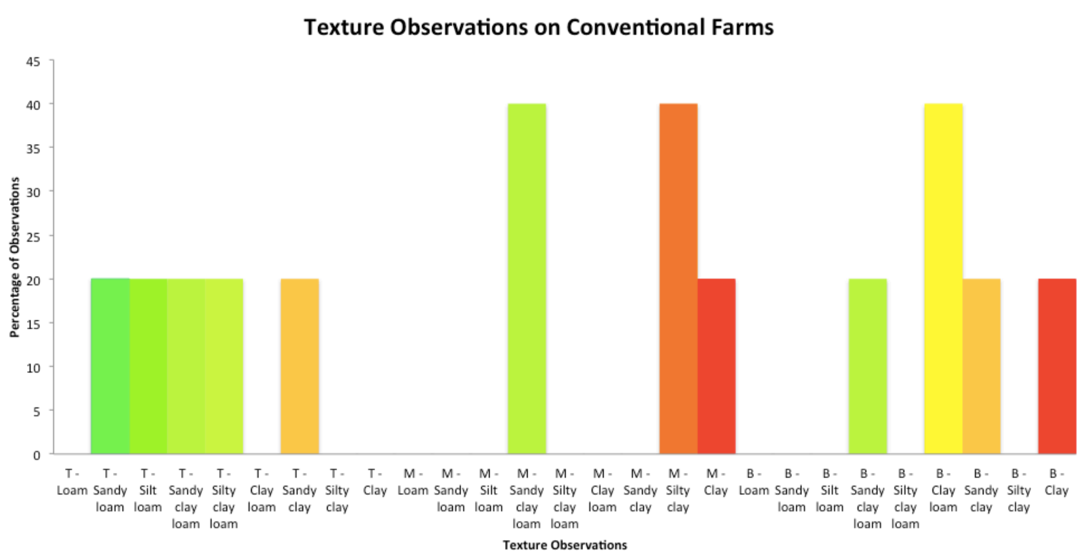
FARM SIZE: Organic and transitioning farms tended to be smaller than conventional farms, with organic farms being slightly more variable in size. It should be noted that while organic farms were generally smaller than conventional farms, the homes of organic farmers tended to be larger and more modern (brick, concrete, or multi-story) than the homes of conventional farmers (single-story, sometimes built of mud and straw).

ACIDITY: Though pH-values generally fell between 5.0 and 5.8, the pH-values of soil samples collected from the top, middle, and bottom of the slopes were slightly more variable on conventional farms than on organic or transitioning farms. Most farmers regardless of farm type were applying lime to increase their pH, but none of their pH values were considerably low. Data on lime application schedules and amounts was inconsistently collected. It is unclear whether the farmers applied the lime in order to maintain the pH (as the average across all farms was 5.6, which is well within the recommended range for coffee of 4.5-7.0 (Wellman, 1961)), or with the intention of increasing the pH for coffee or other crops.

ACTIVE CARBON: There was no statistical difference in active carbon between organic and conventional farms (Mean Active Carbon: Organic - 747 mg/kg, Transitioning - 771 mg/kg, Conventional - 719 mg/kg). Transitioning farms had the highest mean value. Interestingly, the highest individual active carbon value was recorded on an organic farm (1,144 mg/kg) and the lowest individual active carbon value was recorded on a conventional farm (337 mg/kg).







Figures 7, 8, 9: Texture information from the top, middle, and bottom of the slope by farm type.

TEXTURE: Farmers on steeper slopes, which also tended to be conventional, had less balanced soil textures at each of the three sampling points (top, middle, and bottom) and more texture variation throughout the slope. This can be seen in Figures 7 to 9, in which the green color indicates loam-dominated soils and the red color indicates clay-dominated soils. Farmers on more gradual slopes, which tended to be organic, had more balanced textures at each sampling point and less texture variation throughout the slope.

LABOR RATES: Data on the price of hired outside labor was not consistently collected, with s some farmers reporting hour wages and others reporting daily wages. The rate cannot be below $1.18 per hour, the minimum wage in Colombia (Alsema, 2017; Avila, et al. 2015).

Motivations for Adoption

The primary motivation cited by farmers for adopting organic methods was a desire to be ecologically sustainable and deep aversion to agrochemicals due to negative personal or community experiences (e.g. child ingesting pesticides and suffering brain damage, farmer losing eyesight in one eye after spraying pesticides).

Economically, some organic farmers insist that organic fertilizer is cheaper and more cost-effective in terms of per plant application than chemical fertilizer. One organic farmer calculated that one bag of chemical fertilizer priced at 14,000 pesos ($4.83) supplied 700 coffee trees while one bag or organic fertilizer priced at 25,000 ($8.62) pesos supplied 1,500 coffee trees, rendering the per tree cost of fertilizer 20 pesos for chemical and 16 pesos for organic (a difference of $0.002 per plant). Organic and transitioning farmers also could make most of their own compost at home or buy organic fertilizer from the FCC. Organic premiums and the higher baseline price for organic coffee earn organic farmers more income. However, the FCC functions as a cooperative because the portion a member's income earned from organic premiums is invested into the community. Quality premiums are kept by the farmer, although according to the FCC organic farmers do not score higher on quality tests than conventional farmers. Therefore the higher baseline price for organic coffee and the lower cost of inputs are the two main economic motivations for adopting organic methods.

Obstacles to Adoption

The major obstacles to adoption involved: the requirements and costs of certification, the difficulty of cultivating on steep slopes, and lack of record keeping. One of the requirements for organic certification is full-farm transfer. This means that though a farmer can test out organic methods in one part of the farm, that farmer will not be able to officially certify that part of the farm. The farmer will therefore experience the decrease in yields per hectare associated with organic agriculture in the 'organic' test plot, but will not earn organic premiums for the coffee produced in that 'organic' plot because the plot is not certified. This discourages farmers from testing organic methods. Another requirement of certification is buying new de-shelling and drying equipment that can cost several hundred to several thousand dollars, depending on size and quality. Transitioning farmers must buy new equipment because according to certification guidelines, old equipment cannot be cleaned after use with conventional coffee, but must be fully replaced.

Conventional farmers on steep slopes cited the incline of their farm's slope as an obstacle to adoption of organic methods because it is a major labor constraint. Organic cultivation requires more individual care and attention to each coffee tree, but farmers on very steep slopes found climbing the slope daily to be too much work and too expensive to pay laborers. Outside laborers, who must be paid at least $1.17 per hour, take more time to do the same amount of work on steep slopes that they could get done on flat land in less time, thus decreasing the efficiency and increasing the overall price of daily labor.

Proximity to other farms was a concern for farmers who were considering transitioning to organic production, especially in municipalities where there was little communication between farmers concerning their methods for pest and disease control. Farmers who were cultivating in fields near to their neighbors' fields were concerned that a leaf rust or cherry borer outbreak in a neighbor's farm could easily transfer to their farm. These farmers feared that transitioning to organic production would render them unable to use pesticides to control such outbreaks. Farmers stated that talking to neighbors about pest issues and their management decisions was not common. No data was collected on whether or not organic farms were generally more isolated than conventional farms and therefore less prone to the spread of pest and disease outbreaks from other farms.

Lack of recordkeeping was a persistent problem, with some farmers saying that they chose not to keep records because they did not want to know if they were losing money during a bad year. Without financial recordkeeping skills, farmers are unable to justify to themselves that there are economic benefits associated with transitioning to organic production. Without agronomic recordkeeping skills, farmers are unable to prove to organic certification agents that they follow organic certification regulations. Thus, farmers' reluctance to keep records acted as obstacle to adopting organic methods.



Figures 10, 11, 12: (Left) An example of a farm on a steep slope in Cauca. (Center and Right) Examples of de-shelling machines and the rain-protected structures in which they are kept.

5. Discussion:

It was hypothesized that the degree to which a farmer is able or willing to adopt a method promoted by agricultural extension is influenced by biophysical factors and farm structure, personal beliefs and life experiences of the farmer, and the ways in which extension agents present the methods. Furthermore, it was hypothesized that these factors influence method adoption in varying degrees depending on the type of environment. The following analysis will address each of these potential hypotheses in two contrasting tropical environments: Toliara, Madagascar and Cauca, Colombia.

In Toliara, the farmers surveyed were not in the target populations of local NGOs and extension agencies, and were therefore not directly impacted by their activities. Amongst the six surveyed farmer groups, 50% of the farmers used only one of the promoted methods, 17% used two, and 33% used all three, with the most common method being intercropping. Therefore, most farmers were not using all three methods. In Cauca, all farmers surveyed were members of the FCC and therefore directly impacted by its activities and standards. The FCC reports that 4.3% (30 farmers) of its 700 farmers are certified organic and 5.5% (39 farmers) are in the process of transitioning. This study surveyed 7 of the FCC's 30 organic farmers, or 23%, but did not survey farmers in transition or conventional farmers proportionately to the sizes of their populations in FCC's membership. Therefore, while the large majority of FCC's farmers have not yet achieved organic certification, they may be adopting or integrating organic management strategies at rates similar to those found in this study. The rates of adoption in both cases were compared with data concerning the three hypothesized factors thought to influence method adoption. This analysis will refer to quantitative data and incorporate qualitative data collected from both countries to support statements about ways in which these three factors motivate or prevent farmers from adopting certain methods.

5.1 Biophysical Factors and Farm Structure

Landform, Soil Texture, and Soil pH

Based on the results, it can be seen that differences in the landform of a farm such as slope impact adoption of methods, particularly in environments with undulating, hilly topography. The data shows that in Cauca, more of the conventional farms were found on steep slopes (>40°) whereas organic farms tended to be found on flat or gradual slopes (<20°) (See Table 4). Farms in transition tended to be on slopes of medium steepness. The major cited reason for why farmers on steep slopes did not adopt organic methods was labor requirements. Organic cultivation requires increased work and attention to each individual coffee tree. Farmers on steep slopes stated that they did not have the time or energy to attend to each plant because that involved traversing the steep slopes. Farmers also stated that if capital was available, they preferred to hire outside laborers only during the harvest season and not for the daily requirements of labor-intensive organic cultivation.

Another hypothesized reason for why farmers on steep slopes did not adopt organic methods was soil texture. An interesting observation in Cauca was that conventional farms tended to have soil that was more variable throughout the slope and heavier in texture (i.e. clay) (See Figure 9). This observation makes sense, as slope influences the stratification and accumulation of differently sized soil particles along the slope and conventional farms tended to be found on steeper slopes. Farms on steeper slopes with varied texture throughout the plots often had clay accumulation towards the slope's bottom, increasing the likelihood of waterlogging and associated fungal diseases that thrive in wet environments such as coffee leaf rust. This would cause farms on steep slopes to have more severe disease pressures than farms on gradual slopes. Additionally, coffee leaf rust was more likely to be observed at the bottom of the slopes than at the top. Since most farmers lived at the top of their slopes, these increased disease pressures would be concentrated at the most difficult to reach part of the farm; the bottom of the slope. This is a potential reason that farmers cultivating on steep slopes were more likely to rely on pesticides and synthetic inputs to control disease pressures and less able to adopt organic methods than farmers cultivating on gradual slopes (See Tables 3 and 4).

Furthermore, conventional farms on steeper slopes had slightly more variation in pH values from the top to bottom of the slope than organic farms on flat slopes (See Table 4). This may also be attributed to soil stratification on steep slopes. Since pH affects fertilizer and nutrient uptake, differences in pH may result in varying rates of fertilizer uptake and rates of return on fertilizer. Farmers who observe this may be more likely to uniformly over apply synthetic fertilizer to the entire field in order to ensure fertilizing all coffee plants. Ultimately, steeper slopes in Cauca are correlated with more unbalanced and varied soil textures and pH values within the same farm. This lack of uniformity in texture and pH can lead to differing best management practices in different parts of the farm, thus increasing the level of effort farmers on steep slopes must invest in managing their farm. Therefore, steep slopes can render management decisions more complicated than they are for farmers on flat land. The overarching constraint associated with steep slopes is labor, either in physically reaching each plant or or management-wise in controlling coffee leaf rust and fertilizer uptake. For these reasons, farmers cultivating on steep slopes faced multiple obstacles in adopting organic methods.

The flatness of the landscape played less of a role in determining labor requirements and water erosion in the flat, semi-arid environment of Toliara, Madagascar. Data was not collected on topographical differences or landform differences in Toliara. However, major topographical variations in the otherwise flat landscape can determine the intensity and impact of wind and water erosion, a major constraint cited by farmers. Without vegetative cover, the strong, unidirectional winds known as *Tsiokatimo* ("South Wind") lift and carry the often-dry soils, causing erosion. The lack of windbreaks in the area, such as lines of trees, contributes to and enables this wind erosion. The area's high rate of deforestation for agricultural land and charcoal therefore not only diminishes the regions' water supply but also diminishes existing windbreaks and contributes to erosion. Additionally, variations in landform in Toliara such as small valleys may serve as areas of increased water collection and subsequent soil moisture. These landform variations may make a noticeable difference in the success of a crop a water-constrained system. It can be postulated that farmers who cultivate in fields that benefit from the few windbreaks or valleys in the area may feel less of a need to adopt methods to enhance vegetative cover (e.g. covercropping or mulching), but this cannot be confirmed by the results.

Livestock

The presence of livestock impacted whether or not farmers adopted methods in both countries. In Cauca, on-farm livestock (e.g. chickens, cows, rabbits) acted as a direct, on-farm source of manure that could be used in organic fertilizer and compost. The majority of organic farms had on-farm livestock whereas only 20% of conventional farms had on-farm livestock (See Table 3). On-farm livestock was therefore correlated with the farm being organic, so it can be postulated that livestock's byproducts assisted farmers in adopting organic methods. Farms in transition reported having on-farm livestock at a rate slightly higher than conventional farms but more similar to that of conventional farms than organic farms. This low rate of livestock on transitioning farms (25%) may be partially due to the fact that the FCC supplies farmers with affordable organic fertilizer in order to help them transition to organic production. This affordable FCC organic fertilizer enables farmers to transition away from chemical fertilizer, such as urea, as they are making other necessary management changes and before they invest in livestock.

It is important to note that among conventional farmers, the majority (60%) did not use any form of pesticide. However, all interviewed conventional farmers applied some form of chemical fertilizer (80% applied urea and 20% applied an N:P:K mix) (See Table 3). Therefore, farmers depended on chemical inputs primarily for nitrogen access for their crops and not for controlling pests. It can interpreted that dependence on chemical fertilizer, specifically nitrogen fertilizer, was the primary motivation for use of chemical inputs by conventional farmers. This dependence on chemical fertilizer may be partially due to the fact that most conventional farms (80%) had no on-farm livestock and therefore no source of manure-based fertilizer, rendering organic adoption more difficult.

Contrastingly, livestock in Toliara negatively impacted farmers' adoption of two of the promoted methods, namely covercropping and mulching. The importance of feeding *zebu* in the region's traditional belief system has a negative impact on farmers' ability to adopt these methods because they each require leaving biomass in the fields, which takes away from these animals' food source. The main obstacle to adopting covercropping and mulching cited by extension agents was the diversion of crop residues to be used as livestock fodder instead of use as permanent soil cover. Therefore, the need for livestock fodder competed with the use of post-harvest above and below-ground biomass as soil cover, with farmers uprooting maize plants and feeding the roots to *zebu* as well as any other available biomass. Biomass is already limited in this water-constrained region, with trials showing that the region's naturally occurring pasture cannot meet the dietary needs of the *zebu* population, especially during the dry season (Rasambainarivo, 2003). According to these studies, seasonal weight fluctuations within herds are common, with some zebu experiencing a loss of body weight as high as 25%, if not death. Clearly, there is an existing dearth of available pasture or fodder and livestock-owning farmers will do whatever is necessary to avoid losing part of their herd's value. Since the traditional belief system in Atsimo-Andrefana considers *zebu* sacred and integral to daily and spiritual life, farmers place the needs and sustenance of *zebu* high on their lists of priorities. This may explain why the most common method used by surveyed farmers was intercropping. Intercropping was the method used by 66% of farmers who were using only one method. Intercropping was also used by 83% of all farmers surveyed. Though intercropping involves more labor and can potentially enable detrimental competition between crops, it does not require biomass to be left in the field after or between harvests as covercropping or mulching does.

Furthermore, as indicated in the results, the poorest people in the region do not own livestock. While most aspects of poverty render farmers less able to adopt a new method, the fact that the poorest people do not own livestock is one factor that could make them more able to adopt certain methods. However, the results of this study do not support this hypothesis, as Farmer Groups 1 and 6 were the only groups that consumed the majority of their harvests (an indicator of food insecurity and related poverty) but were also the only two groups that used no form of permanent soil cover (neither covercropping or mulching). Therefore, other aspects of poverty may hinder farmers' ability to adopt these methods more than their lack of *zebu* enables method adoption. Ultimately, the presence of on-farm livestock is correlated with adoption of organic methods in Cauca but acts as an obstacle to adoption of methods in Toliara.

Size of Area Under Cultivation

Farm size also appeared to be associated with the adoption of promoted methods in both countries. In Cauca, organic farms tended to be slightly smaller (Mean: 1.6 ha) than conventional farms (Mean. 1.9 ha). Farms in transition were more similar in size to organic farms than to conventional farms (Mean 1.4 ha). These area sizes refer to the area of the farm currently under coffee cultivation as reported by the farmer (See Table 4). As discussed earlier, labor could be a constraint on larger farms because their greater areas require more time and energy to manage than small farms. Considering the additional labor requirements of organic production, such as tending to each plant individually, large farm size can be seen as an obstacle to transitioning to organic production.

Farm size is often associated with wealth and level of risk-aversion. In Cauca, the size of the area under coffee cultivation was not inherently correlated with wealth. This was because despite organic farms' smaller average size and significantly lower tree density, organic farms still generated more gross income per hectare than conventional farms due to the higher market price for organic coffee (See Table 4). Furthermore, when considering the overall cost of running a farm (including the costs of chemical inputs for conventional production), the average organic farm was ultimately equally or more profitable than the average conventional farm, despite having a smaller area of coffee cultivation (Avila, et al. 2015). Despite producing only 53% as much kilograms of coffee per hectare as conventional farms, organic farms made more revenue per hectare due to the higher market price for their organic coffee. Organic farms also did not have the cost of chemical inputs (Avila, et al. 2015). Therefore, the fact that organic farms have a smaller area under cultivation and fewer trees per hectare is economically offset primarily by organic coffee's higher market price and also by the lower cost of inputs. Consequentially, organic farmers have a higher net income and are generally wealthier.

In Toliara, the opposite impact of farm size on method adoption was observed. Larger farms showed more adoption of methods whereas smaller farms had lower rates of adoption (See Table 2). One could envision that on larger farms there is increased availability of biomass whereas on smaller farms there is potentially less biomass available for *zebu* fodder. Therefore, all else being equal, on larger farms there may be enough excess biomass available for use as permanent soil cover even after feeding *zebu*. However, farmers owning large farms are also more likely to own more livestock, so in reality there may be little difference between the amount of leftover biomass on small and large farms. Therefore, depending on the size of their herd in relation to the size of the farm (for which data was not collected), farmers cultivating on more land may be more likely to have biomass leftover to leave in the fields as a covercrop or return to fields as mulch.

In Toliara, farm size was a good indicator of wealth and overall food security, with farmers cultivating on large farms being more likely to have sufficient or surplus harvests and food security (See Table 2). Poverty, food insecurity, and the subsistence-level nature of a farm and farmer were indicated by the proportion of the harvest sold versus consumed. Crop diversity and proportion of crops sold versus consumed will be analyzed under Section 5.2.

In general, the increased labor requirements involved with method adoption are magnified as the size of the farm increases. However, in a flat-lying environment such as Toliara, large farm size does not appear to deter farmers from investing more labor and time into covercropping or mulching to the same degree as it deters farmers on the slopes of Cauca from investing more labor and time into organic cultivation. Furthermore, large farm size is not associated with wealth in Cauca whereas large farm size is an indicator of wealth in Toliara.

5.2 Personal Beliefs and Life Experiences

Personal Beliefs, Trauma, and Religion

Personal beliefs about family health and environment appeared to be correlated method adoption in both countries. In Cauca, farmers who had experienced severely negative outcomes and accidents with agrochemicals displayed an aversion to agrochemicals, and tended towards organic practices. All organic farmers cited ecological sustainability and health as their primary motivations for cultivating organically. Some individual farmers shared stories that explained their aversion to agrochemicals, such as losing their eyesight after spraying pesticides. One of the lead technicians at the FCC told a story of a young child who had accidentally ingested pesticides and suffered severe brain damage, an event that had traumatized an entire community. Both organic and conventional farmers had young children. When asked, organic farmers who had young children cited the desire to create a cleaner environment for their children as one reason for transitioning. Conventional farmers focused on other factors, and did not explicitly indicate that a clean environment was as high of a priority as other basic needs daily they expressed. Therefore, traumatic experiences and personal beliefs and desires in Cauca can be associated with adoption of organic agriculture.

In Toliara, religious beliefs were associated with certain patterns in method adoption. Estimates claim that 55% of Malagasy people adhere to traditional beliefs (Library of Congress, 1994). Extension agents in Toliara explained that farmers who adhere to traditional beliefs perceive taking active measures to increase soil fertility as religiously disrespectful and taboo in some parts of Atsimo-Andrefana. If a farmer takes active measures to improve soil fertility, it implies that the farmer does not have faith that the soil with deliver and the Earth will be enough to sustain the family. This belief is accompanied by the perception that the soil is sufficiently fertile (Bayala et al., 1998). Representatives of the Toliara-based extension and advocacy group La Maison des Paysans cited these beliefs as a reason some of their projects not only failed, but ended in violence. According to one representative, the breaking of this taboo against improving soil fertility resulted in rioting and conflict between farmers who adopted any one of the three promoted methods and those who found them offensive and disrespectful.

As previously discussed, *zebu* are of spiritual importance to Malagasy people, and since feeding them is a priority for farmers with herds, methods that require biomass to be left in the field and not fed to *zebu* are less likely to be adopted by farmers who own *zebu* and especially those who ascribe spiritual significance to their herds. Interestingly, fertilizer use is known to be extremely low, as the majority of farmers in the southwest do not use livestock manure for field fertilization (Hanisch, 2015). This is emphasized in the results of this study, with at least four of the six farmer groups having access to *zebu* but only two groups total reporting using *zebu* manure as fertilizer. The reasons cited by farmers for this lack of manure use are the perceived sufficient fertility of the soil, the high labor demands for manure application, increased disease pressure, and lack of knowledge for its use (Bayala et al., 1998). Therefore, for multiple reasons that are influenced by religious beliefs and taboos, farmers prefer to shift to new land upon noticing that yields are declining instead of investing in labor-intensive soil fertility management (Rollin, 1997). This contributes to the pervasive deforestation in the area. Ultimately, traditional religious beliefs in Toliara constrain farmers' willingness to adopt certain methods, especially those that improve soil fertility.

Methods Used by Parents

Another observation made in both Cauca and Toliara was that farmers' parents also had an impact on the methods a farmer was willing to use. While 71% organic farmers in Cauca cited a certain year they had switched to organic production, 29% stated they had been organic farmers their entire lives because their parents had also cultivated organic coffee. The idea of converting to conventional practices was out of the question and disrespectful to their parents' legacy.

In Toliara, two brothers in Farmer Group 5 stated that they used all three of the NGO-promoted methods primarily because their father used these methods. These brothers claimed that their parents were from the region of Androy in the Deep South, and therefore they had different traditional methods from farmers whose families originated in or near Toliara. Furthermore, when asked why they intercropped certain crops but not others, farmers practicing intercropping often said that their parents traditionally intercropped the same crops they were using. It is interesting to note that the only farmer who was intercropping maize with a legume had parents with origins on the east coast of Madagascar, far from Toliara. It can be postulated that this farmer's parents who lived on Madagascar's east coast – which is significantly wetter and greener than the west coast – did not experience competition between intercropped maize and beans because they were not cultivating in a water-constrained system. While parents' practices therefore seem to be correlated with current method use in both countries, NGOs and extension agents cannot take credit for these farmers' use of methods because they would have probably used these methods with or without the presence of extension agencies.

Risk Aversion: Crop Diversity and Proportion Sold vs. Consumed

Food security and access to capital are associated with less risk aversion and thus increased ability and willingness to undertake the risks involved in adopting a new method. One indicator of food security is the proportion of harvest sold versus consumed. This indicator shows the degree to which a farmer is cultivating at the subsistence level, or whether or not there is excess produce that can be sold at the market. An indicator of stable, diverse sources of income is increased crop diversity on the farm, which can result in increased access to capital. In both countries, proportion of harvest sold and crop diversity were positively correlated with the ability to undertake risks and adopt new methods.

In Cauca, having a larger proportion of non-coffee crops intended for sale was correlated with adoption of organic methods. Organic farmers reported that 71% of their non-coffee crops were intended for sale, whereas only 40% of conventional farmers reported that their non-coffee crops were intended for sale. The number of different non-coffee crops on organic farms was greater than that of conventional farms, with organic farms having an average of 6.3 non-coffee crops and conventional farms having an average of 3.6 non-coffee crops. The FCC indicated that this greater diversity of non-coffee crops on organic farms contributed to synergistic relationships, such as higher levels of soil potassium from fallen plantain tree leaves and the perceived benefit of a fungus associated with cassava that repelled the coffee cherry borer. In addition, the leguminous *Inga feuillei* tree provided increased nitrogen availability, and was only found on organic or transitioning farms. Fruit trees also provided more potential for income on farms with greater crop diversity, which tended to be organic. The presence of certain non-coffee crops and the existing spatial relationships between these crops and coffee trees were therefore associated with method adoption.

Another observation about the spatial relationships between non-coffee crops and coffee trees was that while maize was cultivated on most farms regardless of type, many conventional farmers cultivated maize very close to or completely intercropped with their coffee. As maize is a crop with high nitrogen requirements, it can be postulated that farmers growing maize in the same fields as their coffee felt the need to apply chemical nitrogen fertilizer such as urea to their fields, which is a conventional practice. These conventional farmers were also more likely to be cultivating their non-coffee crops (such as maize) primarily for consumption and not for sale, rendering their maize equally if not more important than their coffee to household food security. This importance of maize to a conventional farmer's food security would justify intercropping maize with coffee throughout the farm, resulting in nutrient competition and subsequent use of chemical fertilizer. Lastly, it was also observed that organic farmers tended to have larger, more modern homes than conventional farmers. Organic and transitioning farmers tended to live in multi-story brick homes whereas the only farmers who lived in homes made of mud and straw were conventional farmers. These observations (type of house, proportion sold versus consumed, crop diversity and spatial relations between crops) are all indicators of food security, access to capital, and associated risk, and are therefore each correlated with method adoption.

In Toliara, farmers who reported that most or all of their produce was intended for sale had the highest rates of method adoption (See Table 2), with the exception of a small-scale vegetable farmer (referred to as Farmer Group 3) who reported selling most of his produce in order to buy grain products. Farmers who adopted the fewest of the three promoted methods reported that they consumed the majority of their harvest, suggesting that farmers cultivating at the subsistence level and with lower levels of food security were less able to undertake the risks associated with adopting a new method. It could also be speculated that farmers who were using most or all of the methods had greater productivity *because* they used these methods, and with more surplus production they were able to sell the majority of their harvest. Greater levels of crop diversity were also correlated with increased method use. Farmers using all three methods reported greater numbers of crops on their farms (Mean: 10.5 crops) while farmers using one or two methods reported lower numbers of crops on their farmers (Mean: 6 crops) (See Table 2). This indicates that farmers who grow a more diverse array of crops and have more diversified income sources are also more able to undertake the risk of adopting a new method.

Therefore, the greater a farms' crop diversity and the higher a farms' percentage of harvest meant for sale, the more likely that farmer is to be food secure, have access to capital from diversified income sources, aware of synergistic relationships between crops, and ultimately able and willing to undertake the risks involved with adopting a new method.

5.3 Attributes of Promotion by Agricultural Extension

Explicitly Addresses Constraint

A method promoted by extension agents or NGO groups that addresses a constraint that is explicitly identified by farmers is more likely to be adopted than a method that does not address a constraint. In the cases of Cauca and Toliara, systems with very different constraints, extension must promote methods that address the overarching constraint in the system. This involves identifying each system's overarching constraint. In Cauca, the FCC has emphasized the importance of improving soil health by raising soil pH and soil organic matter, but neither acidity nor active carbon (an indicator of soil organic matter) levels were found to be unhealthy in any of the farms visited. While these healthy pH and active carbon levels could be the result of widespread successful promotion of lime and compost application by the FCC, it seems that the current constraining factor across all farms is pressure from pest and disease. While the FCC does produce affordable organic pest controls and promotes intercropping for some synergistic effects, there is a lack of research and promotion of appropriate integrated pest management strategies to address this overarching, moderate to severe constraint.

In Toliara, the overarching constraint is water scarcity. However, there is little emphasis on improving farmers' ability to irrigate their fields during periods of drought or unpredictable rainfall, such as water catchment systems. Extension has tried to indirectly address water scarcity by promoting methods that increase soil moisture such as covercropping and mulching, but less is done to address one of the root causes of the region's water scarcity; widespread deforestation. In some ways the three main promoted methods do enhance soil fertility and encourage stationary, intensive cultivation instead of shifting, extensive cultivation, yet an explicit emphasis on curbing deforestation is lacking. Furthermore, one of the major obstacles to adopting two of these methods is limited biomass and the need for *zebu* fodder in the face of insufficient pastureland. Extension does not emphasize finding increased or alternative sources of *zebu* fodder, though doing so would help farmers adopt the very methods promoted by extension. Additionally, pests are a major cited constraint by farmers in the system, yet extension was doing very little to actively address them. While some groups promoted intercropping and soil cover as forms of pest and weed control (but primarily to increase soil moisture), certain farmers were unable or unwilling to adopt these methods for a multitude of previously discussed reasons (e.g. livestock fodder, religious beliefs, size of farm). Pesticides were not promoted by extension agents, yet were being sold by the cotton company Tianli used without proper instruction or training, indicating that there is a need to control pests that was not being addressed by extension. Therefore, extension must be sure of the system's overarching constraint and the major constraints cited by farmers, and tailor the promoted methods to match these constraints. If the methods match the system's constraints, they will gain the interest of the target farmer population and have a better chance of being adopted.

Testability

A method that can be tested in a trial plot and shown to have positive results has a greater likelihood of being adopted. In Toliara, extension agents claimed that the success rates of their projects were higher in townships where they had a trial plot in a central location that local farmers could evaluate and assess the impact of a method promoted by extension. In a generally food insecure, economically unstable, and water-constrained system, visual evidence that a method worked coupled with short waiting time to pay-off increases likelihood of adoption.

However, in Cauca one of the major obstacles to farmers considering transitioning was that in order to achieve organic certification, a farmer has to convert the entire farm to organic production. An individual farmer's test-plot may be organic in practice, but the farmer will not be able to receive organic premiums until the whole farm has transitioned. Since organic cultivation has lower yields per hectare due to less dense tree spacing (See Table 4), this discourages farmers from testing organic methods in test-plots. Without organic certification for their test-plot, this decrease in yields per hectare cannot be offset by the increase in organic coffee's market price as it would on a fully transitioned, certified farm (See Table 4). Therefore, farmers in Cauca have an economic disincentive to test organic cultivation in a trial plot, rendering risk-averse farmers less likely to adopt organic cultivation.

Waiting Time to Pay-Off

A method with a rapid response or quick pay-off is more likely to be adopted, particularly in subsistence systems where long waiting times to pay-off can have direct, negative impacts on family food security. However, in both Cauca and Toliara, the methods being promoted were not rapid, often taking years to pay off economically. Organic certification takes a minimum of three years to complete, and even once certification is achieved the full benefits may not be realized until the trees reach maturity, which can take four years (National Coffee Association, 2017).

In Toliara, as in many dry climates, full pay-off of methods such as covercropping or mulching may take multiple growing seasons to observe due to the slower overall rate of biological activity in a water-constrained system. Farmers living at the subsistence level cannot afford to wait multiple growing seasons for an improvement in soil moisture or fertility.

Furthermore, covercrops in a severely water-constrained system can potentially compete with food crops for space, water, nutrients, or time, rendering their beneficial effects less observable and overshadowed by their competitive, negative effects. Again, the overarching constraint that limits the feasibility of each of these promoted methods is limited water availability, which is not directly addressed by any of these methods. Therefore, while covercrops may pay-off in the long term and improve soil moisture and fertility, if they initially compete with food crops or are perceived as doing so, they will be less likely to be adopted by subsistence-level farmers in this water-constrained system.

Visually obvious or easily measurable pay-offs render a method more likely to be adopted. In Toliara, Farmer Group 5 (which used all three of the promoted methods) pointed to their fields and remarked on the color of the soil, which was darker than the soil in fields where the methods were not being used. These farmers attributed this visible difference in soil color to their soil's increased ability to retain water due to their use of mulching. Therefore, this visible evidence of increased soil moisture served as a motivating factor for these farmers to continue and expand use of the methods. In Cauca, there were no observable visual differences in the health of coffee trees between organic and conventional farms. Signs of coffee leaf rust and cherry borer holes were present on all farms. Therefore, farmers had no visual incentive to change their management decisions

Another longer-term visual indicator of the efficacy of a method is a taller or faster growing crop. Both of these visual cues (darker soil color and taller crops) are ultimately dependent on adequate rainfall, the overarching constraint in the system. For example, local studies showed that use of manure as fertilizer did not have a measurable impact on cassava yields, as cassava has low nutrient requirements and can survive in soils with extremely low fertility levels (Hansich, 2015). Consequently, there was little adoption of manure as a fertilizer for cassava. Therefore, only when farmers can see a visual or measurable benefit of the method will they be likely to adopt the method.

Cost of Method

The cost of a method impacts its rate of adoption, especially amongst resource-constrained and subsistence farmers. In Cauca, the costs of meeting the requirements of organic certification were very high, such as buying new coffee de-shelling equipment instead of cleaning current equipment that had been used with conventional coffee. These de-shellers, also known as coffee bean hullers, can range anywhere from several hundred to several thousand dollars in price depending on size and modernity.

In Toliara, chemical fertilizer use was virtually unheard of by smallholder farmers due to its price and difficulty to access (Hansich, 2015). However, with the recent presence of the textile company Tianli, chemical fertilizer and pesticides have become more accessible. Nevertheless, farmers who had used chemical fertilizer reported that the price of fertilizer was not offset by the income gained from the increase in yield from the fertilizer. Farmers blamed this on two factors; 1) the high prices for fertilizer demanded by foreign agrochemical companies, and 2) the low sale prices for produce in local markets. Therefore, using fertilizer resulted in a net loss for the farmers, as the economic return on fertilizer was too low to justify buying it because of disproportionately low market prices for produce.

In Toliara, the costs associated with adoption of the three methods were mostly opportunity costs and manifested as time, labor, or trade-offs between soil health and livestock fodder. In Cauca, the costs associated with transitioning to organic agriculture were largely monetary, included buying a new de-shelling machine ($500 to $2,000+), certification fees (several hundred dollars), and the economic impact of reduced yields observed during the transitioning period (See Table 4). In both Toliara and Cauca, accessible and low-interest loans were cited as a potential way of easing these economic costs and softening the risks associated with adopting new methods.

Interpersonal and Local Sensitivity

Methods promoted through extension organizations or NGOs that share ethnic, linguistic, or socioeconomic identities with the target farmer population are more likely to be accepted. In Toliara, local NGOs such as SOMONTSOY and state-led organizations such as FOFIFA were often contracted by larger international organizations (e.g. USAID, Land O' Lakes, FAO, WHH). Local institutions had more social capital whereas larger international organizations had more financial capital. Within these partnerships, the local institutions were tasked with assessing community needs and monitoring and evaluating the impacts of projects that were funded by the international organizations. These international organizations, which are often financially supported by the United Nations or the U.S. government, generally adhere to their own agendas. These agendas include promoting adoption of certain well-known suites of methods (e.g. Conservation Agriculture, agroforestry, "biosphere reserves" with specified buffer zones of use and levels of protection). While these suites of methods are widely known and sometimes globally renowned, they have the potential to be uniformly applied in a "cookie-cutter" fashion. Furthermore, these suites of methods may not address the overarching constraint in this particular system or may not be considered feasible or desirable by the farmers. Though partnering with local institutions helps to bridge this divide, projects funded by international organizations may be overly focused on reporting high rates of farmer adoption and may overestimate the appropriateness of their promoted methods.

Methods promoted by organizations that share identities with the target population are more likely to be accepted. This is especially true in Cauca, a region with a long history of conflict and mistrust between different political and ethnic groups. The FCC has striven to remain officially apolitical in the midst of the political violence that plagued the region for so many decades. However, since the FCC was founded by peasant farmers and represents indigenous and rural interests before elite interests, the FCC has been able to gain the trust and following of their target farmer population. This contrasts with the Cooperativa de Caficultores del Cauca, or Caficauca, the other union for coffee growers in Cauca. The primary focus of Caficauca is on improving productivity and increasing yields. Caficauca is a larger organization than the FCC and covers a larger geographic area within Cauca. Their promoted methods do not holistically reflect or address the needs of coffee farmers who are members FCC. For example, FCC staff reported that Caficauca representatives sometimes visit farms and tell farmers to decrease the spacing between each coffee tree and thus increase the coffee tree density. They also tell farmers to remove all plantain trees in order to maximize sunlight. Both of these recommendations are made to increase yields. Caficauca also acts as provider of agrochemicals, and is supplied by several agrochemical companies including Syngenta and Monsanto (Caficauca, 2017). These methods are contradictory to many of the organic practices promoted by the FCC. The FCC has found success in promoting their methods over the methods promoted by Caficauca by developing personal relationships with farmers. The FCC has developed these relationships by establishing a shared identity with their target farmer population through their historical support for peasant land rights and their smaller, more local sphere of influence.

In both countries, organizations that share identities with the target farmer population and are smaller and more specific in scope have an advantage in gaining farmers' trust, learning their constraints, and successfully promoting methods.

Political Upheaval and Recovery

In both Cauca and Toliara, political upheaval may be a factor in influencing the efficacy of an extension organization or NGO in promoting methods. As previously mentioned, this mountainous part of Cauca that is more heavily populated by indigenous people than other parts of the country has been heavily affected by Colombia's civil war. When asked questions about land ownership, several farmers reported or alluded to having been forced to leave their homes and their farms behind for several years. These internally displaced people had since returned to their coffee farms, but no longer owned the land from which they had fled and now rented it from a landlord. Because the FCC has worked for increased peasant ownership of land and improved land rights since its inception, the FCC has proven itself an ally to these war-affected farmers and been able to maintain their trust. The FCC has supported these farmers in re-starting their farms. This is a difficult endeavor especially for organic or transitioning farmers whose implementation of organic methods was disrupted by the conflict and forced displacement. At the time of this research in January 2017, the rebel and military groups involved in the decades-long civil war in Colombia had emerged from pivotal peace negotiations and had signed a peace agreement in late 2016, ending the longest war in the western hemisphere (Walker, 2016).

All of the organizations involved in the Madagascar portion of this study were impacted by the 2009 coup in which the then president was ousted and replaced, throwing the government into a state of turmoil and rapid change. Local organizations such as La Maison des Paysans that depended on government funding were especially affected and suffered cutbacks on the size of their staff and funding, effectively halting their extension programs. External funding sources were also cut back when international organizations whose governments or major funders refused to recognize the new president withdrew financial support from all of Madagascar. Normalcy began to return in 2011 after a new constitution was approved and opposing parties joined in a united government (BBC, 2016). In early 2016 when this research was done, these organizations reported slow but steady recovery from the disruptive and halting effect of the coup, such as partial recovery of pre-2009 staff size.

Timeliness, Appropriateness, and Communication

Lastly, methods introduced to the appropriate actors within the community (with concern for gender, age, education, household roles), in appropriate settings, and at the right time in the growing season, are considered more favorably for adoption. Though little to no data on gender or literacy was collected in either study, levels of education and literacy did seem to impact method adoption because recordkeeping was correlated with adoption of organic methods. Literacy rates are significantly higher in Colombia than they are in Madagascar (See Table 1). Farmers' ability and will to keep records is dependent on their level of literacy. It was observed in Cauca that farmers who were able and willing to keep records were more likely to be organic or transitioning farmers. This may be partially because in order to gain organic certification, one must keep records to show to prove their organic status to the USDA. Therefore, it was observed in Cauca that farmers who applied their literacy skills to keep records were more likely to adopt organic methods.

In Toliara, illiterate farmers were unable to read instructions or expiry dates on pesticide or fertilizer bags. Upon learning the expiry date on their pesticides, the men in Farmer Group 4 expressed anger that Tianli had sold them expired pesticides. This group was also applying pesticides at one of the highest rates (See Table 2). Therefore, it was observed that farmers who had literacy skills were more able to read instructions and details about agrochemicals and correctly use inputs, avoiding pesticide resistance, elimination of beneficial insects, and wasted capital.

Organizations that build strong, long-term relationships with their target population will be more readily trusted with information and deep insights into the personal factors previously discussed. While building relationships between farmers and extension agents is important for this exchange of essential information, emphasizing communication between farmers will also improve extension's success. In Cauca, farmers reported that pests and disease spread easily through adjacent or proximate farms, and that communities that openly discussed these pest issues and their strategies for pest control were able to identify and stop outbreaks more effectively. Therefore, farmers who lived in communities that they considered to have good and open lines of communication were less afraid to transition to organic production, as they believed that issues such as pest and disease outbreaks and control methods would be communicated clearly to all farmers in the area. Farmers, including organic farmers, in communities that they considered to have poor communication were more concerned about the effects of uncontrolled pests and disease spreading from neighbor's farms to their own. In Toliara, Farmer Group 3 stated that the most useful help NGOs or the government could offer would be technical advice that is accessible to illiterate farmers. An example of this would be verbal or pictorial instructions on how to correctly use pesticides and avoid over application, pesticide resistance, and potential killing of beneficial insects, which may explain why some farmers applied pesticides every two days (See Table 2). Farmer Group 3 also expressed the desire for a local record or inventory of what crops farmers were growing each season. This was particularly important for farmers who would be selling in the same market as to avoid market saturation with one crop. Farmers in both Toliara and Cauca cited improved communication with extension agents and with each other as something that would help them undertake collective risk and coordinate efforts.

6. Conclusions, Recommendations, and Lessons Learned:

Conclusions and Recommendations

The factors that were hypothesized to affect method adoption among farmers were not consistent. Biophysical factors and differences in farm structure were the most measurable, quantitative factors that were correlated with method adoption. These factors were also the easiest to compare between Toliara and Cauca, and often could be seen to manifest in opposite ways (as an obstacle to or an enabler of adoption) depending on the environment type. Landscape, livestock, and size of area under cultivation were all positively or negatively correlated with method adoption.

Interestingly, both the presence of livestock and the size of the area under cultivation had inverse effects on method adoption at both sites. Livestock were an enabler of method adoption in Cauca because they provided an on-farm source of manure-based fertilizer that could replace chemical fertilizer. Livestock were an obstacle to method adoption in Toliara because the presence of livestock resulted in competition between the use of biomass as fodder and the use of biomass as permanent soil cover. This forced most livestock-owning farmers into a tradeoff between prioritizing soil health or animal health.

The different manifestations of livestock as an obstacle or enabler of method adoption at the two sites can be attributed to the type of livestock present, the traditional importance of livestock, and the baseline availability of biomass in the system. Livestock on farms in Cauca were mostly chickens and demanded less fodder than the *zebu* cattle in Toliara, which also hold importance in traditional culture. Furthermore, biomass availability is heavily dependent on climate and annual precipitation. Precipitation is much greater in Cauca and therefore biomass is not a limiting factor. In Toliara, annual precipitation is low and less biomass is available. This forces farmers into a tradeoff between using the limited biomass to adopt methods or to feed livestock. Therefore, livestock acts as an obstacle to adoption in Toliara but an enabler to adoption in Cauca.

In the mountainous region of Cauca, landform was a more influential factor than in the flat region of Toliara. In Cauca, farmers cultivating on flatter land were more willing and able to adopt organic practices than those cultivating on steep slopes. This was due to cited labor constraints and postulated soil health variations across steep slopes. In Toliara, a generally flat landscape, there was little difference in landform between farms and therefore landscape did not affect adoption.

Area under cultivation was another important factor that was correlated with method adoption. Farmers in Toliara with more land were more able to adopt methods, but farmers in Cauca with more land seemed reluctant to adopt methods. This difference can be attributed to the importance of biomass and labor constraints in each site, and the relationship of farm size to each of these constraints. For example, in Toliara larger surface areas reap more biomass, which increases the amount of available biomass for methods such as mulching. In Cauca, larger surface areas increase the amount of labor required to cultivate the farm. For farms on steep slopes with larger surface areas, the required labor is even greater than it would be on a flat farm of the same size. These increased labor pressures across a larger area would not be offset by the expected income of adopting organic practices. Therefore, labor constraints render larger areas under cultivation an obstacle to adoption in Cauca. Meanwhile, biomass availability renders larger areas under cultivation an enabler of adoption in Toliara.

These inconsistencies that the biophysical factors have at the two sites bolster the idea that extension strategies and agricultural methods cannot be applied uniformly across the tropics. Furthermore, extension strategies and methods must not only be tailored to certain world regions and climates, but must also be tailored to the variety of farm structures and microclimates present within the same region. For example, finding alternative sources of fodder and improving pastureland may help livestock-owning farmers in Toliara to adopt methods. Promoting the use of terracing to decrease the difficulty and labor involved in climbing steep slope may help farmers cultivating on steep slopes in Cauca to adopt methods. These recommendations will be further expanded upon in the context of how extension organizations can best promote methods to account for factors such as these biophysical differences between farmers.

The personal life experiences that were surveyed and analyzed were found to influence method adoption. This indicates that extension organizations must invest in and prioritize building personal relationships, solidarity, and social capital with their target populations for maximized method adoption. If organizations achieve this, they will gain an understanding of their target populations' traditional beliefs, personal stories, fears, traumas, long-term goals, and risk-aversion. Furthermore, enhancing social capital will clue extension agents into lesser-discussed cultural taboos or community experiences that are not explicitly stated.

With expanded and strengthened social capital, target groups that are characteristic of Farming Systems Adaptive Research (FSAR) can be expanded to account for factors beyond ‘geographical’ (environmental) and ‘hierarchical’ (socioeconomic) differences between farmers (Collinson, 1987). These improvements to FSAR-era understanding of farmers and their particular constraints would help extension agents enhance the specificity, reach, and appropriateness of their programs and methods. Strengthened social capital allows the extension agency to improve communication and interpersonal understanding between extension agents and farmers. Furthermore, it can be used to foster communication between farmers. Open lines of communication between farmers can prevent or slow the spread of disease and pests, a major constraint cited in Cauca. Transparency and communication about seasonal production, such as creating crop inventories, can help farmers coordinate their planting and production with each other to optimize potential market benefits. Lastly, improved communication can improve farmer-to-farmer transfer of knowledge, thus disseminating methods promoted by extension through and beyond the target population.

A key element often missing from the role of extension is the evaluation of the system’s major constraint on the feasibility of the proposed methods. This involves addressing the system’s overarching constraint. If organizations achieve this, they will be able to assess a method’s appropriateness and practicality before investing in and implementing a promotion program or extension service based on that method. In Cauca, pests and disease are constraints that are not fully addressed by the promotion of organic methods because damage from the cherry borer and leaf rust were observed on all farms. Increased emphasis and research on agroecological or integrated pest management strategies might be more effective for risk-averse farmers who have previously lost yields to this constraint. These strategies may also appeal to risk-averse farmers who have had negative or traumatic experiences with pesticides and chemical inputs. Perceived nitrogen availability was another constraint that prevented farmers from adopting organic methods. The chemical input that was most utilized by conventional farmers was urea fertilizer, so it can be postulated that they perceived nitrogen as the limiting nutrient. To address this constraint, future studies could assess and improve the C:N ratio of homemade compost on individual farms or identify nitrogen-fixing plants (e.g. *Inga feuillei*). This would offset conventional farmers' reliance on chemical fertilizers such as urea, thus improving organic method adoption.

In Toliara, mulching and covercropping were promoted with the intention of improving soil moisture, as improved soil moisture can prolong the time that crops could survive between erratic and unpredictable rainfall events. However, the overarching constraint of water scarcity rendered the implementation of these methods impractical. Under conditions of water scarcity, the available biomass was insufficient for mulching. Insufficient biomass, which impedes adoption and results from water scarcity, may be addressed through future research into non-competitive covercrops with low water requirements, improving pastureland with drought tolerant forage plants, and identifying alternative sources of fodder to feed animals that would otherwise eat crop residue biomass.

However, instead of addressing low soil moisture through methods that can be impractical in water-scarce environments (e.g. mulching, which is dependent on excess biomass), extension should develop methods and technologies that first improve water access. Water catchment systems are an example of a short-term, direct option to improve water access and irrigation. Efforts to curb deforestation and reforest the area are long-term options to improve both groundwater storage and precipitation. Efforts to decrease the demand and supply of wood-based charcoal for cooking may curb deforestation. To decrease the demand for charcoal, organizations could develop and promote non-charcoal stoves. To decrease the supply of charcoal, organizations could seek to provide employment or alternative sources of income for the landless poor who produce wood-based charcoal from forested areas. Long-term tree planting programs could be implemented to help reforest the region. Each of these strategies addresses water scarcity, the overarching system constraint, instead of low soil moisture, which is a result of the overarching constraint. After addressing the overarching constraint, available biomass will increase due to improved access to irrigation or groundwater. This will cause methods such as mulching that specifically address low soil moisture to become more feasible, thus improving method adoption.

Perception of a method's feasibility is tantamount to its actual feasibility when it comes to farmer adoption. Perception of a method's feasibility can be influenced by a method's testability, rapid response of visual benefits, and cost. It is therefore integral to the success of extension to create spaces where methods can be tested, their rapid response can be shown to have visual benefits, and their opportunity costs can be alleviated either by extension agents or the community.

In Cauca, the FCC did not have organic test plots to use for demonstration as a way of convincing risk-averse farmers to consider organic production. The use of test plots, especially on steep slopes, would help the FCC better understand the constraints of many of their conventional farmers and help conventional farmers better understand the complexities of organic production in the context of a farm that resembled their own. These test plots would improve farmers' perception of multiple methods in the context of their own farm, such as terracing to decrease labor requirements. The burden of monetary costs, such as those involved in gaining organic certification or the hired labor to harvest or terrace steep slopes, could be alleviated by improving farmers' access to low-interest loans. Access to low-interest loans would improve farmers' perception of the method as economically feasible. Therefore, both establishing test plots and offering pathways to alleviate cost would improve perception of method feasibility, thus improving method adoption.

In Toliara, constraints to method adoption could be alleviated by on-farm testing of methods in small plots. Unlike in Cauca, where partial conversion of a farm to organic production was not possible, testing of methods in small plots in Toliara may be the most practical way forward for farmers who are willing to adopt methods but are concerned about the risks and waiting time to pay-off. For example, a farmer could implement a method in a fraction of one field to see if the results are beneficial and rapid enough to extend to a larger area of the farm. If so, the farmer could expand the area in which the method is implemented during the next season. Through this process of sequential adoption, the method could eventually be implemented throughout the entire farm. While this partial and sequential process of method adoption does extend the overall waiting time to full benefits, it hedges the risk involved in method adoption to a point that is comfortable and controllable for a subsistence-level farmer who cannot afford a major loss in yields or herd size.

Another possible recommendation would be community-supported food banks. These food banks would offset the yield or livestock losses that individual farmers may endure during a method's waiting time to pay-off. To implement these community-supported food banks, the first step would be to identify the most stable farmers in a community. This group of stable farmers would then be divided into two groups: the most innovative, least risk-averse farmers and the most food secure farmers. The first group (most innovative, least risk-averse farmers) would become the first farmers in the area to undertake partial adoption of the promoted methods. Any reduction in yield or herd size would be offset by the second group (most food secure farmers), who would continue to produce as usual and essentially stock the food bank with a small percentage of their production, approximately equal to the percentage expected to be lost by the first group. It may be necessary to compensate the farmers in the second group, which could be done by the extension agency if the budget allows or through the use of farming savings groups. Ideally this model would be repeated until all farmers in the area have adopted the methods. Issues with the practicality of this proposal include poor food storage and ensuring dependability between farmers that the crops supplied by one farmer to offset the yield losses of another will be returned when the second farmer decides to undertake method adoption.

A critique of community-supported food banks is that they ask one farmer to take on the risk of another farmer when the major issue preventing adoption in the first place is the inability of individuals to undertake risk. Furthermore, variation in annual precipitation could make it impossible for the farmers in the second group to produce the same amount of food for the food bank each year. This could become problematic when the groups switch roles and find that precipitation during the second phase of the food bank is less favorable to production than it was during the first phase. Recordkeeping, outside facilitation, and liaising with local authority figures would be essential parts of implementing this strategy over the course of multiple years and with systems in place to hold farmers accountable for their respective roles and account for differences in annual precipitation.

All of these possible recommendations are risky in countries with histories of political unrest, such as Madagascar and Colombia. Extension agents and funders may pull out of the region or country at any moment, or farmers themselves may be displaced and forced to leave the area. Improved strategies that encourage adoption would therefore have to be somewhat self-sustaining without the continuous support of extension agents in order to be most effective in the long-term. This involves training local people or the farmers themselves, who have a vested interest in the success of the program, to carry out necessary supportive tasks.

Extension organizations themselves ought not to evaluate the success of their programs based solely on rates of method adoption. This yardstick can be especially misleading and ineffective in cases where large, umbrella organizations with ample financial capital attempt to promote pre-selected suites of methods in a new area. Major organizations in the fields of food security and environmental protection often use rates of adoption of rigid suites of method as their primary parameter for success. Since continued funding from large donors hinges on high reported rates of adoption, organizations may continue promoting inappropriate or impractical methods for the sole purpose of increasing reportable rates of adoption. This pitfall can be avoided to an extent by contracting small, local organizations with ample social capital. These local organizations will use different, more specific parameters to assess the success of an extension program. These local organizations should not only be given initial surveying tasks, but should also conduct monitoring and evaluation throughout the project timeline to gauge the appropriateness and efficacy of a suite of methods. More monitoring and evaluation tasks should be delegated to these local organizations. This will ensure that the degree to which the promoted methods address the system's constraint and individuals' constraints is given more weight in determining whether to continue, cut, or alter an extension program.

Lessons Learned

A number of research lessons were learned over the course of this project. These include improvements to future survey and project design, accounting for assumptions and researcher bias, and order of research questions. One of the most important improvements to this project would be to interview farmers who are directly engaged with extension (those in the target group of an organization) and those who are not involved with extension. In Cauca I interviewed only farmers affected by extension, and in Toliara I interviewed only farmers who were not affected by extension. Another extremely important improvement would be to ask consistent questions to all participants and to increase the sample size of the surveys.

The survey instrument could be improved by consistently asking all farmers about extremely relevant aspects of their households and livelihoods, such as off-farm income, level of education, cost of children's education, gender, and number of people in the household. Assessing these household costs and alternative sources of income would improve accuracy in determining a farmers' financial stability. In this project I relied on the assumption that there was a link between risk aversion and food security, and that food security could be indicated by the proportion of harvest sold. I also assumed that farmers who were more food secure or seemed wealthier had always been generally more economically stable, and that their stability and lower levels of risk aversion were what enabled them to adopt methods – not the other way around. It is similarly plausible that farmers who seemed more secure by the indicators used in this study were more secure because they had successfully adopted the promoted methods. For example, were farmers on steep slopes in Cauca cultivating conventionally primarily because of the labor, soil, and disease conditions associated with steep slopes, or were those cultivating on steep land historically the poorest farmers in the area and less able to undertake the risks of transitioning to organic? Therefore, was it the slopes that served as the major obstacle to their adoption of organic methods, or was the slope an indicator of their lower economic status and other less observable obstacles to adoption? Furthermore, the degree to which extension is responsible for method usage in a place like Toliara is difficult to assess, as some farmers employed the methods because their parents traditionally used them, whereas others may have adopted the method through farmer-to-farmer transfer or due to extension agents. The survey instrument used in Toliara heavily emphasized questions about which methods the farmers were using, but now why or how they chose to employ that method.

Lastly, it would be interesting to redirect and reorder research efforts towards a system's constraints and the impacts of these constraints before researching the methods. Instead of researching the *methods* promoted in a particular region and orienting research questions around which *factors* influence method adoption, one could research the *factors* constraining a particular region and orient the research questions around which *methods* would be most feasible and appropriate considering the constraints. This approach may be better for extension agents seeking to implement methods or adjust a suite of methods to best fit a new environment and culture, which this study has shown to be essential to the success of extension.

Closing Statements

The gaps in modern agricultural extension can begin to be closed through increased sensitivity to the context-specific obstacles that arise from the biophysical and personal diversity of farming communities in the tropics. Using the recommendations outlined above, extension can account for these variations in obstacles by adjusting their interventions and positively impacting more people. The implications of this project's findings are particularly applicable at this time because of the rising modern pressures and new forces affecting tropical agriculture. Political, economic, technological, and climatic changes often have great and rapid effects on marginalized farming communities in the developing countries. These new changes will only intensify the existing need for sensitivity to the diversity of farmers and their obstacles that will be required for successful agricultural extension in the future. These changes may manifest as price instability, climatic unpredictability, the spread of communications technology, and increased migration. Each of these changes contributes to the rapid evolution of viewpoints and best practices in agriculture and food production. Today, when information can be sent across the globe in milliseconds and temperatures are rising at unprecedented rates, the climatic, socioeconomic, and interpersonal factors analyzed in this project are also likely to evolve at unprecedented rates. It is up to extension agents and organizations to monitor and adapt to this change. Their current emphasis is on maintaining donors through reportable rates of method adoption, but the aspects of mutual teaching and adaptability are lacking. Strengthening these may involve emphasis on local training, local capacity building, and interdisciplinary research concerning the nexus of agriculture, communications, migration, conflict, and other imminent future factors. In the place of emphasis on method adoption by farmers, the new focus should be on the adaptation of extension to meet the diverse needs and goals of current and changing farming communities across the tropics.

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