Adaptation to Climate Change by Smallholder Coffee Producers in Latin America

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EXECUTIVE SUMMARY

Smallholder coffee farmers in Latin America are already being impacted by and adapting to climate change. Our client, Durham-based coffee roaster Counter Culture Coffee (CCC), has a commitment to environmental sustainability and ethical sourcing. As such, CCC seeks to better understand the viability of potential climate change adaptation strategies in order to support their producers in developing resilient livelihood strategies and to ensure sustained, high-quality coffee production.

This project builds on an existing partnership between Duke University's Nicholas School of the Environment and CCC. In 2014-2015, a group of students conducted research with coffee cooperatives in Colombia, Guatemala, and Peru, examining how smallholder coffee farmers are being impacted by climate change, and farmer efforts to increase resiliency and adapt to such changes. Based on their results, the first research team recommended 17 strategies the cooperatives could pursue with the potential to help their members become more resilient to climate change.

The primary objective of the second round of this Master's Project, conducted from May 2015-April 2016, was to help CCC and the producers from whom they purchase coffee better understand the climate change adaptation techniques they are, or could be, utilizing and the feasibility of each. Our research questions were:

1) Do these smallholder coffee cooperatives and/or their producers have, or could they get, the capital necessary to implement the selected adaptation strategies to increase resiliency to climate change?
2) Do the producers themselves perceive these to be viable and attractive strategies?
3) Who would need to be involved in implementation of these strategies at all levels?

Methods

Our research was conducted with two coffee cooperatives that supply and have relationships with CCC: the Coordinadora de Organizaciones de Desarrollo de Concepción Huista (CODECH) in Guatemala and CenfroCafé in Peru. We implemented a participatory action research (PAR) approach to first present the 17 recommended adaptation strategies and select three for further research in each country based on the cooperative leaders' analysis of their potential for positive impacts and perceived feasibility. We then conducted focus groups and individual interviews with cooperative leaders and members, complemented by interviews with key actors involved in supporting smallholder coffee producers in both countries to further explore the feasibility of each strategy. We transcribed and then coded the interview and focus group transcripts using NVivo qualitative data analysis software. We analyzed feasibility according to the capital assets framework, which posits that it is necessary to maintain or increase five types of capital in order to achieve sustainable livelihood improvements and economic growth: financial, human, natural, physical, and social.

Results

In total, we pursued five potential adaptation strategies in our research: income diversification and water collection systems for CODECH in Guatemala, seed banks and nurseries and pest monitoring and management for CenfroCafé in Peru, and solar dryers for both cooperatives. Our report provides background on the strategies, discusses producer experience, identifies the capital assets required for implementation and the costs and benefits of doing so, and provides recommendations on the viability of each strategy.

Income diversification is the adoption of alternative income-generating activities to balance risk amongst multiple sources of income, particularly when considering the potential impacts of climate change. The complexity involved in introducing income diversification relies on the need for a coordinated action among stakeholders and continued technical assistance. As such, based on our research and asset inventory, we assess projects in crop and income diversification at medium-high feasibility for the near future for CODECH in Guatemala.

Collective seed banks are used to preserve genetic diversity of seeds and prevent the destruction of seed variety. Nurseries are established to facilitate the development seed banks, the renovation of existing plots, or even the installation of subsistence crop systems. Funds to secure sufficient land and labor, in addition to infrastructure, are the key drivers for implementation. The implementation of collective seed banks and nurseries are assessed at low feasibility for CenfroCafé in Peru compared to the other two selected strategies.

Solar dryers were selected in both countries. Solar dryers reduce the time and labor required for processing when compared to traditional coffee drying, while increasing cleanliness. Due to lack of experience, CODECH producers questioned the effectiveness, capacity, and durability of solar dryers. Due to this unfamiliarity and lack of adequate land and financial support, we assess feasibility for solar dryers in CODECH as relatively low. Pilot projects in Peru have been successful, indicating relatively high feasibility for CenfroCafé, but further efforts are necessary to secure stable technical and financial assistance.

As temperature increases due to climate change, certain pests and diseases are likely to become more prevalent and affect coffee at a wider altitudinal range. Therefore, proactive monitoring and management of pests and diseases is crucial for farmers to remain resilient. CenfroCafé producer experience monitoring their own coffee and taking measures to reduce disease incidence or pest populations is variable. Due to the lack of related knowledge and motivation, this strategy has medium-low feasibility when considered amongst other strategies for CenfroCafé in Peru.

Water has become a widely discussed topic within the coffee community as producers experience water scarcity and rain unpredictability. As such, collecting water from rain or nearby streams in plastic cisterns or subterranean concrete tanks can provide security for farmers during coffee processing when water is essential. All experience with CODECH members was personal innovation and individual experience. Despite potential lack of suitable land, training and credit,

we consider this strategy to be highly feasible when considered amongst other strategies for CODECH in Guatemala.

Conclusions

Through the application of PAR and capital assessment frameworks, we provide graphics to explain and evaluate the relative feasibility of each strategy to other selected strategy in each country. We also identify the necessary capital assets and stakeholders for successful implementation for each strategy. Based on our analysis, we also present decision trees to assist CCC and smallholder coffee farmers in assessing the desirability and feasibility of each strategy specific to their situation. Finally, we provide other specific recommendations for CCC, CODECH, and CenfroCafé to continue supporting smallholder coffee producers in increasing resiliency to climate change effects.

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INTRODUCTION & SIGNIFICANCE

CLIMATE CHANGE

The inevitability of our changing climate is increasingly accepted around the world by scientists and the public (Capstick, Whitmarsh, Poortinga, Pidgeon, & Upham, 2015; Cook et al., 2013). The Intergovernmental Panel on Climate Change (IPCC) demonstrated in its 2014 report that the Earth's surface in recent decades has been warmer than any preceding decade since 1850 (IPCC, 2014b). An average increase of 0.85°C in the global combined land and ocean surface temperatures was calculated for the period of 1880 to 2012 (IPCC, 2014b). Such changes occur unevenly across the globe, with land masses expected to increase from 1.0 to 4.0°C by IPCC models shown in Figure (IPCC, 2014b; Kwok & Rothrock, 2009). By 2100, the average world temperature is expected to rise another 2.0 to 7.0°C (IPCC, 2014b, p. 3, The Initiative for Coffee & Climate, 2015, p. 8).

As warmer air carries relatively more moisture, rising temperatures lead to variability of precipitation, which leads to unpredictable changes in the frequency of rainfall in some regions and unexpected changes in volume in others, causing more natural disasters such as soil erosion and landslides (The Initiative for Coffee & Climate, 2015). Extreme weather conditions are happening with an increasing frequency, along with other climate change related variation including changes in glaciers, heat waves, droughts, and cyclones (IPCC, 2014b). These events are categorized by a range of timescales: short-term, events such as tropical storms; mid-term, events including El Niño and other oscillations that take months to complete; long-term weather conditions, events with a decade-long cycle; and long-term warming trends, which are predicted for the upcoming century and may continue beyond (The Initiative for Coffee & Climate, 2015).

The key driver for IPCC multi-modal projection is cumulative CO_2 emissions, which is determined by various parameters including population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy (IPCC, 2014a). The projected CO_2-equivalent concentration by 2100 of different Representative Concentration Pathways (RCPs) are based on degree of mitigation policy which is referenced from roughly 300 baseline scenarios

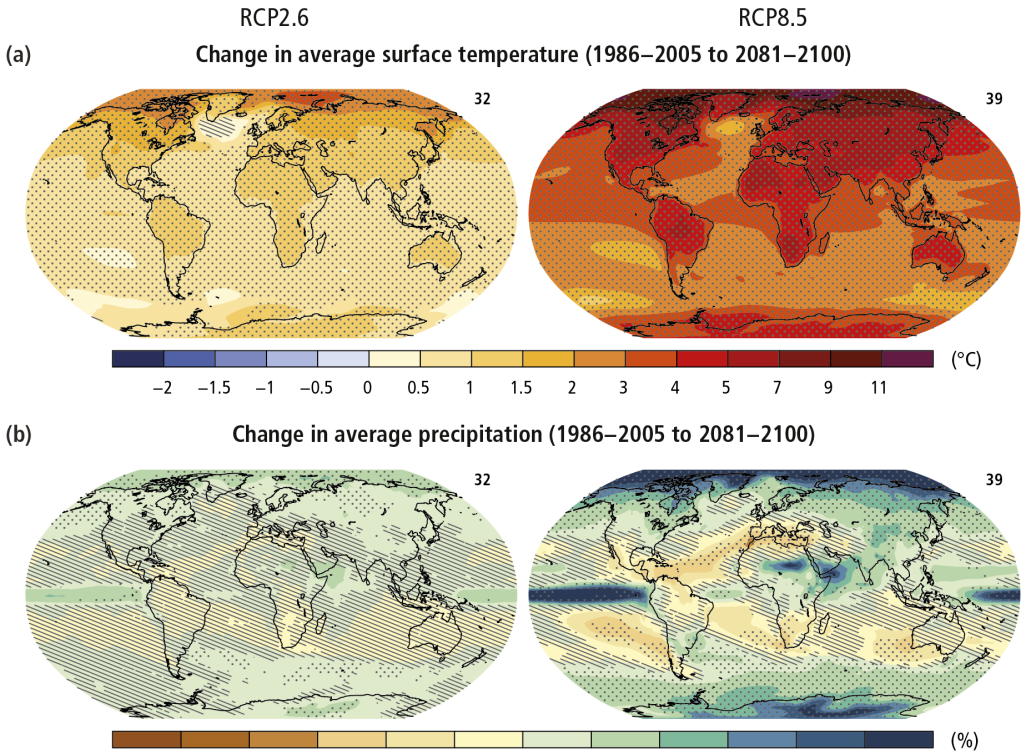

Figure 1: Projected Climate Change

Changes in surface temperature (top) and precipitation (bottom) for a stringent (left) and a very loose (right) mitigation policy modeled by the IPCC (IPCC, 2014b).

and 900 mitigation scenario (IPCC, 2014b). In Figure 1, the RCP2.6 (left) and RCP8.5 (right) represent two extreme scenarios, one with the most stringent mitigation policy and the other with a loose policy and very high GHG emissions, respectively. IPCC models are scenarios based on projections using current factors and historical trends, which is not an accurate prediction for the future. However, considering variable uncertainty with projected changes in the climate system, it is still "virtually certain" that global mean surface temperature will continue to increase, leading to higher frequency of extreme weather events (IPCC, 2014b).

Both higher mean temperature and changes in precipitation patterns will cause a shift in agricultural land use and crop suitability affecting agricultural productivity along with farmer incomes and food security (Laderach et al., 2011; Tucker, Eakin, & Castellanos, 2010). Thus, it is essential to adapt perennial cropping systems to current and future climate changes, particularly for high-value cash crops. Coffee, which is the largest agricultural contributor to

gross domestic product (GDP) in Latin America, is one such high-value crop to be impacted by climate change, potentially leading to major impacts on national economies.

COFFEE

Coffee, which originated in Ethiopia, is a tropical evergreen shrub which grows around the equator between the Tropics of Cancer and Capricorn, approximately 23°S to 23°N. The two most traded varieties of coffee are Arabica, *Coffea arabica,* and Robusta, *Coffea canephora* ("Coffee cultivation," n.d.). Approximately 95% of coffee production in Latin America is the Arabica species. Coffee was first traded between African and European countries in 1615, and is now grown in around 80 countries in South and Central America, the Caribbean, Africa, and Asia (International Coffee Organization, 2014). As the world's second most traded commodity after oil, retail coffee had an estimated total value of US$19.1 billion in the crop year 2012/13 for a volume of 111.6 million bags (International Coffee Organization, 2014). According to the USDA, world coffee production for the crop year 2015/16 is forecasted at 143.4 million bags with an average 60 kg (or 132 lbs) per bag, representing a 1.53% growth from the previous year. However, due to local consumption, export volume does not represent total production volume. In the crop year of 2014/15, 110.4 million bags were exported around the world, with an estimated consumption of 150.2 million bags (European Coffee Federations, 2016; Nolte, 2015). Increasing coffee production and trade is theorized to have been caused by increasing domestic consumption in some exporting Asian countries (European Coffee Federations, 2016).

Prior to 1989, the global price of coffee was controlled by the International Coffee Organization (ICO) through a series of International Coffee Agreements (ICA) setting export quotas for each exporting country to manage supply and maintain price stability (International Coffee Organization, 2014, p. 3; Ponte, 2002). Market liberalization resulted in a rapid increase in global coffee production leading to growing coffee inventories in consumer countries. Coffee became a "buyer-driven commodity chain" (Kolk, 2010). Therefore, the pricing power shifted to the roasting and retailing end of the coffee supply chain, which dramatically drove down price at the end of the 1980s (C. Bacon, 2004; Kolk, 2005). Losing market control, producing countries and coffee farmers had to pay the price. As many national agricultural ministries decreased their

roles in negotiating and coordinating coffee production and commercialization, dominant transnational export-import companies gained control over the majority of coffee trading, which led the collapse of the quota system, followed by the 1989 coffee crisis (Ponte, 2002; C. Bacon, 2004; International Coffee Organization, 2014). During the crisis, the market price of coffee fell by an incredible 50%, and remained low until 1993. A second low price period, referred to as the "coffee crisis," took place from 1999 to 2004, when the booming production from Vietnam pushed global prices down (International Coffee Organization, 2014). The international coffee market price trend from 1989 to 2012 is shown in Figure 2.

Figure 2 Historical Price Paid to Producers

Price paid to producers internationally each August in U.S. cents per pound (International Coffee Organization, 2014).

The crisis reveals the critical issue of price volatility in the coffee market, which directly impacts income security and vulnerability of coffee producers. The general dynamic within the coffee market suggests that consuming countries have far more control on price than do producing countries. When the costs of production inputs (e.g. fertilizers or labor) rise with inadequate rises in coffee prices, farmers bear the entirety of the burden, leading to a severe deterioration in farmers' abilities to remain resilient (Fox, Furgiuele, Haider, Ramirez, & Younis, 2015, p. 14; International Coffee Organization, 2014).

FROM BEAN TO CUP: STAKEHOLDERS & SUPPLY CHAIN

As a complex agricultural product requiring utmost care in growing, harvesting, processing, roasting, and brewing, coffee is a labor intensive business for which education and extra attention are needed at each step for actors throughout the supply chain (Equal Exchange, n.d.). It is important to understand the coffee supply chain and the roles of each stakeholder before distinguishing how key stakeholders adjust to price volatility, adapt to climate change, and react to other issues in the coffee supply chain (Pedersen, Danada, & Presutto, 2005). The primary actors in this study are smallholders and cooperatives.

Smallholders

Coffee production is an essential component of the rural economy in countries throughout the tropics, and is particularly important for smallholders, as it does not necessarily require large plots of land to produce sufficient income. Smallholders are quantified different across sectors and geographies, though are generally defined as cultivating under ten hectares of land (Dixon, Taniguchi, Wattenbach, & Tanyeri-Arbur, 2004). Small-scale agriculture makes up a large portion of income for many people around the world – of an estimated 570 million farms globally, 72% are less than one hectare in size, and 90% are run by an individual or family and rely primarily on family labor (Global Agriculture, *nd*; Lara, 2014). The majority of the world's estimated 25 million coffee producers are smallholder farmers (Donald, 2004); these smallholders cultivate more than 70% of global coffee production (C. Bacon, 2004). A major crop in tropical regions such as Guatemala and Peru, coffee represents 2.49% and 0.88% of those countries' respective GDPs and provides a livelihood for many families ("Climate Change and Coffee," 2009; Fox et al., 2015; King et al., 2009). More secure livelihoods and a higher quality of life may be possible for many smallholder farmers if they are able to grow a more sustainable, secure coffee crop.

Cooperatives

A cooperative is defined by the United Nations as "an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly and democratically controlled enterprise" (UN, n.d.). Coffee cooperatives, made up of anywhere from a dozen to thousands of smallholder coffee producers, provide members with access to markets and better prices, access to credit, training, and technical assistance (C. Bacon, 2004; Feder & Huppi, 1990; Vásquez-León, 2010). In some instances, cooperatives come together under an umbrella cooperative which maintains a license to export and provides organizational and marketing assistance, among other things, to its base cooperatives or sub-associations.

One of the most important roles of a coffee cooperative is serving as a liaison and negotiator between smallholder coffee farmers and coffee buyers or exporters, particularly in the specialty markets. The cooperative assists members with price negotiation, quality sorting and control, and coffee packaging and delivery. Additionally, cooperatives play an important role in providing access to credit for their members, which is crucial for farmers who lack titles to their land and therefore cannot receive credit from traditional financial institutions (Nolte, 2015, p. 3). Many cooperatives provide routine technical assistance to member farmers through training and farm visits by agronomists or other experts. Efficient, accountable, and representative cooperative networks are necessary to promote collective empowerment (C. M. Bacon, Méndez, Flores Gómez, Stuart, & Días Flores, 2008;(Fox et al., 2015, p. 16).

Roasters

Roasters are responsible for preparing coffee for their customers, roasting green coffee into a variety of finished products depending on distinguished flavor profiles desired by their customers. Another responsibility of roasters is retail coffee packaging, which is an opportunity to exhibit any certifications of roasted coffee, highlight the region from where the coffee produced, and display any other details that may appeal to consumers (De Monte, Padoano, & Pozzetto, 2005).

Retailers

Coffee retailers are divided into three categories including mainstream retailers (e.g. supermarket), specialty retailers (e.g. cafes), and out-of-home or institutional market (e.g. coffee shops) (Fox et al., 2015, p. 17; Giovannucci & Koekoek, 2003). Regular retailers emphasize on selling coffee product at a low profit margins. However, specialty retailers focus on differentiating their higher quality coffee products and highlighting their social and environmental initiatives to promote eco-friendlier agricultural practices.

One way to accentuate social and environmental initiatives is through various certifications. Many certifications exist for coffee, as well as other products, and include Fair Trade, Direct Trade, Organic, Bird Friendly, Rainforest Alliance, and UTZ, among others. Fair Trade certification guarantees ethical production of certified products and ensures payment of fair prices to producers, thereby helping to reduce poverty (Fair Trade USA, 2016b, n.d.-a). Bird Friendly coffee is a certification created by the Smithsonian Migratory Bird Center to ensure provision of bird habitat through organic, agroforestry techniques, thereby serving an important role in bird conservation (Smithsonian Migratory Bird Center, n.d.); agroforestry is defined as the production of crops in association with trees (Ramachandran Nair, 1993). Rainforest Alliance and UTZ certifications both aim to ensure social, economic, and environmental best practices (Rainforest Alliance, n.d.; UTZ, n.d.). Certifications offer benefits, and third-party audits increase legitimacy of certifications' claims; however, certifications are expensive to obtain and do not guarantee the procurement of a price premium, as the supply of certified products is higher than demand.

Certifications are an easy way for consumers to quickly compare the relative sustainability of different products, though it is imperative to remember that coffees without a certification seal may also be sustainably produced, though not certified for financial or logistical reasons. Determining whether a product is sustainable is much more nuanced than noting which certifications it has attained, if any. Although specialty coffee only accounts for one-fifth of total coffee sales, it consists of 40% of revenues due to the larger margins on the product (Raynolds, Murray, & Heller, 2007).

Specialty Coffee

Specialty coffee is its own distinct market, defined as "all coffees that are not traditional industrial blends, either because of their high quality and/or limited availability on the producing side, or because of flavoring, [or] packaging" (Ponte, 2002). Despite being a relatively new competitor in the global coffee market, the specialty or gourmet market segment represents 51% of US coffee imports by volume and 55% of the retail market by value (C. Bacon, 2004; Germain, 2012).

Due to the fact that specialty coffee is more rare, and generally requires a fair amount of knowledge and care, many coffee buyers and roasters in the specialty coffee market have direct relationships with the coffee producers from whom they purchase coffee. Counter Culture Coffee (CCC), our client for this project, is included amongst those who implement this model of direct trade or relationship coffee, defined as "a proactive and mutually beneficial collaboration between coffee farmers and coffee roasters aimed at increasing the quality, value, and consistency of coffees produced, where the farmer and the roaster are committed to working together transparently and long-term" (Germain, 2012). A similar model is that of fair trade (which does not necessarily mean the coffee is Fair Trade certified, though the fair trade model also offers a guaranteed lowest price to producers, providing some level of income stability). In the fair trade model, consumers contribute directly to the livelihood of a "distant coffee producer" by removing many middleman costs, while also allowing them to build a sense "relationship with the individuals who produce the commodities" (Lyon, 2011).

- **Location-based Factors**

As mentioned above, Arabica and Robusta are the two most common types of coffee. Robusta is a heartier variety, generally more pest and disease resistant, and grows best on flat land at lower altitudes of 600 – 3,000 feet (or 180 – 900 meters) (Daggett, 2015; Elevation Coffee Traders, 2014). Due to this combination of factors, it is more readily available and widely produced than Arabica, and therefore lower in price. On the other hand, Arabica grows at higher elevations, from 3,000 – 6,000 feet (or 900 – 1825 meters) on mountainous terrain. Such conditions require

hand-picking, a significant process in terms of time and labor, which is reflected in the coffee's higher price (Elevation Coffee Traders, 2014).

While a variety of factors can impact the taste of coffee, studies have shown that altitude has the biggest impact on coffee quality (Leonel & Philippe, 2007; National Coffee Association, n.d.; Wintgens, 2004). Due to the lower temperatures and oxygen levels at high elevations, the coffee fruits grow more slowly, producing a denser, higher-quality bean with a more concentrated flavor (Elevation Coffee Traders, 2014). The highest quality, most sought-after "strictly hard beans" are grown above 4,500 feet (or 1,375 meters), which can be found in Guatemala and Peru, amongst other countries (Daggett, 2015; National Coffee Association, n.d.).

CLIMATE CHANGE & COFFEE PRODUCTION

Coffee productivity and quality is highly dependent on temperature and rainfall conditions (Haggar & Schepp, 2012, p. 7), and is relatively sensitive to drought, excessive moisture, and wind damage (Tucker et al., 2010, p. 24). The blossoming and fructification of Arabica coffee, in particular, requires a specific series of dry and rainy seasonal alternation (Haggar & Schepp, 2012; The Initiative for Coffee & Climate, 2015, p. 8). Steps in coffee production and potential impacts from climate change are included in Table 1 (FAO, n.d.; The Initiative for Coffee & Climate, 2015).

Table 1: Potential Climate Change Impacts on Coffee Production

Stages of Coffee Growth	Condition Needed	Climate Changes*	Potential Outcomes
Pre-Blossoming	3-month dry period	UP	Weak plants
Blossoming	Regular rainfall	UP	Over-soaking or water shortage
Fructification	Regular rainfall	UP & RT**	Pests, diseases, physiological problems
Harvesting	Dry season	UP	Unable to fruit pick in time
Post-Harvesting	Dry but enough water for processing	UP	Water shortage; unable to dry beans

** Predicted impacts include unpredictable precipitation (UP) and/or rising temperature (RT).*
*** FAO EcoCrop model estimates optimal temperatures for ripening of Arabica coffee is 14-28°C*

Thus, although future variations in climate across regions remains uncertain, rising temperatures and unpredictable rainfall patterns are expected to have negative consequences on coffee production in terms of quality, yield, and pests and diseases. (The Initiative for Coffee & Climate, 2015, p. 8).

Climate Change Adaptation Strategies

Climate change effects are both complex and highly uncertain. Adaptation strategies are the "efforts by society or ecosystems to prepare for or adjust to future climate change" (US EPA, n.d.). These can be either proactive to minimize negative impacts of climate change or opportunistic to inspire and initiate new development practices (The Initiative for Coffee & Climate, 2015). Although people have faced and adapted to climatic changes since our species evolved, the climate change predicted for this century is far greater and faster than anything previously known in human history and prehistory (Salik & Byg, 2007; US EPA, n.d.). Due to our increasingly interdependent world, negative effects of climate change can have repercussions in every social sector and ecosystem (US EPA, n.d.).

In order to implement the appropriate intervention to adapt to the impacts of climate change, governments and agencies need to understand the main factors of smallholders' choices of strategy and major barriers of selected adaptation strategy (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009). Smallholder producers could either change their agricultural practice by altering planting dates or other methods to increase their crops' resiliency, or explore other income streams to increase their livelihood resiliency to climate change (Komba & Muchapondwa, 2015, p. 31; Lin, 2011). For this project, in order for smallholder producers to adapt to uncertain future climate change impacts, it is important to ensure that all aspects of their livelihood strategies are resilient to changing and unpredictable conditions via adaptation strategies.

Nevertheless, it is important to note that adaptation alone may have limitations in the face of climate change, and further mitigation strategies may be necessary to fight with climate change effects. Ongoing efforts are required from governments and communities to sufficiently not only

adapt to all the projected impacts of climate change, but also to mitigate its causal factors (e.g., greenhouse gas emissions) (Solomon et al., 2007; US EPA, n.d.).

Climate Change & Coffee in Latin America

As mentioned above, the uneven distribution of climate changes leads to predominantly regional effects. The IPCC predicts that by 2100, the temperature will increase from 1.6°C to 6.7°C across Latin America (IPCC, 2014a). Climate change models also indicate an increase in unpredictability in precipitation in the entirety of Latin America, which has historically been categorized by highly predictable rainy and dry seasons. Due to the variation in projection model designs, predictions in South America are immensely variable with percentage change ranging from -22 to +25%, while those in Central America are slightly less extreme, ranging from -22 to +7%, which are varied by the different baseline scenarios and mitigation scenarios utilized in projection models (IPCC, 2014a). By 2050, Central America may see a reduction in rain of 12% to 20% in the dry season, and an increase of 3% to 10% in the wet season (Solomon et al., 2007). According to World Bank, with a 4-degree warming scenario, 90% of Latin American land would be under influence of heat events, which leads to extreme droughts in the Amazon basin and complete glacier loss in Andean mountains (World Bank, 2014).

Effects of Climate Change on Coffee Production in Latin America

Latin America has been experiencing unusually extreme weather events under El Niño effects since 1997, which reached a peak in 2005 when Hurricane Stan caused damage to 720,000 hectares of agricultural land for variety of crops just before harvest season began (Tucker et al., 2010).

The combination of volatile prices, aggressive *Roya* infestations and damaging climate conditions has posed multiple challenges for smallholder producers for the last decade. The fungus *Roya*, or coffee leaf rust is currently found in all coffee-growing regions in the world, which affects the coffee leaf surface and causes premature defoliation leading to the termination of coffee fruit growth (Arneson, 2000). The continuous effects of *Roya* infection from previous season and increased temperature and humidity could reduce the yields of upcoming consecutive

years (Helfer, 2014; Arneson, 2000). Another coffee disease, a fungus called *Ojo de Gallo*, or American Leaf Spot, has similar impacts on coffee leaf and plants by reducing coffee tree's photosynthetic capability weakening the overall health of the plant (Helfer, 2014). Such pest and diseases infection was one of perceived climate change effects by smallholders producers and cooperatives. Particularly, shifting in climatic patterns may contribute to the outbreak of Roya epidemic (Fox et al., 2015, p. 32). The most recent *Roya* epidemic of 2012 - 2015 affected 70% of coffee cultivation land costing approximately US$101 million in total economic losses (Haggar & Schepp, 2012; Helfer, 2014).

Thus, coffee rust is the most economically costly coffee disease. With a small reduction in coffee yields and increase in production costs, coffee rust and other pests and diseases would add another level of instability threatening smallholder coffee producers' livelihoods and those Latin American countries whose economies heavily dependent on coffee production (Arneson, 2000; Eakin, Tucker, & Castellanos, 2006).

CONTEXT & SITE DESCRIPTION

This project builds on an existing partnership between Duke University's Nicholas School of the Environment and CCC, which began with the first group of students in 2014. Site selection was initially determined by CCC, and included cooperatives in Colombia, Guatemala, and Peru, which were of particular interest due to their smallholder farmers, remote location, range of organizational capacities, and varied co-operative size (Fox et al., 2015). These cooperatives were also accessible in terms of conducting research on behalf of CCC due to the fact that they have direct trade relationships and sufficient organizational capacity and interest.

Our analysis included participatory action research (PAR) to better understand the ways in which smallholder coffee farmers in Peru and Guatemala are adapting to climate change, as well as to further feasibility studies regarding the effectiveness of these and additional adaptation strategies. Three attainable adaptation strategies per country were identified for smallholder coffee farmers in the cooperatives of CODECH in Guatemala and CenfroCafé in Peru through discussions with cooperative leaders and administrative councils; we asked the cooperative

leaders and decision-makers to indicate which strategies they perceived to be most viable, interesting, and useful, thereby narrowing our focus to three strategies per cooperative. We then interviewed the cooperative leaders, and conducted focus groups with cooperative members, to gather information to conduct feasibility studies. The results of our feasibility studies demonstrate the types of capital required to successfully implement each strategy. Through key findings in the research, recommendations are made to major stakeholders on capacity development of implementing the strategies.

RESEARCH TEAM

Research was conducted in Guatemala by a total of three students, with two during the summer of 2015 (Jared Ginn, MSc-GH '15 and Ariadne Rivera, MPP '16) and two during January 2016 (Danielle King, MEM '16 and Ariadne Rivera), and in Peru by two students, during the summer of 2015 (Jennifer Finley-Lezcano, MEM '16 and Tianyu (Sapphire) Wang, MEM '16). The ability to design research questions and conduct interviews was greatly enriched due to the interdisciplinary makeup of the team. Jared Ginn was involved in study design and data collection, but not in data analysis or the writing of this document. Jennifer Finley-Lezcano, Danielle King, and Tianyu (Sapphire) Wang conducted data analysis in partnership with Ariadne Rivera. Finley-Lezcano, King, and Wang completed the research, data analysis and written report in partial fulfillment of the Master of Environmental Management degree requirements at Duke University's Nicholas School of the Environment. Rivera also contributed to research and data analysis and produced a written report in completion of her Masters Project requirements at Duke's Sanford School of Public Policy. Portions of this report – in particular, the sections on income diversification – were completed in partnership with Rivera; her separate report should be consulted for deeper exploration (Rivera Aguierre, 2016).

OUR CLIENT: COUNTER CULTURE COFFEE

CCC is a specialty coffee roaster founded locally in Durham, North Carolina in 1995, with a commitment to sourcing high quality coffee directly from farmers and cooperatives in Asia, Africa, and Latin America ("About Us," 2014). CCC is interested in environmental sustainability

in the coffee chain and in coffee growing communities, which also ensures a sustainable, viable business and product for market (Taylor, 2015). In order to assess performance on their sustainability and social welfare goals, CCC utilizes the triple bottom line framework. This framework, which considers social, environmental/ecological, and economic performance, is also referred to as the three Ps: people, planet, and profits (Slaper & Hall, 2011). By researching more about the feasibility of potential climate change adaptation strategies for smallholder coffee producers, CCC is able to better understand and prepare themselves and support their partners and growers to ensure a sustained, high-quality product in the face of a changing climate. Following the practices of a "relationship-coffee" model, CCC is committed to making improvements along the supply chain, starting with the producers and cooperatives (Counter Culture Coffee, 2013).

GUATEMALA

Coffee was introduced to Guatemala during the 1760s, only a few decades after its introduction in Colombia, and was first exported in the 1840s (Eakin et al., 2006). In 1960, the Guatemalan government established a national association of coffee, Asociación Nacional del Café (Anacafé), which every coffee farmer is part of, to promote and support the export of the commodity (Eakin, Tucker, & Castellanos, 2006). After civil war in Guatemala finally ended with the signing of the Peace Accord in December of 1996, many Guatemalans who had fled returned, and significant international aid came into the country (Sieder, Thomas, Vickers, & Spence, 2002). Much of this aid required some sort of organization to whom to dispense aid; thus, cooperatives began forming for coffee and a variety of other products (Personal communication, January 2016; Sieder et al., 2002).

Guatemala currently cultivates coffee on more land than any other country in Central America at over 300,000 hectares (Taylor, 2015). Coffee production, in general, is a large portion of Guatemala's agricultural GDP, and makes up approximately 1.5% of national GDP. Roughly 43% of Guatemala's coffee exports go to the United States (Tay, 2015). Production is almost exclusively Arabica, composed of Caturra, Catuaí, Bourbon, and Catimor, in descending order (Tay, 2014). Estimated coffee production in crop year 2014/15 is around 3.51 million bags, with

a global market share of 2.5% (Tay, 2015). Prices paid to farmers are only a portion of prices received by exporters, and range from $2.30-2.80/Kg (Tay, 2015). Coffee has been Guatemala's most important export for almost the last 150 years and the industry is still growing with 50,000 new smallholder coffee farmers over the last 20 years (Fischer & Victor, 2014).

Guatemala has a higher vulnerability in terms of extreme weather events risk, and rain-fed agriculture and agricultural employment dependency among Latin American countries (Haggar & Schepp, 2012, p. 15; Kreft, Eckstein, Kerestan, & Hagen, 2015). Guatemala is projected to experience an increase in temperature ranging from 2.0°C to 2.5°C by 2050 and a decrease in rainfall leading to droughts and occasional intense rainfall events in the July-September flowering period (Haggar & Schepp, 2012, p. 8). Climate effects will disproportionately impact the country, with the coastal regions suffering from increased variability more than the inland highlands. While lower altitude regions near the coasts will lose suitable area for coffee production, the high mountains and plateaus of the central and western highlands will roughly maintain climatic conditions (Haggar & Schepp, 2012, p. 11).

The country suffered from a coffee rust epidemic from 2012-2014, which reduced their production by 20-25% from the 2011/2012 harvest (Tay, 2015). Fortunately, with heavy management, the harvest is now increasing at 3% per year and projected to do so again for the 2015/2016 harvest, which is estimated at 3.61 million bags. Guatemala's Ministry of Environment & Natural Resources (*Ministerio de Ambiente y Recursos Naturales*) has been developing plans to enhance governmental capacity in increasing national disaster resiliency due to its ranking as one of the countries most at risk to the impacts of climate change ("The Global Climate Legislation Study: Guatemala," 2015). Increasing temperature may cause a shift in the elevation range in which Arabica coffee is suited within the country, potentially leading to a loss of suitability for coffee production in some regions (Haggar & Schepp, 2012).

CODECH

Research was conducted with the top level cooperative CODECH (*Coordinadora de Organizaciones de Desarrollo de Concepción Huista*), founded in 1999, in the Western

Highlands of Guatemala in Concepcion Huista, Huehuetenango (CODECH, 2012) (see Figure 3). CODECH has over 1250 members amongst seven base organizations spread throughout the municipalities of Concepcion Huista and Jacaltenango, which are dominated by smallholder farmers ("Tasting@Ten," 2014b).

About half, or 675, of CODECH's members are coffee farmers, who belong to one of five coffee-related base cooperatives: ADAT (*Asociación de Agricultores Tinecos*), ADINTHEC, ADIPY (*Asociación de Desarrollo Integral Productivo Yamanonh*), BITENAM (*Bienvenidos Todos en Nombre de la Amistad Máyense*), and Cooperativa Quixabaj (Personal communication, January 2016). Most of these five were founded around the time of the Peace Accords, but joined under CODECH for managerial support and access to buyers for export. The other two cooperatives that make up CODECH's seven are a Women's Association and Teacher's Council (CODECH, 2012). Benefits of membership include access to market, agricultural training, field visits, access to credit from the cooperative, and additional livelihood or lifestyle workshops.

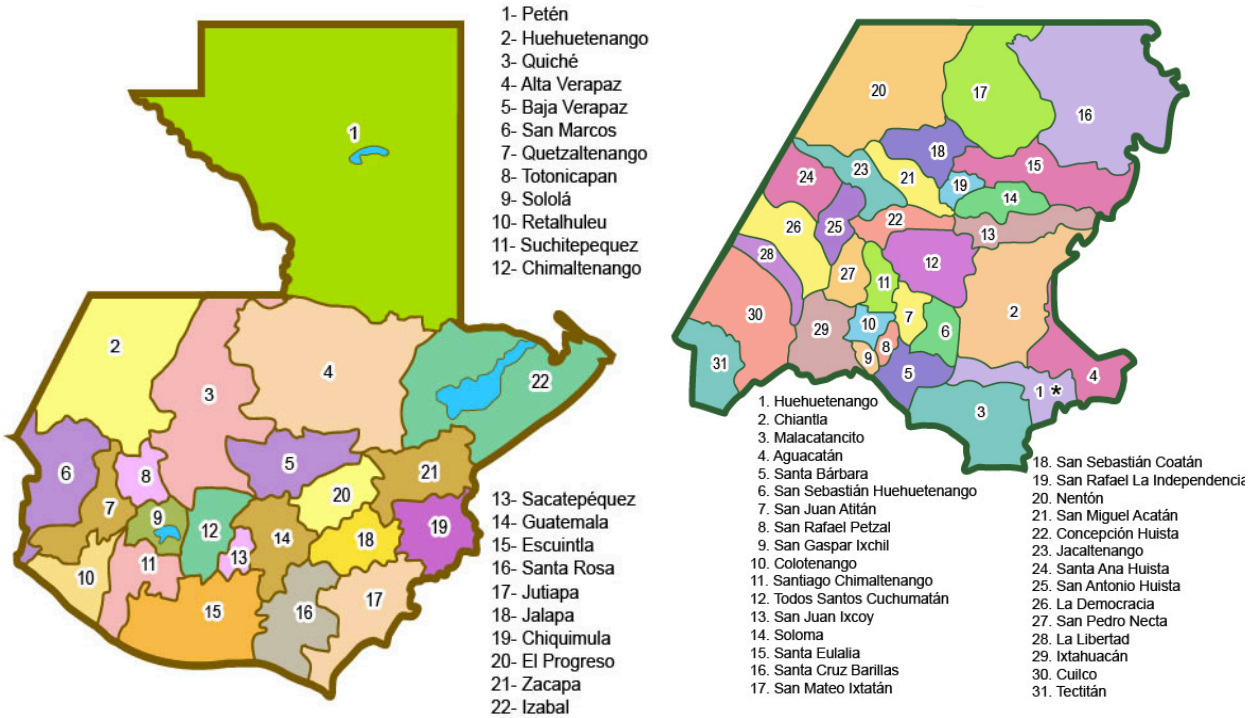

Figure 3: Map of Study Site in Guatemala

Research was conducted in the municipalities of Concepcion Huista and Jacaltenango (#22 and #23, respectively, in the map on the right) in the department of Jacaltenango (#2 in the map on the left) in the Western Highlands of Guatemala ("Mapa de Guatemala," n.d.).

The CODECH team consists of five employees: Cooperative Manager, Field Technician – locally referred to as a *técnico*, Accountant, Cupper (who assesses the quality of the coffee, employed only during harvest), and Secretary/Assistant (Personal communication, January 2016). Each of the coffee-related base cooperatives also has a small staff, consisting of at least a manager, accountant, and technician. As the top level cooperative, CODECH has been registered and licensed by Anacafé to export coffee, while the base cooperatives are not permitted to so do. CODECH also has the capacity and relationships to assist farmers in organic and/or Fair Trade certification, both of which carry a price premium (Personal communication, January 2016).

CODECH's slogan is *Coffee of High Elevation!*, with cultivation from 1,000–2,032 meters in elevation (CODECH, 2012). Their producers cultivate coffee considered as traditional varieties, the most common varietals grown being Caturra (a Bourbon variety), Bourbon (generally), Catuaí, and Pache Roja (Fox et al., 2015). While these plants contain substantial variety and are less prone to disease than large mono-variety plantations, many of these traditional strains have been grown at high elevations for centuries, and the impacts of climate change on their production remains uncertain. The majority of members own their plots, which average less than one hectare in size. Of the 550 ha in production through CODECH, 250 ha are certified organic and 300 ha are Fair Trade certified (CODECH, 2012).

Nearly all of CODECH's members are of Mayan descent, speaking local languages such as Mam and Popti', and usually also Spanish as a second language (Personal communication, May 2015). While many members live on their parcels, many others live in town and travel back and forth to their parcel as needed, sometimes living there in temporary establishments during harvest from January through March (Personal communication, January 2016). Many locals in this region fled to Mexico in the 1970s and 80s during Guatemala's civil war, temporarily living in the Chiapas region, and still maintain strong ties on both sides of the border (Jonas, 2013).

CCC first purchased coffee from CODECH in 2010, and has worked with them extensively to improve the quality of their coffee so that the farmers can, in turn, receive the highest price premiums. When the quality is high enough, CCC roasts CODECH's coffee as their single origin

Concepción Huista named after the town in which CODECH is located ("Tasting@Ten," 2014a; Personal communication, January 2016).

PERU

Coffee cultivation in Peru dates back to its introduction into the country in 1742, with exportation of the crop beginning more than one hundred years later, in the 1880s (Vargas, 2009). In the 1970s, coffee started to become an important export with more and more technical training available for coffee producers. The country has seen an incredible rise in coffee production in the last two decades (Toulet & Pérez, 2010). Currently, coffee is Peru's top agricultural export (Nolte, 2015). There are three main growing regions in the country: the northern highlands of the Cajamarca, San Martín, and Amazonas regions, the central highlands in the Chanchamayo region, and the southern highlands in the vicinity of Cusco and Puno. Nearly half of coffee production is from the central region of Peru, followed by the northern region. The top varieties grown in Peru are Typica, Caturra, Pache, Catimor, and Castillo (Vargas, 2009). The Typica and Pache varieties are more susceptible to diseases but provide generally higher quality coffee, whereas Caturra, Catimor and Castillo are disease tolerant and produce a lower quality coffee. Disease-tolerant coffee is potentially a valuable resource as climate change creates conditions which encourage higher pest loads and disease ocurrences.

Currently, Peru is the world's sixth largest exporter of coffee (ICC, 2009) and the world's leading exporter of organic coffee (USDA Foreign Agricultural Service, 2013), with some 90,000 certified organic hectares (Fox et al., 2015, p. 19; Luque, 2015). The total production for crop year 2014/15 was approximately 4.0 million bags (60 kilogram bags, known in Spanish as *quintales*), 2.8% of world production (Nolte, 2015). Peru began exporting specialty coffee in 1997 and has steadily increased the amount in the intervening years; the specialty coffee market compromises a significant portion of Peruvian exports, with an estimated 14% of the volume of exported coffee designated as such in 2006 (Toulet & Pérez, 2010). Organic, Fair Trade, "Sustainable" and gourmet coffee combined make up the specialty coffee market in Peru (Junta Nacional de Café, cited by Toulet & Pérez, 2010).

Peru is one of the most vulnerable countries to climate change, expecting the greatest temperature rises in the future (Kreft et al., 2015). Though Peru has the world's largest concentration of tropical glaciers, in recent years the country has lost approximately 40% of them, resulting in water shortages for both drinking water and agricultural irrigation (Collyns, 2014). Similar to Guatemala, Peru is one of most affected countries under the impacts of El Niño with more than six fold occurrences of extreme weather events from 1997 to 2006 (Niquen, 2014). In Peru, it is estimated that an increase of 2 °C in the maximum temperature and 20% in rainfall variability by 2050, which would generate a loss of over 20% over the potential GDP in 2050 (Vargas, 2009). Peru also suffered from *roya* infestation during the last three years, which affected nearly 40% of the coffee crop. With the recovering from the leaf rust outbreak, the coffee production is forecasted to increase in 2015/2016 (Nolte, 2015).

CenfroCafé

CenfroCafé was founded in 1999 in northern Peru and began as an association of 40 producers. Officially gaining cooperative status in 2010, CenfroCafé was one of the first cooperatives in the region to bill itself as a *cooperativa de servicios múltiples*, or a multi-service cooperative, not only providing a market for coffee producers to sell their coffee but providing markets for other goods such as rice and cacao as well as providing loans and other services to its members. CenfroCafé provides technical assistance to farmers, offers drying tarps and string trimmers at a reduced cost, provides the service of roasting the coffee for those farmers who want to sell their coffee roasted, offers maintenance of farmers' depulping machines, and the development of grant projects and the associated technical documentation. Like CODECH, CenfroCafé is also a second-level cooperative, and is comprised of around 84 smaller, local associations organized into 12 mid-level cooperatives. CenfroCafé is currently the largest coffee cooperative in Peru, with approximately 2,600 member families.

CenfroCafé's main office complex is located in the town of Jaén, in Cajamarca Province, though it serves smallholder coffee producers living in remote, rural areas in Cajamarca Department and Amazonas Department (see Figure 4). CenfroCafé has a total of 64 employees, with half of those being permanent positions and the other half part-time, seasonal positions receiving coffee

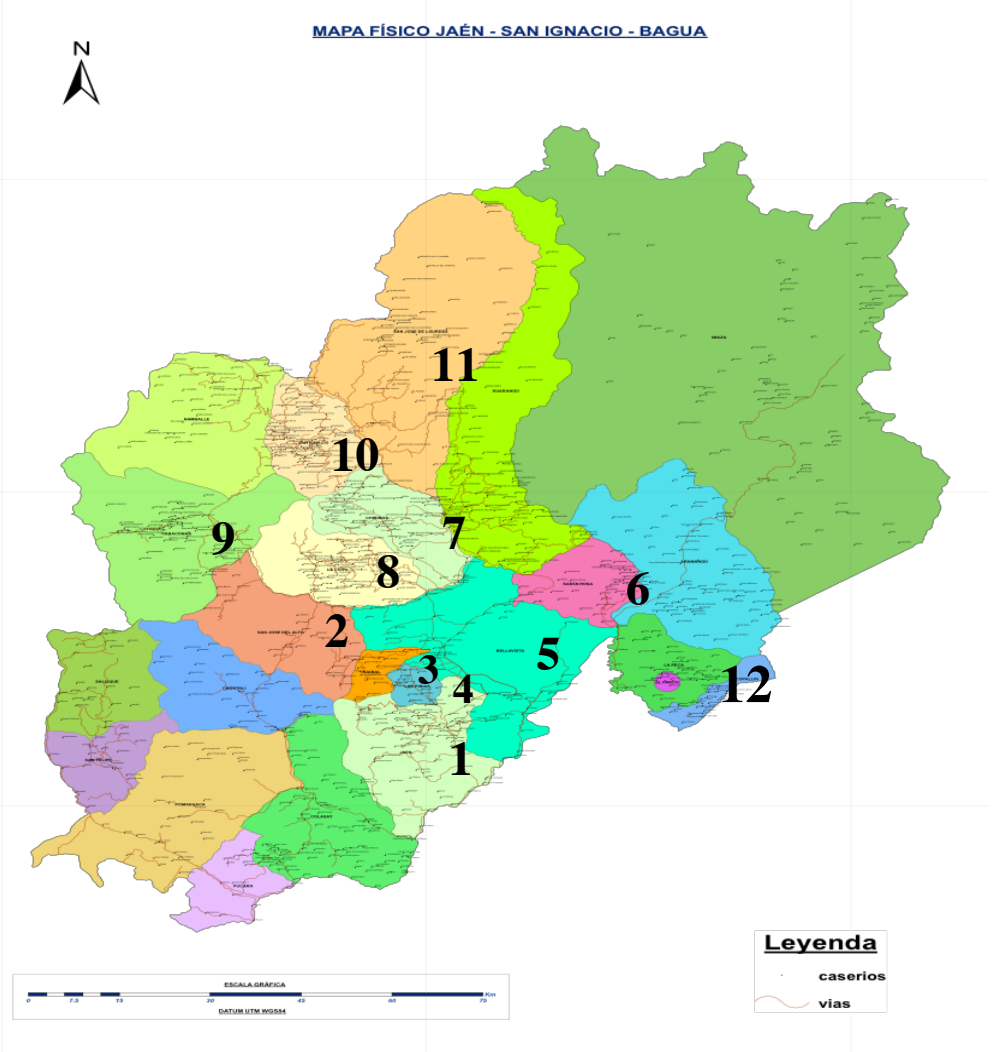

Figure 4: Map of Study Sites in Peru

Regional map of Jaén, San Ignacio, and Bagua. Research was conducted within the 12 networks of CenfroCafé, as labeled above. Source: CenfroCafé.

1. *Jaén*
2. *San Jose de Alto*
3. *Huabal*
4. *Las Pirias*
5. *Bellavista*
6. *Santa Rosa*
7. *Chirinos*
8. *La Coipa*
9. *Tabaconas*
10. *San Ignacio*
11. *San José de Lourdes*
12. *Amazonas*

at warehouses (Personal Communication, March 17 2016). The main office complex consists of offices for the cooperative's administrative staff, marketing department, financial services department, certification department, production department and project development department, meeting rooms, a large warehouse for storage of coffee *pergamino*, or dried coffee in its natural parchment, the farmers sell to the cooperative, and a large drying patio where many producers come to dry their coffee in the heat of the valley. Several smaller satellite offices and warehouses are strategically located to associations, allowing for easier transport of coffee to the warehouse from the producers' fields. CCC purchases coffee from CenfroCafé's base-level associations in the Ihuamaca region of San Ignacio Province, which is located in the northern part of Cajamarca Province; Counter Culture has fostered this direct trade relationship since 2007.

COMPARISION OF COOPERATIVES

The coffee-growing communities in Jaén, Peru (where CenfroCafé is based) and Huehuetenango, Guatemala (where CODECH is based) are ones that share similar economic motivations, community values, and common adversities. For example, a significant problem facing smallholder coffee producers in both countries (and indeed, worldwide) is the *roya* epidemic and the tension between *roya*-resistant varieties versus varieties that produce higher quality flavor profiles. A further similarity between the two cooperatives is their remote location and makeup of smallholder farmers (Fox et al., 2015). These cooperatives were also accessible in terms of conducting research on behalf of CCC due to the fact that they have direct trade relationships with the company, as well as sufficient organizational capacity and interest in the project. One key difference in the political context of the cooperatives is that Guatemala has a national government-supported coffee federation, whereas Peru lacks a strong, well-funded government agency serving as a coffee support program on a national level.

While both are second-level coffee cooperatives, CenfroCafé is larger than CODECH in terms of number of members, average size of parcels, and organizational support personnel. On average, CODECH members have less than one hectare of land, almost entirely dedicated to coffee (Personal communication, January 2016). However, CenfroCafé members have five hectares of land, on average, containing pastures, forests, and areas for cultivation of coffee and other crops, with an average of two hectares in coffee (Personal communication, April 2016).

METHODS

The primary objective of this Master's Project was to help CCC, and the smallholder farmers and cooperatives from whom they purchase coffee, better understand the climate change adaptation techniques they are, or could be, utilizing and the feasibility of each. Our research questions are:

(1) Do these smallholder coffee cooperatives and/or their producers have, or could they obtain, the capital necessary to implement the selected adaptation strategies to increase resiliency to climate change?

(2) Do the producers themselves perceive these strategies to be viable and attractive?

(3) Who would need to be involved at all levels in the implementation of these strategies?

PRECEDING RESEARCH: RESILIENCY & ADAPTATION

During the summer of 2014, a group of students from Duke's Nicholas School conducted research in Colombia, Guatemala, and Peru, looking at how smallholder coffee farmers perceived they were being impacted by climate change and their efforts to increase their resiliency for their Masters Project during the 2014-2015 academic year. Resiliency is the ability of people to adjust in anticipation of or in response to climate change "in a manner that reduces chronic vulnerability and facilitates inclusive growth" (Department of Defense, 2016; USAID, 2015).

Based on their analysis, the students provided 17 recommendations (see Appendix A) that CCC and the cooperatives could consider pursuing in an effort to increase resiliency of coffee production, and the livelihoods of those involved, and promote adaptation to climate change (Fox et al., 2015, p. 97):

> These recommendations seek to strike a balance between increasing resilience to climate change of coffee production while considering the permanency of the household and livelihood strategy of each of the producers. Also, these recommendations look to maintain the quality and reliability of coffee supply […], however, as part of the larger system of coffee production there are topics that are not strictly related with climate change, but that are threats that combined could largely affect the producers or even push them to leave the market.

Therefore, while some of the recommendations are more obviously linked to climatic impacts, all of the strategies pursued would improve a producer's ability to adapt by increasing their resiliency.

INITIAL PARTICIPATORY ACTION RESEARCH

The first step upon arrival for the teams in Guatemala and Peru was to share these findings and recommendations from the first year's research, for the cooperative itself and sharing

information from the other case study countries, after which we implemented a participatory approach to select the top three strategies worth pursuing in each country. Participatory action research (PAR) capitalizes on collaboration and social relations to yield the most accurate, relevant, and useful information for the community with which the research is being conducted (Fine et al., 2003). PAR is a cyclical process, consisting of four steps: planning, action, observation/evaluation, and reflection (see Figure 5) ("Factsheets," 2012; Pain, Whitman, & Milledge, n.d.).

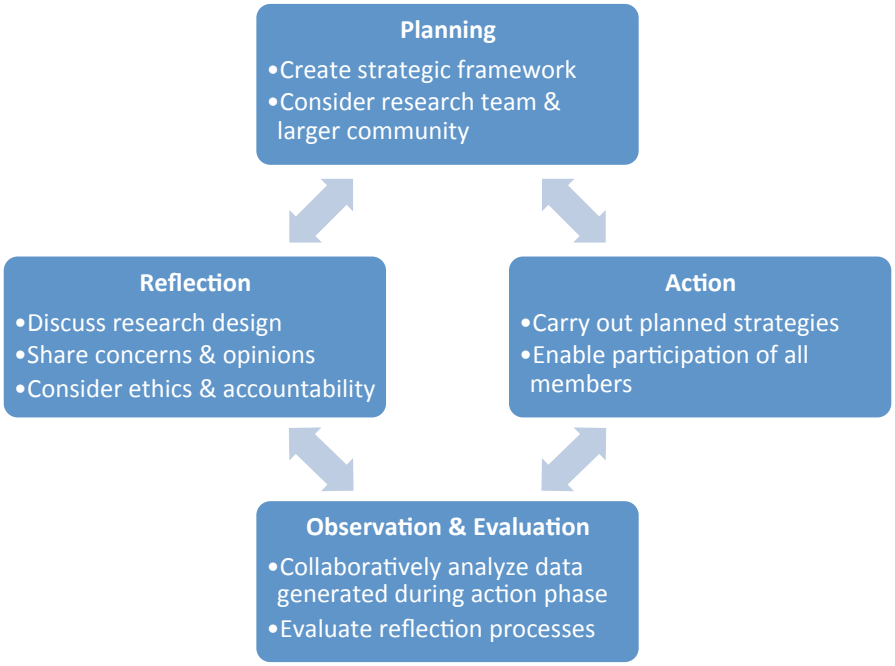

Figure 5: Participatory Action Research

Description of the PAR process (Pain, Whitman, & Milledge, n.d.).

Our study began with broad discussions and interviews with cooperative leaders in both Guatemala and Peru during which we discussed their opinions on the most feasible of the 17 recommended strategies for their cooperative. From there, we selected the top three perceived to be most feasible in each country. This was followed with focus groups and individual interviews with cooperative leaders and members, and ultimately by key actor interviews. This process of discussions inclusive of a variety of stakeholders and complemented by individual producer interviews allowed us to further explore the issues of most concern and relevance to the cooperatives and their members.

PAR is particularly useful and appropriate for qualitative research, and is uniquely useful in our research for several reasons (Rabinowitz, 2015):

- People living what is being researched are able to provide a depth of information that cannot be found in outside sources, and include additional factors which an outside researcher may not consider on their own.
- Those who are personally experiencing the issue may be able to provide more thought-out, intuitive information and ideas.
- PAR is conducted with nearly constant contact between the community and researcher, allowing for more complete data collection.
- Community members become more engaged in the project and interested in its findings and results when they are active members of the research.

PRIMARY DATA COLLECTION

The majority of the 90 interviews conducted were in Spanish, excluding several conducted in local languages via a Spanish interpreter and four conducted in English (see Figure 6).

Figure 6: Breakdown of Primary Data Collection

While several interviewees were identified before arriving in the field, the majority were selected using snowball sampling, a social-network based approach wherein each interviewee suggesting additional interviewees with whom we would then follow-up (Miller et al., 2011, p. 36). Interviews were coded using NVivo qualitative analysis software (*NVivo*, 2012); in the software, the researcher can import interview transcripts, videos, and photos (among other media), and code items to reveal trends and patterns.

Key Actor Interviews

Interviews were conducted with a selection of actors at the local, regional, and national level in a range of government, for-profit, and nonprofit organizations who were able to provide in-country context in addition to a unique understanding of the types of resources and potential barriers that

exist in terms of feasibility for the selected adaptation strategies. Some key actors at the national level who work generally with smallholder coffee producers were identified ahead of time, though the majority were selected once we narrowed down the adaptation strategies of study. *Total: 24 Guatemala, 16 Peru; see* Appendix B *for interview guide.*

Cooperative Leader Interviews

Interviews were conducted with those in leadership positions at both the top level cooperative in-country, in addition to the base cooperatives. Cooperative leader interviews were used in the beginning of the summer to select the three adaptation strategies of interest, as cooperative leaders are able assess the feasibility and potential usefulness of adaptation strategies. Additional cooperative leaders were interviewed to collect information on details of the cooperatives themselves, and on the economic, political, environmental, and historical contexts of the region. Considerable effort was made to interview a broad range of actors amongst the leadership in the cooperatives and base cooperatives. It is also important to note that in the majority of cases, cooperative leaders are either coffee farmers themselves, the spouse of a coffee farmer, and/or from a coffee producing family. *Total: 19 Guatemala, 10 Peru; see*

Appendix C *for interview guide.*

Focus Groups

Cooperative members from across the base cooperatives and coffee growing communities were selected in consultation with cooperative leadership. Both single- and mixed-sex focus groups were conducted with cooperative members, some of which included community asset mapping, which is a participatory approach that involves citizen engagement in "documenting the tangible and intangible resources" of a community (Kerka, 2003). It is crucial to hear directly from cooperative members which methods have been tried in the past and where interest lies in new strategies, and to discuss the costs and benefits of implementing such adaptation strategies at a very practical level. *Total: 5 Guatemala, 8 Peru; see*

Appendix D *for interview guide.*

Cooperative Member Interviews

In some cases in Guatemala, farmers with remote plots were interviewed one-on-one and not as part of a focus group. This allowed for more detailed follow-up to the interviews conducted with cooperative leaders and the focus groups. *Total: 8 Guatemala; see*

Appendix E *for interview guide.*

THEORETICAL FRAMEWORK FOR ANALYSIS

In order to assess the feasibility of the selected adaptation strategies in each country, we have taken inventory, through interviews and subsequent coding, of the assets available and needed in order to implement the strategies. Referred to as a capital asset model or sustainable livelihood framework, this included five types of capital: financial – the monetary assets which facilitate economic production; human – the productive capacities of the community; natural – the environmental resources and ecological services; physical – manufactured assets; and social – the social network of trust, norms, and shared values (see Figure 7 for examples) (Rakodi, 1999; "The Five Capitals," n.d.).

According to the capital assets model, despite the fact that levels of capital may fluctuate over time, it is necessary to maintain or increase all five types of capital in order to achieve sustained livelihood improvements (Goodwin, 2003; Smith, Simard, & Sharpe, 2001). When

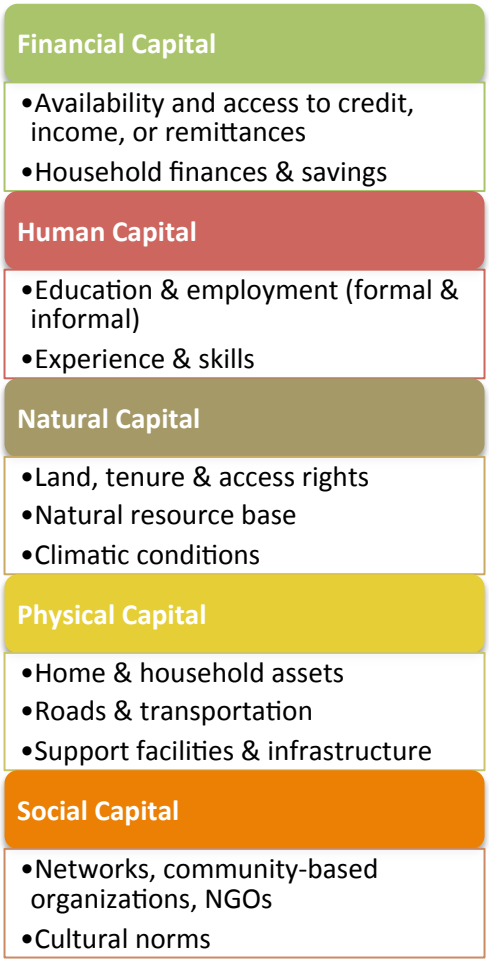

Figure 7: Key Components & Examples of Capital Assets

Examples of types of capital. (Asian Development Bank, 2005; "The Five Capitals," n.d.)

any of the five capitals is being depleted due to consumption outpacing replenishment, such development cannot be sustained ("The Five Capitals," n.d.). This framework is human-centric, and does not attempt to analyze livelihood quality and resiliency in a linear manner, but rather attempts to do so holistically, emphasizing "the multiple interactions between the various factors which affect livelihoods" (DFID, 1999). Moreover, it aims to encourage stakeholders with different perspectives to engage in research and identify both barriers and potential assets (ATHA, 2014). Due to the fact that our research includes participatory action research and focuses on individuals in rural areas of developing countries, this model for analysis is particularly relevant.

We analyzed our interviews following a detailed coding guide based on three themes, or areas: (1) context under which smallholder coffee farmers are operating; (2) previous experience in project implementation; and (3) feasibility of the strategy (see Appendix F).

BIAS

We acknowledge our biases in having academic backgrounds and understandings of climate change causes and projections. However, in this study we approach our research questions accepting all perceptions of climate change without guiding discussion with particular attention not to rely on our assumptions. Other potentially introduced bias includes translations. In Guatemala, we used a translator for the participants that spoke Popti' therefore we do not have the direct words of the participant. The translators may have not translated all of the participants' words without our knowledge. Additionally, as Spanish is not our native language, the fact that almost all research and analysis was conducted in Spanish is an area of potential bias. While we made every effort to combat this bias, we recognize it still exists and may influence our results.

Although we conducted all analysis in Spanish (with the exception of six key actor interviews conducted in English), we have translated here the direct quotes in our results sections from Spanish to English; for longer quotations we have also included the original words of the speaker as to increase transparency. Additionally, all eight individual farmer interviews in Guatemala, all focus groups in Guatemala, and all but one focus group in Peru were conducted in the presence

of an official figure from CODECH or CenfroCafé. The presence of cooperative leaders in Guatemala was for translation purposes from Popti' and other languages to Spanish; in the case of Peru, the co-operative employee(s) who were present in the focus groups provided our transportation to the remote communities, and therefore sat in on our focus groups. The presence of a representative of the co-operative may have hindered some cooperative members from speaking more freely or may have led them to overly accentuate issues because that is what they believe people want them to say.

It is also worth reiterating that our results and recommendations for the two countries are based almost exclusively on interviews and information from one top-level cooperative in one region of the country, and should not be considered as sweeping recommendations across the countries or region. Additionally, the perspectives of farmers whom we did not interview are not represented in this study and must be considered. In Peru, we selected focus group locations in consultation with cooperative technicians in order to include stratification of altitudes within the sample, as well as to include farmers from both areas that generally produce high quality coffee and areas that do not tend to produce much high quality coffee. We conducted focus groups in four communities within different "*redes*" in CenfroCafé's network: Caserio Santa Cruz de Morochal in Bagua, Amazonas (1400-1500 masl), Caserio Santo Domingo in Huabal District (a medium altitude zone), the town of Chirinos in Chirinos District (with producers representing both medium and high altitude zones), and the "*micro-red*" of Ihuamaca which included producers from across five *caserios*, or villages, at high altitudes (approximately 1600- 1900 masl) (Personal communication, March and April 2016).

STRATEGIES OF INTEREST

Five potential adaptation strategies were pursued in our research: income diversification, solar dryers, seed banks and nurseries, pest monitoring and management, and water collection systems. The selection of these strategies is discussed in the Methods section of this report (see page 21). Graphics representing our capital assessment, for use and distribution by CCC, are included in Appendix G.

CROP & INCOME DIVERSIFICATION

Income diversification is the adoption of alternative income-generating activities, generally with the goal of reducing risks to shocks in markets (Delgado & Siamwalla, 1997). When a farmer's income is diversified, they are more resilient to various shocks in or changes to markets, and can better adapt accordingly. Smallholders and rural populations worldwide diversify their income by seeking paid work in their community or migrating, by incorporating value-added products into their portfolios, by growing a variety of crops, among other options; however, research on diversification is still lacking in determining conditions under which it is most successful and the impact it has on livelihoods (Läderach, 2012).

It is important to account for scale in any diversification project, particularly when considering the varying impacts climate change can have at different levels (Osbahr, Twyman, Neil Adger, & Thomas, 2008). Many times, strategies are local and customized; however, these tend to be reactive, while institutional approaches can be anticipatory, which may be necessary for something as serious as climate change (Smit, Burton, Klein, & Street, 1999). Studies have argued that poverty reduction and income diversification strategies should be geared towards smallholders in particular, and attempt to foster improved access to markets and financial tools, as the size of one's landholding is the main constraint in crop diversification (Bigsten & Tengstam, 2011; Osbahr et al., 2008).

Research has shown that rural populations – including farmers – depending on a single source of income earn a lower, more inconsistent income than those with a higher degree of diversification (Bigsten & Tengstam, 2011; Delgado & Siamwalla, 1997; Israr, Khan, Jan, & Ahmad, 2014). The degree to which farmers diversify is directly related to their assets and resources, including land and human capital, and access to markets and financial resources. Moreover, studies have shown that farmers experienced improved food security and increased income when following conservation agriculture practices, which mandate a variety of crops grown in succession or groups (Friedrich & Kienzle, n.d.; Jat, Sahrawat, & Kassam, 2013; REOSA, 2010). However, many still diversify their income through outside business or salaried work, which is particularly effective in terms of livelihood resiliency (Speranza, 2013).

Cooperatives have also been shown to provide significant assistance in helping members maximize income streams by supporting diversification amongst smallholder farmers. During Brazil's financial crisis in the 1980s, coffee cooperatives pushed product diversification strategies (Martins & Lucato, 2014). Smallholders can also have difficulty producing enough volume to enter market and be competitive higher up in the value chain, as has been shown in Mozambique, which is where cooperatives can sometimes play a role to help pool volume of a secondary crop for market (Osbahr et al., 2008).

Think tanks and nonprofits have identified several opportunities for income diversification in Latin America, particularly considering crop diversification. For example, the International Center for Tropical Agriculture (CIAT) identified ten crops for use as alternative income sources, based on crops that farmers are currently growing in the region, including avocados, banana, cacao, corn, tomatoes, oranges, and peas, among others (Läderach, 2012). Others, including Catholic Relief Services, have identified spices as a crop with low risk and high profit for smallholders; moreover, spices are relatively small and insensitive to storage conditions, making them easy to transport to market (CRS, 2014). Bananas, maize, beans, and macadamia nuts are among the crops researched and used for intercropping with coffee (Famaye, 2009; Jassogne, Laderach, & Van Asten, 2013).

As discussed previously, diversification can come in many forms, including cultivating multiple crops, producing value-added products, or working outside of the farm. The primary form of diversification discussed by interviewees was that of crop diversification.

Producer Experience

As income diversification was not selected amongst the top three strategies for further research in Peru, our understanding of previous experience is dictated by interviews from Guatemala.

- **Guatemala**

Interviews in Guatemala mentioned numerous crops and products that have been used in diversification (see Appendix H). Several noteworthy examples and topics are worth discussing in greater detail:

- Avocados were the most widely discussed crop in terms of diversification activities, both in terms of personal experience and in reference to projects interviewees had observed elsewhere in-country. Like coffee, avocados require about four years after planting to bear fruit; moreover, some producers require assistance to collect avocados from the trees, in some cases needing to contract out and pay someone to harvest. In terms of inputs for growth, avocados do not require much individualized attention and are a well-suited complement in the field for coffee plants, providing shade and bearing fruit, but not taking up much room so as to maintain area for coffee production. Unfortunately, despite many stories of successful cultivation, the vast majority were accompanied by insurmountable challenges with markets. In terms of local market, avocado is one of the main crops being grown in the area, so during harvesting the local market is inundated and prices drop extremely low. In terms of a national or export market, the avocados require specialized shipping containers, which the producers did not have, in order to get to market without suffering damage.

- Both CODECH and some of their sub-associations have implemented projects to grow crops in addition to coffee in the past. With the exception of ADAT, which was established for both vegetables and coffee, all other projects have ultimately been unsuccessful. In each case, interviewees identified the termination of project funds – and, in turn, project assistance – as the reason for failure. Technical assistance was provided for sowing the crops, but did not continue long enough for producers to continue through cultivation and harvest, as they did not know how to prune, spray, fertilize, et cetera. A cooperative's coffee technician cannot double as a technician for additional crops; moreover, while coffee technicians are plentiful in the region, technicians specializing in other crops are much more difficult to find.

- The traditional corn-based *milpa* system in the area balanced crop rotation and diversification with multiple varieties of corn, beans, and squash, many times with fruit-bearing trees such as avocado. Several interviews identified an erosion of knowledge in terms of growing a diversity of crops, due to either the perception that monoculture is easier to manage and cultivate or the fact that many Guatemalans fled the area during their civil war, causing them to lose much of their historical knowledge of cultivation in the area as opposed to passing on traditional agricultural practices to the next generation. Another reason suggested as to why farmers had switched to growing monoculture coffee is that the organizational capacity brought by the establishment of Anacafé gave people a sense of security in growing coffee.

- CODECH is currently in the first year of a pilot project raising bees and producing honey; CODECH supported a handful of producers with credit to assist with initial costs. At the time of this report, the successfulness of the project is yet to be determined; however, the project was on track for success. The main issue with bees is that generally neighbors don't appreciate the increased risk of being stung, so it is better suited for producers who are on larger and/or more isolated plots. However, there were also instances of theft, so it is necessary to have the hive at least relatively close to the producer for security.

- A focus group with one of CODECH's sub-associations described a prior project they knew of, but had not participated in, growing and canning peaches. This was the only example of previous experience in processing; unfortunately, no one in the focus group or subsequent interviews was able to identify why the project ultimately failed.

Overall, the top reasons identified as contributing to the failure of crop diversification projects were: insufficient quantity, inadequate quality, lack of continued technical support, and misdirection in selection of a secondary crop with which to diversify. Interestingly, several producers also noted that changes in climate and weather patterns have impacted the viability of many secondary crops. For example, many areas which once grew potatoes now find the weather cannot support the production of sellable potatoes.

- **Peru**

Based on interviews with cooperative leaders, income diversification is not of particular interest or priority to smallholder producers in the Peruvian cooperative CenfroCafé. The few interviews providing details on diversification in Peru mentioned chickens, pigs, guinea pigs, pineapple, and passion fruit as secondary sources of income they had seen farmers cultivate or raise in addition to their coffee.

Capital Assessment

As income diversification was not among the top three strategies selected in Peru, our capital assessment is based almost exclusively on interviews and focus groups from Guatemala.

- **Financial**: The top financial asset perceived as necessary to implement diversification strategies was that of access to markets, which also requires social capital; farmers described a major disconnect between producers and markets, particularly when considering markets for export. Almost as frequently mentioned was the need for financial support for a technician – to assist in everything from training and sowing to harvesting and processing – in order to successfully produce an additional crop.

  Financing to purchase seeds in addition to any crop-specific fertilizers or pesticides was also mentioned, though to a lesser degree. One producer also identified the need for financing to pay for a truck, gasoline, and a driver to transport additional crops to market.

- **Human**: Many interviewees identified a significant lack of human capital in terms of producers knowing how to grow additional crops. This was frequently coupled with producers voicing need for a technician to improve capacity within the cooperative to produce additional crops. Continued, consistent technical support is necessary for any agricultural project, and this is no exception. One key actor stated that, "*la debilidad más grande es mantener la calidad y el volumen, pero eso depende mucho de la*

asistencia técnica constante" ("the main weakness is to maintain quality and volume, by this depends heavily upon ongoing technical assistance") (Personal communication, June 2015).

One key actor at an international financial institution indicated that while this area was once flush with diversified *milpa* systems,

> *…el tema es que ha habido un proceso, erosión del conocimiento, un problema de inculturación tan fuerte, y un problema de política, dado que han abandonado el área rural como medida para promover la migración hacia las ciudades*. ("…the issue is that there has been a process, erosion of knowledge, a problem of enculturation so strong, and a problem of politics, as they have abandoned the rural areas as a means to promote migration to the cities.") (Personal communication, July 2015).

According to this interviewee, not only are farmers so disconnected from their ancestors that they have lost the knowledge of how to cultivate crops, but political and social forces are encouraging them to abandon this lifestyle anyway.

An additional noteworthy need for human capital identified by one focus group is that with coffee, the beans are taken directly to the cooperative warehouse. However, with many other crops, family time and labor is required to bring crops to market and spend an afternoon or a day selling at the local market. One Peruvian interviewee also identified a need for someone to manage a demonstration plot for crop diversification projects.

- **Natural**: Mentions of natural capital were sparse in comparison to the other capitals in this strategy. The need for enough land and water to grow and process both coffee and an additional crop was identified by three respondents. While not mentioned, sufficient soil composition would also be necessary.

- **Physical**: Means of transport to market was identified as the top need in terms of physical assets, including adequate roads and refrigerated trucks. Many of these communities are only accessible by steep, narrow dirt roads, which can be unsafe to travel at times due to weather conditions. Such barriers can make it nearly impossible to get certain products to market on a regular basis and in good condition.

  Seeds, fertilizers, pesticides, and other inputs would be needed to begin cultivation of a second crop. However, some crops are more compatible with coffee in terms of inputs required, so additional physical materials needed may vary. While coffee is particularly hardy and easy to store, many other agricultural products are not, and would require refrigeration or other storage conditions. In terms of value-added products, a processing plant with proper equipment and packaging materials would also be necessary.

- **Social**: A major lack of social capital was identified by many interviewees, equally weighted with access to markets and collective action to achieve volume. As discussed above, access to markets is a major barrier; many producers see a lack of access to both local markets and markets for export. While many factors are required to facilitate access to market, a significant factor is having the ability to forge and maintain social and professional relationships with other stakeholders throughout the value chain. There also seemed to be a consensus that group collection would be necessary to achieve sufficient volume for export; however, there remains some fear of sharing and joining efforts amongst cooperative members.

  Several key actor interviews also discussed the issue of many producers being resistant to change and unwilling to try new crops. Therefore, a cultural and behavioral shift would be required so that producers are interesting in and willing to try new crops and products.

Feasibility

There are many upfront investments associated with diversifying, including a deep understanding of a new crop and where it fits in the market. The main issues impeding feasibility, broadly identified across stakeholders, seem to be: quantity, "organization, quality, [and] regular schedule of delivery" (Personal communication, July 2015).

- **Costs & Benefits**

One of the main factors for a farmer to take into account when considering crop diversification is the necessary changes between the current versus proposed land and resource allocations for shifting the proportion of their farm away from being 100% coffee. Many smallholders in Guatemala are operating on less than a hectare of land with finite water supplies and limited resources for inputs such as fertilizers and pesticides. While crops such as avocados are well-suited to grow amongst coffee – producers stated they needed no extra space to intercrop coffee and avocado trees – many others would require replacing coffee with the second crop. In this case, it will be important for not only the producers, but any external support organizations, to consider the labor, inputs, and space requirements for each crop, in addition to when they are harvested, to ensure compatibility.

Two of the main reasons producers join cooperatives are for access to market and continued technical assistance. When it comes to additional crops – for example, avocado – the lack of organized production and long-term technical training are the primary barriers. It may benefit members of cooperatives to have support for a second crop in addition to coffee; however, this would come at the cost of hiring an additional technician, who would need to ensure sufficient quality and quantity. It is unclear whether the profits from a second crop would make up for the salary of a non-coffee technician. Also, while local markets are definitely under consideration, for crops like avocados, which sell for too low a price in the local market, export markets would need to be considered, and there are also regulations in terms of quality when crops are being sold for export, which would need to be taken into consideration.

Many crops, including coffee, require several years of growth before bearing fruit. As things are, CODECH's technician already has significant difficulty convincing members to replace their old coffee plants due to the fact that they won't bear fruit for several years. Taking this into consideration, the cost of having plants that don't bring in income for several years may be a cost that some producers are unwilling, or unable, to bear.

Income diversification in terms of crop diversification can have a significant positive impact on nutrition if families are able to grow a more diverse range of crops to meet a variety of dietary needs. Maize, beans, and chickens would fit this need, in addition to medicinal herbs. This was referenced by two key actors, including one who mentioned it in regards to prenatal maternal health.

- **Information Required for Decision-making**

While there are many factors to consider before implementation of any project, the following are of particular importance for income diversification projects:

- To begin, it is crucial to evaluate whether there are enough individuals with sufficient interest in implementing a project with a secondary crop. One of the biggest barriers is achieving volume, and if only a few members are willing to sow a new crop, this will not achieve sufficient volume to enter the market.

- In the same way coffee is not best suited for cultivation across the entirety of Guatemala, many other crops require certain conditions to prosper. Before implementing any diversification projects, it is absolutely necessary to have pilot projects trying different crops to determine their suitability to the region. This will become particularly important as the climate and weather patterns continue to change, and may require research into the most resilient crops for the area and anticipated future conditions. At the same time, one must identify potential markets and assess the marketability of potential crops which are well-suited for the area.

- Many smallholder farmers rely exclusively on family labor for growing, processing, and selling their crops. It is important to take into account the implications of additional labor when planting additional crops, and consider whether the family has the capacity to cultivate and take to market a new crop without impacting the attention they are able to give their coffee.

- Before implementing projects, it is crucial to assess whether or not the producer has sufficient land and water to grow, capacity to tend to, and financials to purchase inputs for a second crop.

- One must also assess the physical infrastructure of the area to determine whether or not it is feasible to transport crops to the market. Some roads are inaccessible during portions of the year, so if that aligns with when a particular crop is harvested, it should not be sown in the region. Moreover, some products require refrigerated trucks or specialized shipping containers, so the producers should assess whether they are able to meet the conditions necessary to transport the crop in a timely manner without damaging it.

- The last point involves considering the organizational and financial capacity of the cooperatives. As sustained technical assistance and logistical support will be necessary for any successful diversification scheme, the cooperative must assess not just on a seasonal basis, but on a multi-year basis whether or not they have access to the financial resources necessary to continue technical assistance and logistics management.

Context

- **Varying Perception & Potential**

There is a clear divide in terms of perception of both the current situation and future feasibility between cooperatives and key actors. Perhaps of most significance, cooperative members and

leaders only discussed diversification in terms of agricultural crops, while key actors also discussed raising livestock. This is potentially due to the fact that while all cooperative leaders and members were in Jacaltenango, where plots are steep and small, livestock is less practical than in other parts of Guatemala where key actors may have experience implementing other projects. One key actor also suggested that many smallholder farmers migrate several months of the year to the coast or to Mexico, though none of the farmers interviewed said they migrate for work. It is possible that farmers in other regions are implementing such diversification strategies, however, this was unsubstantiated in our research.

Interestingly, while several cooperative leaders and members mentioned an erosion of knowledge in terms of agricultural skills, one key actor was the only interviewee to discuss the former *milpa* system when asked about previous experience. It's unclear whether this is due to the fact that current cooperative members themselves have not implemented a *milpa* system, so did not find it worth mentioning, or whether they are unsure of what such a system entails.

It is worth noting that only key actors discussed the need for improved quality in addition to quantity when it comes to crops, while cooperative members and leaders only viewed the problem as a lack of quantity. Key actors are also the only interviewees to perceive that there is a great demand for fruits and vegetables in Guatemala, but insufficient supply.

- **Access**

As previously mentioned, some key actors suggested diversifying with livestock, which the majority of cooperative members deemed fairly infeasible – other than small livestock like chickens – due to their small plots of land. Another major issue is that with people living in a wide geographic region, the majority of which is rural and lightly populated with difficult roads, participation in crop diversification and access to market can vary widely across members.

In general, while all interviewees stressed the need for increased, consistent, continued training, some key actors perceived greater access to state resources, for example, than did the farmers actually receive or have access to.

Recommendations

Projects in crop and income diversification are assessed as medium-high feasibility for CODECH based on our research. Despite significant up-front costs, this strategy would provide significant improvements in resiliency if implemented in an effective, organized manner with a crop and/or method of processing that has proven successful in the region. Many capitals would require attention for successful implementation, including:

- **Financial**: In terms of financing crop diversification projects, considerations are similar to those for the coffee nurseries that CODECH has been implementing: seeds, dirt, space, fertilizer, et cetera. Such inputs, including someone working to germinate seedlings, may be required for some of the potential crops for diversification, including avocado and peach trees. For some crops, even less is required, as farmers are able to directly sow the seeds in their plots and expect germination. Such projects could be farmer-financed; CODECH and/or the sub-associations would ideally provide small loans for members who need them, and purchase materials in bulk for lower prices. Loans would also be necessary to supplement incomes of diversifying farmers in the first several years before their secondary crop began bearing fruit. However, if products are selected which require processing facilities and/or transportation in refrigerated or otherwise special vehicles, these are significant upfront costs which individuals, and many times, even cooperatives, cannot afford.

  In every scenario, cooperatives will need to be involved. In most scenarios, outside support from international aid agencies or domestic agrarian organizations will be necessary for implementation.

- **Human**: As indicated in the Results section, there are major improvements are needed to have any chance of success implementing a diversification project. One key actor stated that while,

  > *sí, creo que este tema tiene potencial importante, pero como digo, hay que hacer un trabajo que encontrar actores locales que tengan la*

> *capacidad de masificar ese tipo de conocimientos, o sea recuperarlo de nuevo* ("yes, I do believe this issue has significant potential, as I said, it would take work to find local actors who have the ability to collect this type of knowledge, or to recover it again") (Personal communication, July 2015).

This type of major investment in and improvement of human capital is not feasible for individual producers to undertake themselves, despite the fact that diversification must take place within an individual producer's plot. Such organization, management, and distribution of knowledge must come from CODECH or one of their sub-associations.

It seems unlikely any of the current stakeholders possesses, or could easily obtain, the capacity necessary to undertake such a project. Therefore, it will be necessary to partner with other cooperatives, international aid agencies, domestic government agencies or NGOs, and/or private buyers or exporters.

- **Social/Financial**: Navigating markets, both local and for export, is challenging in any situation, though only more difficult when many producers and cooperatives have incomplete and/or inaccurate information. Market analysis by cooperatives, ideally in partnership with co-implementers or funders, is necessary in order to successfully make market connections.

- **Physical**: In addition to the physical inputs listed above under Financial requirements, access to market in the literal sense can also be a major challenge for remote communities in difficult terrain. Many examples of being unable to transport crops to market without damaging them or being unable to transport them at all have left producers disillusioned. It is absolutely necessary that cooperatives consider the equipment necessary to transport products.

  It seems that most of these difficulties could be addressed if producers pooled resources. For example, coffee cooperatives pool their coffee beans at *bodegas*, or

> warehouses, in order to sell the products and ship them for export. While such a system may not be feasible, collective actions like sharing a stall at market or splitting the cost of hiring a truck to transport produce could serve fruitful for producers.

Holistically, the types of capital most lacking roughly match those services provided by cooperatives: access to credit, training, and connection to markets. Across interviews, it seems that due to the severity of agricultural knowledge erosion, intense technical assistance is required. One key actor stated that projects always need to be:

> …heavy on technical assistance and extension in those first years, especially if families are starting a new crop. It's going to be a big investment […], you're really going to want to do kind of participatory research with the farmers so that they can try out various things […], but that definitely requires some technical assistance. I mean, there's not any way to get around that, it's just a must (Personal communication, July 2015).

As such, there are three recommended potential routes forward which seem at least moderately feasible:

1. Partner with a cooperative that focuses on crops other than coffee: in this case, CODECH and/or their sub-associations would tap into the existing structure and network of a cooperative focusing on an additional product, such as avocado or honey. In exchange, CODECH could offer a small payment, participating CODECH members could be required to make a small payment, or CODECH could offer support with exporting coffee. In this instance, the partnering cooperative would be almost exclusively responsible for organization and logistics of export, not technical support.
2. Share a technician with another cooperative: in this case, CODECH and/or their sub-associations could partner with another cooperative to share a technician for a second crop. In this instance, one of the cooperatives involved would need to navigate access to market. CODECH and/or their sub-association would pay for the technician, or participating CODECH members could be required to make a small payment.
3. Provide support for another crop through CODECH: in this case, CODECH would begin to look a bit more like ADAT, one of its sub-associations, which works on both coffee

and vegetables. CODECH would need to navigate markets and provide full support for a technician in this instance.

In any of these scenarios, but particularly the second and third, pilot projects are absolutely necessary to determine which crops to grow. This was discussed by cooperative members and leaders, and key actor interviews. They may also want to consider returning to more traditional crops, such as maize and beans, which were originally included in the *milpa* system and still represent a strong cultural connection for Guatemalans.

One key actor in particular summed up some of the main issues with access to market, ending by stating that "…you need to find a buyer that is willing to come to the table and negotiate with you a plan, but then the farmers need to do their end of the bargain as well" (Personal communication, July 2015). Both CODECH and CenfroCafé have successfully navigated the business of exporting specialty coffee; however, they need to keep in mind that it takes significant time and effort in terms of producing crops and navigating markets to successfully produce and sell any product, never mind a secondary product in addition to coffee. Moreover, not all crops are well suited for collective and/or rural production and export.

Please see Appendix I for a decision tree to help assess the feasibility of implementing crop diversification within a particular cooperative.

SOLAR DRYERS

Coffee drying is an essential step during post-harvest to ensure quality and obtain a good price. The coffee cherries must be dried from their original state containing a humidity level of 50-70% down to a maximum of 12% to be considered high quality coffee (Martinez Sosa & Aguilar, 2011, p. 1). With unpredictable rains and cloudy conditions during the coffee drying period, the grain can get wet and moldy (Martinez Sosa & Aguilar, 2011). In order to increase producer resiliency to such climate conditions, solar dryers have been introduced.

Figure 9: A *Berrueta Soriano* Solar Dryer

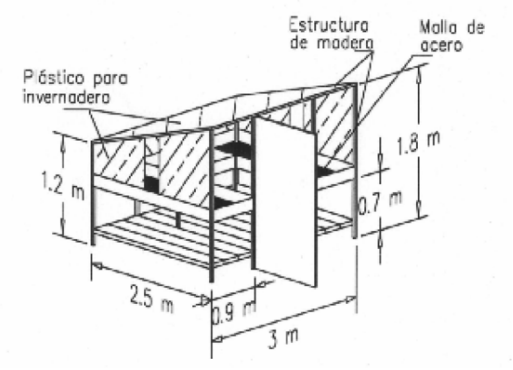

Figure 9: Diagram of a Solar Dryer

The traditional method of drying coffee is to spread the coffee beans over cement plots or plastic squares in the open air. The coffee beans are rotated and moved periodically to ensure even exposure to sun during daylight hours for as little as three days up to one week or more (Martinez Sosa & Aguilar, 2011; The Sexto Sol Center, 2004; Weiss & Buchinger, 2004). The length of the coffee drying process with this method is highly variable, depending on the availability of sunlight and associated winds. Furthermore, coffee farmers have to continually protect the coffee beans from dust and small animals, as well as collect all grains at dusk to avoid the risk of rain and dew overnight. This method for drying is highly labor-intensive, time-consuming, and unpredictable.

One technological adaption to address this problem is a solar dryer: a greenhouse-inspired wooden structure covered by transparent plastic (see Figure 9 & Figure 9). The solar dryer in Figure 9 is known as *Berrueta Soriano*, named after its designer Victor Berrueta Soriano, who conducted a project developing effective and practical solar dryer designs in the rainforest communities of Chiapas, Mexico (Martinez Sosa & Aguilar, 2011). It is also called as *Secador Parabólico*, or Parabolic Dryer (Oliveros-Tascon, Ramirez-Gomez, Sanz-Uribe, & Penuela-Martinez, 2008). The solar dryers perform best when located in an adequate open space with direct exposure to the sun, and oriented towards the south to follow the sun's trajectory (Martinez Sosa & Aguilar, n.d.). Windows and a door are included in the designs to best capitalize upon the solar heat and increase air circulation during the daytime. Within the structure, a raised bed is constructed at a height of 70 cm (or 2.3 ft) above ground to ease coffee bean selection process, maximize air circulation, and obtain a more hygienic coffee drying

practice (Martinez Sosa & Aguilar, n.d.). According to previous research studies, coffee producers could benefit from solar dryers in terms of less physical work, more hygienic process and shorter drying time (Hii, Jangam, Ong, & Mujumdar, 2012; Martinez Sosa & Aguilar, 2011; Oliveros-Tascon, Ramirez-Gomez, Sanz-Uribe, & Penuela-Martinez, 2006; Weiss & Buchinger, 2004).

Another model of solar dryer has been implemented specifically in Peru. Instead of covering the wooden or iron structure by transparent plastic as in the *Berrueta Soriano* model, the *Calamina Transparente* model uses corrugated transparent fiberglass sheets on the top of the structure (see Figure 10). With a designated space for coffee drying, producers would eliminate the work of daily collection at dusk. With the covered structure and raised beds, over 40% of drying time is saved; and the process, which is more hygienic, reduces risk to coffee quality (Oliveros-Tascon et al., 2006). Interestingly, producers in Mexico have been using solar dryers in their daily lives in many diverse ways including clothes drying, crop storage, nesting place for farm raised animals, and lodging for guests (Berrueta Soriano & Limon Aguirre, 2005).

Figure 10: A *Calamina Transparente* Solar Dryer

However, there are drawbacks which need to be considered for this method. Two key factors require attention to ensure the effectiveness of solar dryer design: air circulation and internal temperature control (Martinez Sosa & Aguilar, n.d.). In regions with high humidity, lack of air circulation within solar dryers may negatively effect the coffee quality, since the cup quality may be at risk if the solar dryer's internal temperatures rise above 40°C ("Coffee and Climate: Coffee Drying," 2015). Furthermore, the costs of solar dryers may become another burden to smallholder coffee producers, who are generally with limited financial resources. The costs of construction and maintenance of the solar dryers may raise production costs by increasing per unit area of coffee drying. Thus, for this adaptation strategy, the cooperatives should help

evaluate the feasibility of implementing solar dryers for their members; provide technical training and support in the design, construction, and maintenance; and fund the materials for solar driers for at least every base cooperative, so that farmers could share a communal space for drying coffee in case of poor weather conditions (Fox et al., 2015, p. 100).

Implementing solar dryer projects was selected as one of the most appealing strategies in both countries. Respondents ranging from smallholder coffee producers to key actors were all interested in implementing solar dryers to assist in the drying process, ensuring the quality and price of coffee beans for the producers. With unevenly distributed external effort across regions from international NGOs (e.g. Fair Trade International, USAID, and Root Capital), many interviewees still doubt the viability of implementing solar dryers. The following analysis is based on the interviews conducted during in-country research trips to both Guatemala and Peru.

Producer Experience

According to the respondents, smallholder coffee producers in both countries had previous experience with solar dryers, and reported that the quality of coffee was improved when drying with solar dryers. Both cooperatives have received support from NGOs at the national level and international level and have conducted a variety of pilot projects via donations to construct solar dryers at the level of individual producers. However, the common problem is that the projects were relatively small in scale and unevenly geographically distributed, causing resource mismatches and knowledge gaps among the communities.

- **Guatemala**

In Guatemala, the solar dryer donation projects were organized in *los Huistas*, a region including the municipalities of *Concepción Huista*, *San Antonio Huista*, and *San Andrés Huista*). Through an international development grant from Fair Trade International, three solar dryer pilot projects, each with one producer, have been implemented at varying elevations in differing sub-associations.

Producers generally have doubts on effectiveness, capacity, and durability of solar dryers; all three of CODECH's greenhouse-inspired solar dryers will study its effects on coffee quality. The greenhouse pilot in Huehuetenango with the plastic *Berrueta Soriano* design is the only solar dryer model implemented in the CODECH cooperative in Guatemala. Each solar dryer in the cooperative has a capacity of four *quintales* (quintals)[1] due to the limitation of open space, which is less than what producers generally produce in one harvesting season. Thus, producers often prefer to take their beans to an open field with conventional drying practices, which allows them to dry all their harvested coffee beans at the same time. According to one co-op leader, the lifetime of a solar dryer is usually three to four years. However, producers mentioned that without proper maintenance, their solar dryers are already failing after one season.

- **Peru**

In Peru, producers have better access to financing, as CenfroCafé already has an internal credit system supporting solar dryers, in addition to loan programs established by local financial institutions. As mentioned previously, such projects have distributional issues; one focus group from a lower elevation community reported that they all own solar dryers on their parcels, while another focus group stated they were in need of assistance to construct solar dryers. The durability of plastic model was also questioned by producers. However, the more general debate in Peru was between the two models of solar dryers, the plastic model and the transparent fiberglass model. Sufficient information on the effectiveness of both models is not clearly explained to producers such that they are able to make decisions on models.

Capital Assessment

Solar dryers require a high initial investment and regular maintenance to ensure proper function throughout their lifetime. Thus, the following section discusses the capitals required for successfully implementing solar dryers in each country.

[1] Quintal: a unit of weight equals to 1000 kg or 220 lb, as defined by Merriam-Webster's Dictionary.

- **Guatemala**

In Guatemala, many respondents mentioned that natural and financial capitals are the primary barriers in implementing solar dryers on their parcels.

- **Financial:** The cost of each solar dryer, including materials, transportation, and construction, ranges from GTQ5,000 - 20,000 or approximately US$650 - $2,500[2], as reported by the respondents. The types of materials and distance to purchase them varied greatly by respondents. Costs are usually shared among three parties: producers, organizations, and donors. However, the high up-front investment leads to hesitations among many producers. One cooperative leader expressed the concern by saying, *"yo pienso que tal vez no todos van a tener esa capacidad de invertir y tener esos proyectos"* ("I believe that not all (producers) have the ability to invest and have these projects implemented") (Personal Communication, June 2015).

  As solar dryers are only utilized during the harvest season, the value of such investment was criticized by CODECH member respondents. Interviewees did not specify the degree of difficulty to access funding opportunities from other organizations.

- **Human:** Respondents indicated the need for more technological training including construction, operation, monitoring, and maintenance of solar dryers. Many of the solar dryers installed in the CODECH cooperative in Guatemala were donated via projects by national and international NGOs. Producers did not have access to proper training on how to operate solar dryers and did not treat solar dryers as their own investment. As one interviewee mentioned that, "*Que hubiera un encargado del secado de café sería excelente también, que pudiera amaestrar cómo se usa más que todo*." ("It would be great if there was someone in charge of drying coffee [with solar

[2] Based on exchange rate of USD $1 = GTQ 7.75 as of March 2016.

dryers], then I could get trained to use it [solar dryer].") (Personal communication, June 2015).

Follow-up training and monitoring for donated solar dryers would be beneficial for maintaining their durability. Thus, additional technical personnel are also required.

- **Natural:** Natural capital is the most mentioned barrier in Guatemala. Their limited land and steep terrain does not provide enough flat space for all producers to build solar dryers. To solve the land issue, some respondents suggested providing common solar dryers for smallholders in the region where enough open space exists in the center of the field. However, some farmers disagreed with the idea of sharing the usage of solar dryers due to the small capacity. CODECH interviewees also indicated that during the harvest season, they either have to buy or rent land for members to dry coffee in a closed and covered space. One respondent said:

> *Sí se puede implementar uno grande o dos para grupos pequeños que puedan secar sus cafetales. Pero como organización se tiene que comprar un predio grande. Aquí no tenemos predio…tendríamos que comprar o alquilar* ("Yes, you can implement a large one or two for small groups to dry their coffee. However, as an organization, we have to buy a big piece of land, since we do not have one here…we would have to buy or rent.") (Personal communication, 2015).

Another natural capital discussed among respondents is elevation and the availability of sunshine. Producers located at the lower elevations have access to sufficient sunshine and temperature to dry their coffee beans without the necessity to seek another alternative. When implementing this strategy, the priority should be provided to the coffee farmers located at the higher elevation.

- **Physical:** Respondents indicated the lack of proper building materials for the solar dryers, specifically in regards to the plastic sheets used to cover the solar dryer frame. Eight out of twenty respondents said that the plastic they can purchase in their community is of inferior quality and therefore results in a large investment every year

to replace the plastic. They indicated a preference for a stronger and higher quality plastic, which would be much more durable and cost-effective despite a higher initial installation price.

- **Social:** Respondents mentioned the problem of the cooperation among the groups in terms of maintenance of solar dryers, particularly when considering collective projects.

- **Peru**

As in Guatemala, Peruvian respondents indicated the difficulty of obtaining the sufficient level of financial and human capital required for this strategy.

- **Financial:** As reported by cooperative leaders, the cost of each solar dryer in Peru, including materials, transportation, labor and construction, ranges from PEN6,000 to PEN12,000 or approximately US$1820 - $3,600[3] depending on the specific solar dryer model. One interviewee explained a brief cost breakdown of the *Calamina Transparente* model:

> *…3.000 soles esto son maderas. Calamina transparente es 1.500 – 1.700 soles. Humano de obra, 1.500 soles. Agregado de constitución… 1.500 soles, y fierro para columnas, 500 soles, y cementos, 500 soles* ("…PEN3,000 just for wooden materials. Corrugated transparent fiberglass sheets are PEN1,500 to PEN1,700. Labor PEN1,500. And irons for columns worth PEN500. Cement costs another PEN500.") (Personal Communication, June 2015).

Credit and loan programs are available for some communities in Peru. Credit programs are a method to finance farmers by pre-trading their share of coffee revenue in exchange for financial support in the current period, which means that producers would receive a lower payment for their coffee, as they've diverted part of their

[3] Based on exchange rate of USD $1 = PEN 3.37 as of March 2016.

revenue to invest now. Despite existing financing programs, the majority of respondents still mentioned the need for continuous support financing the construction and maintenance of the solar dryers, perhaps in the form of loans from CenfroCafé or as a grant program from a government-backed agency.

- **Human:** Interviewees in Peru mentioned that high levels of human capitals at all cooperative levels are necessary for successful implementation of solar dryers. At the top cooperative level, leaders would need training on project management. Specialized solar dryer designers or project coordinators would be necessary to manage selling and purchasing of solar dryer materials. At the mid network level, properly-trained laborers and construction engineers are needed to evaluate the optimal model of solar dryer for each parcel and to provide training to producers. At the base association level, respondents mentioned that the community "promoter" model could be effective for solar dryers. The *promotor* system in place in CenfroCafé is a formal system of select farmers (who have undergone training and have shown to be leader coffee farmers) who visit other farmers' parcels to conduct monitoring, pest management, and disease control, as well as providing other advice or information where available. As one cooperative leader described it:

  > *…creemos que lo otro podemos capacitar a unos diez promotores, para que ellos sean los que capaciten a los demás socios e implementarse de manera conjunta, siendo una cooperativa pues, mucho, se trabajen en cooperación* ("…we believe that one [engineer] can train ten promoters. Then, they can train the rest of the cooperative members and can work together, functioning as a co-operative, which involves working in cooperation") (Personal Communication, 2015).

- **Natural:** Although land and open space is not an issue for CenfroCafé members in Peru, respondents from lower altitudes ranging from 1,400 meters to 1,800 meters complained about insufficient sunshine and temperature during the daytime to dry their coffee. Thus, solar dryers in this area could be particularly beneficial to these producers.

The wood for the base structure of solar dryer is also necessary natural capital. Some producers suggested that they could utilize the local wood resources, such as bamboo from their field. However, the suitability of the local wood for construction was questioned by one respondent who said:

> *Porque madera buena para que vaya allá a la tierra, no la hay. Entonces, sería eso de buscarse alguna forma como que sea un poco más duradera porque lo haríamos de madera. Pero a los, que sé yo, máximo de unos 3, 4 años ya estaría cayéndose. Se malograría. Todo lo que es esto arriba, sí; eso no se malogra. Pero lo que entra a la tierra sí se malogra. No hay madera de esa buena; antiguamente ha habido acá, pero ya no hay. Entonces eso sería desde abajo columna de fierro con cemento o fierro solo. Pero lo que es arriba sí se consigue.* ("The wood is good, but if you bury it in the ground to stabilize the structure, it would rot…within 3, 4 years it would be falling apart. The wood we have here does not work as a foundation, since it would rot. Wood above ground as columns, that is okay. But you need cement to have the base or cement and iron base, then have wood on top of that. We can get the wood for the above-ground part of the structure) (Personal Communication, June, 2015).

However, besides the materials, smallholders also have problems transporting the cement and other materials to the construction sites. The only transportation tools mentioned by several respondents were donkeys.

- **Physical:** Local government agencies have the tools to construct the solar dryers and materials available for smallholder coffee producers. However, the many physical materials mentioned as requirements in Guatemala are also needed for construction in Peru.

- **Social:** The issue of property rights was mentioned in some regions. Some producers do not own their agricultural plot but are renting the land, so may not legally build on the land. Interviewees did not provide a viable solution to this issue.

  Respondents in Peru also requested a scientific confirmation of the benefits from different designs of solar dryers as compared to the conventional practice of coffee

drying, and other alternatives. This lack of information could potentially be addressed through the "promoter" program at the base cooperative level. At the top cooperative level, alliances among institutions and other cooperatives was suggested by cooperative leaders and in-country key actors to stimulate distribution of local and regional information and technical support to coffee producers.

Feasibility

With the capital framework discussion above, the feasibility of solar dryers in either country can be further analyzed through costs and benefits of solar dryers.

- **Costs & Benefits**

Benefits are similar in both countries in terms of higher quality of coffee beans, reduction of labor required, more hygienic process, and faster drying times. With a designated covered space for coffee drying, producers eliminate the work of collection at dusk when drying coffee to avoid overnight humidity or dew. With the covered structure and raised sheets, drying time is shortened from 5-8 days to 3-4 days. However, there is no specific number indicated in the interviews on how much the price is improved from drying with solar dryers.

In addition to the initial investment of purchasing supplies to construct solar dryers, other costs include transportation, labor, and maintenance costs. As mentioned above, the initial investment needed varies by the design and size of solar dryers. The distance from a producer's parcel to supply centers is, on average, one to three hours of driving. However, most of the producers do not have access to a vehicle. They would have to walk to the source location to obtain the materials with multiple visits. In terms of maintenance costs, proper and regular care including cleaning the surface of plastic periodically, re-stabilizing the framing structure and other practices would guarantee longer duration for solar dryer investments. The quality of initial material determines the needed frequency of renovation and maintenance. It is also important to consider the opportunity costs of land used for solar dryers. This could be a particular problem in

Guatemala, since producers may have to buy or rent land for constructing solar dryers, which are only used for less than a month per year to dry coffee.

- **Information Required for Decision-making**

Additional information may be required before considering the implementation of solar dryers. In both countries, inadequate information and studies on the costs, benefits and construction and maintenance needs of the various models of solar dryers may discourage farmers' implementing them. In Guatemala, the CODECH team is working on obtaining more of such information through their pilot projects. Many cooperative leaders expressed positivity towards the outcomes of these pilot labs. In Peru, several cooperative leaders and key actors mentioned the success stories of solar dryers in Colombia and other coffee producing countries. They have organized a research team to do on-site studies and observation abroad, which was initially for other agricultural practice purposes, but they could include solar dryers into the observation agenda (Personal communication, June & July 2015). Furthermore, key actors from both national and international NGOs expressed interest in learning more about the effectiveness of different solar dryer models, and working to acquire more studies from their other regional and global offices to share with local cooperatives (Personal communication, July 2015).

Additionally, a pre-implementation needs assessment for each parcel would be ideal prior to installing solar dryers. In Guatemala, it must be determined if producers have sufficient space and flat terrain to evaluate whether a solar dryer is a viable option for each interested member. Since financial support is as critical to the implementation of solar dryers, CODECH could potentially explore and develop credit programs with support from local financial institutions and international organizations such as Fair Trade International and USAID. However, financial conditions of each credit applicants would need to be considered before issuing loans. Information on whether increased producers' incomes from solar dryers would be enough to pay back the loan and interests is also required to test the feasibility of such credit programs. In Peru, both the available natural capital and financial capital of the smallholder coffee producers need to be considered when deciding whether to build solar dryers on their farms or which solar dryer design is suitable for each parcel. Regarding the natural capital, as mentioned previously, certain

models of solar dryers may become ineffective under certain microclimate conditions. Thus, a thorough understanding of local climate condition is essential prior to implementation. With respect to financial conditions, a respondent indicated difficulty in determining the financial readiness of cooperative members by saying,

> *Algunos productores piensan que tu le vas a dar dinero en efectivo no que les vas a dar en bienes y servicios; entonces cuando ellos se enteran de que tienen que dar una contrapartida de un 20% o de un 30% como que se alejan*. ("Some producers think that you [the cooperative] will give cash instead of services; then when they find out they have to give a partial investment ranging from 20% or 30% of up-front costs, they move away from getting solar dryers") (Personal Communication, July 2015).

Finally, before proceeding to implementation, cooperatives need to ensure the availability of proper training and follow-up assistance for members. With the limited number of technicians in both cooperatives, sufficient follow-up training to every member is not viable. However, many cooperative leaders and members mentioned that there are a number of workshops available organized by either international NGOs (*e.g.*, Rainforest Alliance) or national organizations (*e.g.*, AGROIDEAS) for the staff of cooperatives. Perhaps cooperative leaders could use such opportunities to initiate a workshop specifically for solar dryers, combined with "promotor" programs to train these promoters (or producer leaders) to spread proper training, knowledge and follow-up skills.

Another major issue that exists in both countries is the lack of transparency among the organizations at multiple levels. As mentioned in previous sections, the projects are unevenly distributed across the regions. The knowledge of current practices only spread to the regions with pilot projects. Thus, the lack of collaboration causes the development gap among the communities.

Context

- **Varying Perception & Potential**

With the unpredictable precipitation and temperature change, stakeholders in both countries indicate great interests in implementing solar dryers to improve and expedite the drying processes. Suggested by multiple interviewees, the outcome of such strategy would benefit all members of the smallholder families and cooperatives from the improved and ensured coffee quality. However, because of high costs and lack of land and training, there is a significant variation in terms of readiness and preparedness for solar dryers among producers in the two countries.

- **Guatemala**: Due to the lack of experience with solar dryers in CODECH, respondents from different levels do not exhibit much variation in their perceptions towards solar dryers. Based on the focus group interviews, producers are generally excited about the idea of drying coffee with solar dryers. However, they are aware that lack of land and financing could be obstacles. Furthermore, some of interviewees are skeptical about the effectiveness and marginal value of solar dryers. Cooperative leaders have been making efforts to address such uncertainty through existing pilot projects.

- **Peru**: As mentioned above in the capital assessment, the cooperative in Peru has relatively more experience with solar dryers than the cooperative in Guatemala through pilot projects. However, there is still significant variation in perceptions of the need for solar dryers amongst the various geographic elevations and effectiveness across various models. The climate conditions at various geographic locations may have direct impacts on performances of different models. With high humidity levels at some locations, the air circulation within the *Berrueta Soriano* model may not be sufficient to dry coffee beans in the required time. With the lack of sunlight availability or low temperature in some locations at high elevation, neither the *Berrueta Soriano* nor *Calamina Transparente* model could generate high enough heat to dry coffee beans. Instead, some farmers may still have to carry their coffee beans to lower elevation, laying them out to dry. Other farmers with higher income level might instead invest in mechanical dryers, which are fueled by electricity or burning coal to dry coffee beans mechanically. Although such models are not widely used

amongst the producers – as one respondent in focus groups indicated, costs of mechanic dryer are much higher than the two models – it is also a great alternative to other models. Further financial capital would be required for it to be implemented, or to replace the current models.

- **Access**

The majority of producers in both countries only have access to the models to which cooperatives introduce them, and domestic and international donors determine where the projects will be implemented. There is a lack of national-level governmental involvement in the promotion of solar dryers in both countries. Although Guatemala has Anacafé and other federal programs to oversee the coffee sector, there is no evidence of their support or engagement in implementing solar dryer projects from the interviews conducted for this project. Furthermore, local-level associations or international philanthropic organizations may over-emphasize the outcomes of a few successfully-implemented solar dryers as opposed to addressing capital shortages on a larger scale.

This lack of access to solar dryers and support for their implementation is also an issue in Peru. The only national level coffee organization, the *Junta Nacional de Café,* is an NGO that does not have strong political power within the country. Thus, lack of collaboration amongst implementing government agencies and NGOs limits the development of better access to financial support and more comprehensive training and technical assistance to either cooperative leaders or smallholder producers.

Recommendations

Implementing solar dryers was preferred by stakeholders in both countries. Although solar dryers can serve as a constructive instrument for smallholder coffee producers to improve their resiliency to current precipitation changes, the feasibility of implementation in both countries are varied by capitals assessed in the previous sections.

- **Guatemala**

The feasibility of adopting the strategy of solar dryers in Guatemala is relatively low compared to the other two adaptation strategies researched. In order to proceed to implementation, three major capital limitations would need stakeholder attention.

- **Natural capital**, as mentioned above, is the main obstacle for Guatemalan smallholders. Although producers expressed their unwillingness to share common solar dryers, it seems that in the short-term, no other alternative can resolve such difficulty. A viable systematic sharing program at the association level can be designed by cooperative leaders and technicians. Further assessment on model capacity, usage density, and geographic factors would be required and conducted by cooperative technicians, as well.

- **Financial and human capitals** would be the second steps when considering implementation. Since solar dryer projects are still new to CODECH, further exploration and establishment of funding sources and technical personnel would be needed. For these steps, CODECH would take a leader role to organize and facilitate the financial and training services from stakeholders at the national and international levels for its members.

▪ **Peru**

The feasibility of implementing this strategy in Peru is relatively high due to the level of producer experience with solar dryers when compared to the other two selected adaptation strategies. Although the pilot projects in Peru have been successful, further efforts on the following three capitals are essential for moving towards full implementation of solar dryers.

- **Human capital** is the most lacking factor for solar dryer projects in Peru. With a low technician-producer ratio in CenfroCafé, many smallholders requested more training and follow-up monitoring to ensure the proper operation of their significant investment. To resolve such issues, utilizing and further developing the current "promotor" or farmer-to-farmer training program can facilitate the spread of

knowledge on solar dryer operation and maintenance. On the other hand, cooperative leaders would also need to be more involved in terms of collecting and learning alternative designs of solar dryers from other external stakeholders to acknowledge the most updated technology.

- **Financial capital** was mentioned by the majority of respondents. With the current credit program, the coverage of up-front investment for solar dryers is varied across communities, resulting in unevenly distributed projects and financial assistance. Thus, CenfroCafé would need to explore more financing options for its members. As cooperative leaders indicated, potential stakeholders who could contribute to the financial support include: national-level financial institutions (*e.g.*, FINCYT); national federal agencies and organizations (*e.g.*, Ministry of Agriculture, INIA, AGROIDEAS); or international NGOs and coffee buyers.

- **Physical capital** is the final step to consider before implementing. As CenfroCafé's members are located in communities widely spread across the northern Peruvian mountain regions, access to materials for construction and transportation infrastructures can be the major barriers. Thus, organizing a supplies purchasing trip by the local associations or mid-level cooperatives could reduce the transportation costs or other additional expenses on producers.

In both countries, the strategy of building solar dryers is all-inclusive, since all family members could participate in the post-harvesting drying process and benefit from higher income potential of the high quality coffee.

An overall decision tree for solar dryer implementation is shown in Appendix J.

SEED BANKS & NURSERIES

The establishment of seed banks and nurseries is common in order to promote the conservation of traditional crop varietals (which tend to produce high cup quality beans (Vernooy, Shrestha, &

Sthapit, 2015)) and the cultivation and spread of crop varietals that are more pest and disease tolerant, which will be more important with climate change increasing pest loads.

- **Seed Banks**

Seed banks are used to preserve genetic diversity of seeds and prevent the destruction of seed variety, and are not generally open to the public (Penn State College of Agricultural Sciences, 2010). The purpose of a seed banks is the preservation of varieties into the future, as opposed to seed libraries or seed swaps, which serve as distribution hubs. In case of an environmental or ecological disaster that would wipe out the species or variety *in situ*, seed banks serve to preserve genetic variety *ex situ* (Penn State College of Agricultural Sciences, 2010). Traditional seed banks require drying of the seed to around 5% moisture content or lower, depending on the species, and long-term storage at -18°C. For the seeds to maintain viability, periodic planting and re-harvesting of the pure seed variety is required.

Another method of preserving the germplasm is cryopreservation, or cryogenic seed banks, which involves storing the plant material (i.e., seeds) at "ultra-low" temperatures (Millam, 2001). Cryogenic seed banks are more technologically advanced and require much higher levels of investment to establish and maintain, as they involve the storage of seeds in liquid nitrogen at temperatures as low as -196°C. Seeds stored in liquid nitrogen can be stored indefinitely; however, not all seeds have been successfully cryobanked, as certain types of seeds are recalcitrant and resist desiccation (CGIAR, n.d.). Coffee is one such problem seed, which has proven difficult to preserve under cryopreservation techniques (Dulloo et al., 2009; Keller, Kaczmarczyk, & Senula, 2008; Millam, 2001; Berjak & Pammenter, 2014; Dussert et al., 2006; Dussert et al., 2001). At any rate, such preservation is likely to be cost-prohibitive for even the largest cooperative and should be undertaken at a national level, perhaps by the federal government, a consortium of universities, or a well-funded national coffee federation.

In the course of our research, when we spoke of seed banks with farmers and cooperative leaders, the term 'seed bank' was understood to infer a certain level of trading and exchange of seeds for cultivation among producers, more comparable to a seed library or swap. This was due

to a lack of comprehensive understanding of the fundamental differences between seed banks and seed libraries. In any case, seed libraries also require systematic labeling and investment of time, money, and personnel for their proper maintenance.

- **Nurseries**

In an effort to make preservation and sharing of coffee varietals less technically challenging, the creation of coffee nurseries was another proffered method of *ex situ* seed conservation (Li & Pritchard, 2009) identified and selected by CenfroCafé cooperative leaders. Creation of nurseries involves planting coffee seeds in the soil, awaiting germination after a period of approximately 40 days, and the subsequent transplanting of the seedlings into plastic bags where they will mature until time to transplant the saplings in the soil again where they will grow into productive coffee trees. Nurseries are established to facilitate the development seed banks, the renovation of existing plots, or even the installation of a subsistence crop system (Trewin, n.d.).

Producer Experience

The implementation of seed banks or nurseries was only selected as one of the top three strategies for further feasibility research in Peru, therefore our understanding of producer experience with these methods only reflects the reality in the CenfroCafé cooperative.

- **Peru**

Farmers have little to no experience with collective seed banks or collective nurseries of coffee varieties. In order to plant new coffee trees on their farms, producers commonly create coffee seedling nurseries for themselves, but only on an individual basis and therefore have no experience in the implementation and challenges of collective nurseries. As one farmer said, group nurseries often involve higher costs "*porque las parcelas son lejos*" ("because the parcels are far apart") which "*genera gasto para hacer los plantones acá llevarlos hasta la chacra*" "generates a cost to care for the plants here [and then] take them to the field" (Personal communication, July 2015).

In one community focus group, farmers referenced a past collective seed nursery project that was not very successful. Problems experienced included theft of the seedlings, which then necessitated hiring someone to guard the nursery site and raised costs as well as created delay on the part of some collaborators to retrieve their plants. As a result, the group decided "*que cada uno mejor lo haga en su chacra y lo cuida allá*" ("that it was better if individual farmers tended their own personal nursery in their farm") and were therefore less interested in pursuing a collective nursery (Personal communication, June 2015).

In the course of our research, when we spoke of seed banks with farmers and cooperative leaders, the term 'seed bank' was understood to infer a certain level of trading and exchange of seeds for cultivation among producers (more in the line of a seed library or seed swap). This was due to a lack of a comprehensive understanding of the fundamental differences between seed banks and seed libraries on the part of the researchers and producers.

Capital Assessment

The following capital assessment is drawn almost exclusively from interviews and focus groups conducted in Peru. There were a few mentions of seed banks or seed nurseries for other crops with CODECH, but not for coffee. As this was not a selected adaptation strategy for Guatemala, the data we have on it is scarce and insufficient to come to any conclusions about the feasibility of the adaptation strategy for CODECH producers.

- **Financial:** Very few people we spoke with mentioned needing funds in order to implement a cooperative-level seed bank or nursery, though one farmer told us that farmers in the area where he lives could contribute seeds to a seed bank, but only if "the cooperative pays us for the seed" (Personal communication, July 2015). However, it is important to remember that implementing a seed nursery would require the purchase of grow bags, payment for the months of labor involved to nurture and care for germinating seeds, as well as potential rent or costs for a space where the nursery would be constructed. Likewise, implementing a collective seed bank requires space in a secure building (which may need to be rented or borrowed) in a

convenient, central location, or potentially adjustments can be made to shift around space within existing cooperative offices.

- **Human:** Some producers were not sure what a seed bank is or how it could benefit them, and therefore lack the knowledge (and potentially the interest) necessary for successful implementation of collective seed banks. In fact, a key actor we interviewed mentioned the need for "some educational component just to make sure producers are informed and see benefits" of seed banks or nurseries (Personal communication, July 2015). Additionally, all farmers spoke of the desire and need for more training to be able to properly implement such a seed bank. Producers are familiar with implementing nurseries, as they regularly create and maintain their own to re-plant coffee in their fields; however, they either do not have experience or have negative experiences with collective nursery implementation.

- **Natural:** A large selection of diverse varietals of coffee are required if one is to create a seed bank or seed nursery with the intent of enabling producers to cultivate many diverse varieties. In the focus groups we conducted, farmers indicated that they are currently cultivating a wide selection of coffee varieties and that they would be willing to donate seeds so that their fellow cooperative members could also have access. However, in cases where the individual producers already have a lot of varieties in their farm, there was less interest expressed in the program. One coffee farmer told us that he "did not see [why] he would purchase seeds from the Engineer" (as the técnicos are commonly called) ("*yo no veo comprar semillas al Ingeniero*")) when he already has a lot of varieties growing on his farm; "if I have [a variety] why would I go purchase it?" ("*por ejemplo de bourbón, si yo tengo para que voy a ir a comprar?*") (Personal communication, July 2015).

- **Physical**: A robust road network in good traversable condition is necessary for collective implementation of seed banks or seed nurseries. Producers must be able to travel easily between the nursery site and back to their farms with the coffee plants (or, in the case of collective seed banks, between their farms and the seed bank

location). In many of the smaller communities, transportation is a problem and people often walk long distances between their homes and meeting places, farm plots, or other destinations. There are no buses or taxis in these more remote regions and if people do not have access to a vehicle or motorcycle, they must take a horse or donkey or walk. The increased travel time is a burden on the producers, but it is especially problematic to transport coffee plantlets from a nursery to a distant destination. A farmer mentioned that even if they were able to use a motorcycle to transport the plantlets they would have to fasten the plants to the back of the motorcycle and then travel on the bumpy, often rutted dirt roads would likely damage the small saplings or lead to spillage of much of the soil or fertilizer substrate (Personal communication, July 2015).

- **Social**: When asked about capital needed to implement seed banks or nurseries, respondents mentioned the need for a research center for the development of novel coffee varieties, which would be better adapted to projected future climatic conditions and suitable for cultivation in different regions and elevations of the country. While some imagined such a research center as something to be implemented by a large cooperative or a consortium of cooperatives, others envisioned a government-led research center where universities and private companies could collaborate. However, there appears to be a lack of political capital, of organizations and people working together to achieve the foundation of a coffee research center. A key actor we interviewed informed us that a few years back, there were a lot of people and agencies talking about a coffee research center and mentioned that it is still in development. Furthermore, the interviewee told us that Peru had announced the creation of a National Coffee Institute, though "there is currently nothing concrete for the institute, everything is still plans" ("*y hasta ahorita en el instituto nacional de café…pero hasta ahorita no hay nada concreto del instituto, todavía sigue en planes*") (Personal communication, July 2015).

  Potentially, with more collaboration between actors, increased functionality at working collaboratively in a group, and a pooling of resources, such ambitious

projects are reachable. As the same key actor said, "*yo creo que depende de todos, hay mucha falta de financiamiento para poder hacer esto, yo creo que tenemos que hacer una integración para poder lograrlo y ver*" ("I think that [implementation] depends on everyone; there is a lot of lack of financing to be able to do this, and I think we have to integrate to be able to achieve and see [this happen]") (Personal communication, July 2015).

Feasibility

- **Costs & Benefits**

A number of key actors, cooperative leaders, and farmers mentioned that, in designing seed banks, it is important to consider only encouraging farmers to plant coffees from within the same or similar region – whether the same microclimate, or same elevation – as they are seeds which are already "adapted to the region" (Personal communication, July 2015). The focus group respondents suggested that small groups of base-level associations have their own seed banks, in order to maintain the seeds' adaptations to local conditions. They also suggested that it would be best not to "bring in seeds from other places, [because] it is not known" how those varieties from other regions can affect the already adapted seed varietals (Personal communication, July 2015). Therefore, one cost to implement a collective seed bank would be the time and effort spent by the cooperative to determine which producers have which cultivars that they would potentially contribute to the collective seed bank. This could be determined by surveys over the phone as well as augmented by visits to the farms to improve the likelihood of correct cultivar identification.

In one of the focus groups we conducted, farmers did not perceive seed bank establishment as important because they feel they can obtain varietals from their own farms without relying on a collective seed bank. Additionally, they maintained that there are not markets in which to sell different seed varieties. This highlights another cost, which is arguably the largest cost, to implementing a collective seed bank: getting everyone (or many producers) to cooperate, even if

some individuals do not perceive a direct benefit to themselves through their participation in the program.

Another cost to consider before implementing seed banks is that of a physical structure for housing the collection. CenfroCafé operates many offices throughout their geographic reach and there is potential to dedicate a cool, dry, dark area or room to house potential regional seed banks. If this is not possible, you must consider the cost of renting or constructing a building in which to store the seeds for the seed bank. In terms of implementing collective nurseries for coffee, one major cost is that of space to locate the nursery. Additionally, a large, collective nursery would require a very significant amount of water to ensure the production of healthy coffee plants. One cost which is sometimes underestimated is that of labor to care for the seedlings.

The benefits of implementing collective seed banks or nurseries are potentially huge, especially when considering that the increased access to, and subsequent cultivation of, diverse coffee cultivars greatly improves the capacity of smallholder farmers to be resilient as climate change continues.

We do not have sufficient information on CenfroCafé's resources or the availability of said resources to determine whether the costs would prove too high to implement either collective seed banks or nurseries. Specifically, we recognize the need for trust and collective action required to design, build, implement, and manage a community coffee nursery or seed bank: without sufficient social capital, the implementation of seed banks or nurseries will not succeed, and there is a need for an analysis to determine if enough social capital exists within the cooperative (particularly within the base-level associations) to succeed. Further analysis and valuation of the benefits from this strategy would need to be undertaken by the cooperative.

- **Information Required for Decision-making**

Many factors need to be considered when deciding whether to implement any project or strategy in a cooperative. Some of the more salient factors to consider before implementing the strategy

of seed banks and nurseries in the cooperative are discussed below (for a more complete group of considerations, please refer to Appendix K.

- First, cooperative leaders should assess the need and desire coffee farmers have to expand the varietals of coffee they cultivate on their land. If few of CenfroCafé's cooperative members wished to purchase or barter for coffee varietals they have not grown before, the cooperative could search for potential markets outside of the cooperative in which to sell such seeds. A cooperative member indicated interest in implementation of a cooperative level seed bank, but quickly pointed out that if no one is interested in purchasing the seeds then there is no benefit to anyone in this system:

  > *Tengo semillas de borbón, pero si yo la llevo, allí nadie la compra, allí estará almacenada [...], allí pueden pasar un años dos años y nadie se la lleva. Habría que ver si ya hay mercado donde venderla.* ("I have Bourbon variety seeds, but if I take them there and no one buys the seeds, it will be in storage […], one or two years may pass and no one wants it. You would have to see if there are already markets where it can be sold.") (Personal communication, July 2015).

- Another useful consideration is to take stock of available financial contributions from all cooperative levels, whether as a donation for the good of the cooperative (*i.e.*, CenfroCafé sets aside money to fund pilot projects on these collective projects) or as a loan or personal contribution, or a lump sum of money contributed by coffee buyers or NGOs for crop and infrastructure improvement. Implementing a seed nursery would require the purchase of grow bags, payment for the months of labor involved to nurture and care for germinating seeds until they become small coffee trees, as well as potential rent or purchase costs for a space where the nursery will be constructed.

- Some producers were not sure what a seed bank is or how it could benefit them, and therefore lack the knowledge (and potentially the interest) necessary for successful implementation. In fact, a key actor we interviewed mentioned the need for "some educational component just to make sure producers are informed and see benefits" of

seed banks or nurseries (Personal communication, July 2015). Additionally, all farmers spoke of the desire and need for more training to be able to properly implement such a seed bank.

Context

- **Varying Perception & Potential**

For coffee farmers who live near each other and/or whose farm parcels are sufficiently close, it is more feasible to implement a group-level seed bank or a collective seed nursery. If farmers only have to transport their seedlings a short distance, many of the issues related to transporting the seedlings are much easier to overcome. Coffee producers who are more isolated are less likely to be interested in participating in a collective seed bank or nursery due to the costs involved in transportation, time spent away from their farms when traveling, as well as difficulty bringing the plantlets back safely to their parcels for transplanting.

Implementing collective coffee nurseries was perceived as more problematic than setting up a collective seed bank where the farmers can obtain a more portable and durable form of characteristically different coffee variety. Focus group attendees opined that:

> *Para manejarlo grupalmente es más difícil porque vamos a estar cargando tierra, venir a trabajar al grupo como siempre, vivimos lejos y entonces es más dificultoso* ("managing [seed nurseries] for the group is more difficult because we will be moving soil, we will come to work with the group as always, we live far away and so it is more difficult") (Personal communication, July 2015).

On the other hand, producers voiced favorable opinions of organizing seed banks within the cooperative, with the condition that the *Autoridad Regulacion de Semillas* (ARS) approve the seeds. The creation of a seed bank with approved coffee seeds assures farmers of the proper identification of coffee varietals, so that the coffee variety they believe they purchase is what grows once it has been planted. As stated by one cooperative member:

> *... sí yo creo que sí se debe trabajar en hacer un banco, así como una área de repente solo destinada a recolección de buenas semillas certificadas donde los*

> *socios tengan buena confianza y traigan sus semillas* ("I think that yes we should try to work on a seed bank, like as an area only built for gathering and compiling good certified seeds, where cooperative members are confident in the system and bring their seeds [to contribute]") (Personal communication, July 2015).

- **Access**

Peru does not currently have a system for certifying coffee seeds. Certified seeds are those whose origin, germination proportions, and exact varietal type are known scientifically and empirically. Seed banks with certified seeds are ideal, but given the political, regulatory and environmental context in Peru, we recommend using ARS-approved seeds to set up a seed bank. The Authority for Seed Regulation (or ARS) has compiled a list of registered coffee seed producers on the national level so that farmers can find quality coffee seeds that will help guarantee successful germination and characteristic traits of the correct varietal (Personal communication, July 2015). This way, producers have more confidence in the genetic material they purchase. This is especially important because otherwise farmers purchase "what [they] think is one variety of coffee and that is not what [they] received" (Personal communication, July 2015). Not only is the varietal of coffee incorrect, the provided germination success rate for the purchased seeds is often inaccurate. A key actor we interviewed shared an example that "has happened a lot" that farmers purchase seeds and are told the rate of germination, but when growing out the seedlings, they realize the germination success rate is "not even half of what farmers were told" (Personal communication, July 2015).

Results

As mentioned above, the implementation of seed banks or seed nurseries are two different approaches to achieving the same outcome: increasing access to and cultivation of more diverse varieties of coffee in order to improve farmers' resilience to shocks from such climate change scenarios as increased pest loads, drought, excess rainfall, and higher temperatures. Both approaches were selected by cooperative leaders during selection of strategies to pursue, and were frequently talked about as if they were interchangeable, as the coop leaders were focused on the outcome of providing many cultivars to the farmers as opposed to the method used to obtain varietal diversity.

In the short-term, and in terms of actions CenfroCafé should take now to prioritize implementation of the strategies selected, we do not perceive this strategy to be very feasible, especially compared to the other two selected strategies for CenfroCafé in Peru. As a long-term strategy, we perceive this strategy as more feasible than for the short term. Therefore, we recommend that CenfroCafé begin working to set up the necessary logistics and other necessary requirements to ensure successful implementation of such projects. Based on what we heard from farmers, cooperative leaders, and key actors, the areas we perceive as most requiring attention are outlined below.

- **Financial**: In terms of financing seed bank or nursery projects, there needs to be more funding for the creation and maintenance of such facilities. If the cooperative or members do not have access to such liquid assets, they must investigate if they can obtain funding elsewhere (through government grant programs, private companies' grant programs, funding provided by NGOs like agricultural lender Root Capital, loans from the second-level cooperative, or profits from individual coffee farmers). Financial resources must be sufficient to cover the purchase of all necessary materials (e.g., grow bags, trowels, shovels, wheelbarrows, fertilizer, fencing materials if desired), as well as the transport of the materials to the collective nursery site.

- **Human:** Interviewees expressed a need for increased knowledge on the part of producers as to how to best create coffee nurseries, along with best practices for storing seeds to lengthen their viability period. If a cooperative decides to implement a seed bank program, the cooperative should first ensure there is sufficient knowledge amongst the members to successfully implement a seed bank program (in the form of a seed swap or seed library). Training may be required to ensure success.

- **Social/Human:** For successful implementation, there needs to be more support for seed banks or nurseries. This support could perhaps come from the federal government through INIA (the Peruvian National Institute of Agricultural Innovation) and SENASA (the Authority for Agrarian Sanitation) in the form of improved regulations for certifying seeds (so that farmers can trust they are receiving the

variety they are told and that the seed has a high likelihood of germination). A longer-term policy approach would be for SENASA (who is in charge of such national regulation) to loosen tight controls on legally importing seeds into the country, as many farmers and key actors mentioned the long and complicated legal process as an encouraging factor for seed smuggling.

Additionally, before implementing this strategy in the cooperative, leaders should assess the need and desire coffee farmers have to expand the varietals of coffee they cultivate on their land. If few of CenfroCafé's cooperative members wished to purchase or barter for coffee varietals they have not grown before, the cooperative could search for potential markets outside of the cooperative in which to sell such seeds.

- **Physical:** The nursery must be in a central location (and above all) in a convenient location to all interested producers. If it is not possible to locate one nursery in a site conducive to participation from all interested parties, one potential avenue for remediation would be to implement multiple nurseries in various locations. In this way, all farmers who wish to participate can benefit from the creation of a shared nursery.

- **Natural:** The cooperative (or base level association or network of associations) needs to have sufficient terrain and space to house a collective coffee nursery. If they do not already have this, and do not have the capacity to obtain it through purchase, rental, loans, or borrowing, they should consider a seed bank instead of a collective coffee nursery. Requirements for a collective seed bank include access to a secure room or building where they can store seeds in specific environmental conditions (*i.e.*, within a specific temperature and humidity range, and in a dry, dark place) in order to maintain seed viability. Additionally, the cooperative (or groups of individual farmers considered collectively) must have access to a wide range of coffee varietals, to assemble a diverse (and therefore more resilient) collection of varietals for a seed bank and/or nursery.

Refer to the decision tree for seed banks and nurseries, found in Appendix K.

PEST MONITORING & MANAGEMENT

Given the predicted temperature increases due to climate change, certain pests and diseases are predicted to increase and affect coffee at more altitudes than before (Baker & Haggar, 2007). Two diseases in particular, coffee leaf rust (*Hemileia vastatrix*) (called *roya*) and American leaf spot (*Mycena citricolor*) (known as *ojo de gallo* or *ojo de pollo* in Spanish) are predicted to begin affecting plants in increasingly higher altitudinal ranges (Baker & Haggar, 2007). Therefore, proactive monitoring and treatment of pests and diseases is crucial for farmers to remain resilient.

Integrated pest management (IPM) is an approach to agricultural production based on diligent monitoring and integrated control methods, while minimizing environmental impacts ("What is IPM?," 2016). In addition to controlling and managing pest populations and minimizing disease outbreaks, an important piece of IPM is monitoring. One crucial resource for smallholder cooperative members is the knowledge and guidance from *técnicos*, or field technicians, who are trained agronomists (or in some cases, environmental engineers or forestry engineers) who work full-time for the cooperatives. In some cases, farmers seek advice from agricultural extensionists working for the agricultural agency or ministry of their country, though there is more demand for these services than personnel can supply. Another limitation to keep in mind is the remoteness of many farmers' plots from not only their homes, but from the bases out of which these trained professionals operate. In such rural areas in the tropics, road conditions are frequently bad, further slowing or discouraging the help from outside experts.

The use of pesticides is widespread and effects coffee production, worker health, plant health, and the environment. Though some coffee farmers in the two cooperatives are certified organic, not all cooperative members are, and therefore use such pesticides and are subject to the risks described below. The use of pesticides in coffee production in Central America is "intensive, extensive, and thoroughly out of control" (Wesseling, 1991). A World Resource Institute report highlights several Guatemala-specific pesticide intensity issues and even "though Guatemala was

the least intensive user in this group, other evidence nonetheless suggests serious overuse and exposure problems (Repetto & Baliga, 1996). From 1984 to 1994, the U.S. Food and Drug Administration (FDA) detained shipments of fruits and vegetables from Guatemala worth nearly $18 million because of excessive pesticide residue levels" (Repetto & Baliga, 1996, p. 5). Those people exposed to pesticide are mainly "agricultural laborers and small farmers in areas of plantation or intensive agriculture" (Repetto & Baliga, 1996, p. 9). A recent comparative study of pesticide use and exposure patterns in tropical countries around the world concluded that "in Third World countries, pesticides cannot be used with safety. Health and safety issues are exacerbated by a general lack of hazard awareness; the lack of protective clothing, or difficulty of wearing protective clothing in tropical climates; shortage of facilities for washing after use, or in case of accidents; the value of containers for re-use in storing food and drink; illiteracy; labeling difficulties relating either to language, complexity or misleading information; lack of regulatory authorities; and lack of enforcement" (Dinham, 1993, p. 38; Repetto & Baliga, 1996, p. 10). Negative health impacts of pesticide usage in coffee include serious birth defects or even fetal death as "many organic and metal-based pesticides can also pass from mother to unborn child through the placenta" and can potentially lead to "birth defects, abnormal development of the immune system, and fetal death (Repetto & Baliga, 1996; Sesline & Jackson, 1994; Slikker & Miller, 1994).

Considering the widespread misapplication of pesticides, IPM is an even more crucial approach to agriculture. A study of smallholder Arabica coffee farmers in Uganda reports that the rural income multiplier effect when adopting IPM practices is both positive and significant, finding that farmers were able to intensify their production while being environmentally friendly (Isoto, Kraybill, & Erbaugh, 2014). A similar study with coffee farmers in Colombia also deemed IPM a highly successful strategy, finding that in just two years from 2002 to 2004, the farmers in the study were able to: decrease chemical endosulfan use from 250kg down to zero; increase the presence of a pest-deterring, naturally-occurring fungus from 20kg up to 80kg; decrease insect damage on the coffee harvest from 2.3% down to 0.7%; and increase the proportion of harvest sold as high-quality specialty coffee from 50% up to 86% (Aristizábal, Lara, & Arthurs, 2012). IPM methods have also proven to be an effective strategy in combating coffee borer beetles and leaf rust, which are common across coffee growing communities in Latin America. Such

measures include the regular picking of mature berries, monitoring of sample trees, use of natural enemies, and strict post-harvest pest control (Elston, 2012).

Many crop management practices are interrelated. Interestingly, the interrelationship between crop management practices is more apparent in coffee than for many other crops, and includes the relationships between nursery management and crop maintenance, between shade management and biodiversity levels, or between postharvest processes and microbial problems (Waller, Bigger, & Hillocks, 2007). Therefore, an integrated approach to pest management is of particular utility for coffee. Efforts can be aimed at the pest, including reducing the sources of pathogens or physical application of pesticides, or at the crop, including selection of tolerant cultivars or encouraging cultural practices to improve crop health (Waller et al., 2007).

While the majority of publications praise the success of IPM, it is also important to consider its limitations and potential shortcomings. One study has found that in East Africa, there are two primary flaws in the IPM strategies being disseminated: (1) many of the plans only addressed one disease or pest, and/or (2) many of the plans only addressed one crop, despite the fact that many East African farmers are practicing intercropping (Nyambo, Masaba, & Hakiza, 1996).

To improve pest monitoring and management, the proposed strategy involves cooperative member farmers observing problems on their plots, recording the issues systematically and consistently, subsequent collection and aggregation of the data so it can be analyzed by CenfroCafé staff and technicians can provide more targeted recommendations and practices for the control and management of diseases. The design and implementation of pest monitoring and management systems was chosen as one of three strategies in Peru for additional research. Given that pest monitoring and management programs was not a selected strategy for further research in Guatemala, we are unable to provide much analysis in terms of capital available and feasibility for this strategy in that country.

Producer Experience

Producer experience monitoring one's own coffee plantation and taking proactive measures to reduce disease incidence or pest populations is variable, though generally with little efficacy and certainly no widespread implementation across the coffee growing sector.

- **Guatemala**

A key actor we interviewed told us that pest monitoring and management by farmers is widely under-implemented, saying that "2% of the coffee growing population has reacted. It's a hard labor, some are changing now, they have their control programs, they are fertilizing and pruning. [….] 2 or 3% is nothing" ("*un 2% de la población caficultora ha reaccionado. Es una labor fuerte, unos ya están cambiando, ya tienen sus programas de control, ya están fertilizando y podando [...] 2 o 3% es nada*") (Personal communication, July 2015). While some farmers are implementing such systems on their own parcels, monitoring and managing their pest levels, this is happening on such a micro-scale and is not generally effective, in terms of global cooperative-wide results.

One CODECH cooperative member opined that frequent recordkeeping by farmers on the state of their crops would be useful in informing appropriate pest control measures or coffee care techniques farmers should implement, given the length of time between visits from the cooperative's technician. The major obstacle for implementation of such record keeping would be the need for "more training" because although the farmers apply fertilizers and other inputs to their coffee farms, they "don't know if what [they] are doing is correct, because you have to apply the proper amounts" (Personal communication, July 2015). As this interviewee mentioned, the farmers "just apply it however we do it because we don't know" the right treatment or the right amount to apply (Personal communication, July 2015).

A key actor in Guatemala mentioned the lack of training and stressed the need for "more training for the producers in phytosanitary management of coffee" because without that knowledge, the "farmers cannot advance" (Personal communication, July 2015). An example was that farmers confuse nutritional deficiencies with pests such as the red spider mite, as both cause the coffee leaves to turn brown. In this case, "people see the [plant affected by] the red spider mite and

proceed to fertilize instead of fumigating," which does not correct the problem (Personal Communication, July 2015).

- **Peru**

As mentioned above, producer experience monitoring their own coffee plantations and taking proactive measures to reduce disease incidence or pest populations is variable. It appears that, when implemented, it has not been very effective or widely adopted. Most respondents in Peru expressed that farmers have little to no success or experience with implementation of pest monitoring and management. One CenfroCafé cooperative leader mentioned:

> *En general, en la región, no existe esa estrategia o esa forma de monitoreo de plagas. Lo que existe [es] una protección en roya. Y esto lo hace que los productores están cambiando de las variedades de más resistentes*. ("In general, in the region, this strategy or this form of pest monitoring is nonexistent. What does exist [is] a protection against leaf rust. And this causes the producers to change varieties to more resistant ones.") (Personal communication, June 2015).

However, some cooperative members mentioned that some had experience in a similar monitoring program conducted by farmers, known as the "promotor" system within the CenfroCafé cooperative. It is worth noting that the farmer who brought up the promotor system as an example of experience in such monitoring and management programs is a promotor.

Capital Assessment

Given that pest monitoring and management was not a selected strategy in Guatemala, the following discussion on capital types required and available for successful implementation mainly involves interviews and focus groups conducted in Peru.

- **Financial:** Interviewees did not specifically mention a need for funds to ensure proper monitoring or management, though they identified potential sources of funding. However, several cooperative leaders and key actors considered the establishment of a long-term research site as a necessary piece of the plan to improve

pest monitoring and management. One of the cooperative leaders explained that a certain percentage of the price premium paid for Fair Trade returns to the cooperative as money to invest in projects. The "*asamblea*" (administrative assembly) decides the distribution of the price premium from Fair Trade on a yearly basis (Personal communication, June 2016). Other sources of funding include income from coffee sales for individual producers, as well as the credit office at CenfroCafé and the international NGO Root Capital for loans.

- **Human**: In terms of trained staff members or disease monitoring experts, there is a widespread deficiency of personnel; this fact was a key reason for the development of this strategy for the coffee farmers to monitor their own parcels, in order to bridge this gap. A major barrier to implementing widespread monitoring from governmental institutions related to agriculture and technical assistance to producers is the lack of technicians who can travel to farmers' fields. For example, a governmental agency will have a small portion of budget to train farmers in a certain cooperative or organization and you "convoke thirty or forty producers, but the training is done and perhaps they will not follow-up on this on all of the parcels" (Personal communication, July 2015). In many cases, it is not always sufficient to provide educational workshops and other capacity building trainings if the effort to monitor pests and diseases is not sustained.

  Another major theme that occurred in a majority of interviews was the need for training, and many CenfroCafé members voiced their desire for training to increase the farmers' knowledge base on appropriate management techniques. Relatedly, respondents informed us that many farmers do not know how to correctly identify certain pests, and that there widespread confusion and misinformation on distinguishing between diseases and nutritional deficiencies. For example, in other regions of the country where the farmers have more experience with red spider mites, coffee berry borer beetles, and leaf rust, they "see a 10% incidence of the pest or disease and will fumigate" whereas those farmers not accustomed to such management "have allowed 60% infestation rates in their farms" (Personal

communication, July 2015). INIA is a potential support partner and source of information for innovative pest control techniques. Currently, INIA has several dozen pilot programs for pest and disease management throughout Peru, and seems to be obtaining good results for some pest management strategies.

In addition to having the capacity to properly recognize and effectively treat infestations on their coffee parcels, farmers need to keep a written record of what they observe, so that it can be compiled periodically at the cooperative level and the farmers can receive necessary information on treatment for what they have noticed in their plots. If the farmers do not keep a written record, the strategy will not be effective. Additionally, a key actor commented that monitoring pests and diseases "is critical" and that the proposed approach is "viable" though the interviewee had "not seen or heard of very high success rates of having producers fill things out" (Personal communication, July 2015). Though perceived as important and beneficial by the farmers, it does not appear likely that farmers will keep an updated written record, as exemplified by what coffee growers voiced in focus groups. One farmer expressed that the strategy "is very important for us, but we don't keep records," saying it is "neglectfulness on [the] part [of producers who] leave [their] fields tired" at the end of the day (Personal communication, July 2015). Another producer affirmed that the "lack of time to record so many things" would be the limiting factor for all of the farmers (Personal communication, July 2015). Eventually, the farmers "become careless [and] do not continue doing" the monitoring and recording (Personal communication, July 2015).

Another barrier to keeping written records is farmer illiteracy. Although we heard in focus groups that "everyone knows how to write, [and] the others" have someone who can read or write for them (Personal communication, July 2015), we also heard from others that it should not be "assumed that everyone can read and write, because that's not the reality" (Personal communication, July 2015).

- **Natural**: Other than the existence of coffee plantations to monitor the incidence of pests and diseases for which to control, no further natural capital was mentioned as required to implement a farmer auto-monitoring program and pest management regime.

- **Physical**: Notebooks and writing utensils were mentioned as necessary tools required to keep a record of pests and diseases observed within each farmer's parcel. The majority of producers said they could obtain notebooks and pens or pencils to keep a record and it was not a problem for implementation. Additionally, CenfroCafé provides its members with a producer's notebook each year for recordkeeping, and some suggested the addition of another page to the notebook with a simple form to track pest and disease incidences in the farm.

Feasibility

In theory, we view this strategy as feasible. The only major barriers for implementation are the need to increase knowledge of pest recognition and treatments to apply for those farmers who require it, and commitment of time and energy by every individual producer to make sure to write an account of any trends or patterns occurring in their parcels. That said, the farmer auto-monitoring and record keeping is a less feasible strategy due to the likely difficulty in getting farmers to consistently write down their observations in a timely manner.

- **Costs & Benefits**

The most significant cost required to implement the proposed pest monitoring and management system is that of getting farmers to implement it; as illustrated above, some farmers do not perceive there to be sufficient will amongst the producers to consistently maintain a written record of problem areas in their coffee farm. Another significant barrier is the uneven level of knowledge amongst producers to correctly recognize pests and diseases when they occur, and to know the correct measures to take to mitigate these issues. While some CenfroCafé members are very knowledgeable, and some are even *promotores*, others are lacking in their ability to identify

and treat problems affecting their coffee plants. If the cooperative wants to ensure a successful implementation of this system that benefits all producers, more training and consciousness-raising is needed.

Through increased individual and collective awareness and recognition of common pests, diseases, and other problems, coffee producers throughout the cooperative will require less basic training from the cooperative or other agencies, and can begin to benefit from advanced pest control measures, or can focus on other key areas such as improving post-harvest processing of their coffee. This will serve to empower the producers and raise the productive capacity of the cooperative, in addition to allowing resources (*i.e.*, time, money, transport, etc.) which would have been spent on basic pest management training to instead be allocated to other projects (for example, improving coffee yield or quality). Increased time and resource availability is another co-benefit that farmers would likely receive from implementation of this system, as it would lead to more timely and proactive measures to combat pests and diseases (thus saving the farmers time, effort combating pests when they are advanced, and potentially reducing otherwise lost productivity).

The costs of implementation may potentially outweigh the benefits, especially if very few farmers are willing to actually implement the program. However, the benefits of implementation – both individual farmer-level benefits and collective, cooperative-wide benefits – have the potential to far outweigh the costs to the individual farmer of dedicating several minutes daily to record any notable or new issues in the coffee. More information is needed and should be considered by the cooperatives before determining whether or not to implement.

- **Information Required for Decision-making**

A thorough inventory of all producers, at least at the base association level in Peru, should be taken via informal surveys to gauge actual interest and motivation towards this self-monitoring strategy on behalf of the farmers. The results of this analysis can provide information about whether or not to implement the strategy, or indicate at what level data should be collected (*i.e.*, at a base association level or a higher organizational level). If the farmers think the strategy is a

good idea, but no one is actually going to fill out the forms or keep a record, then the strategy will not succeed and resources invested in its implementation will be misspent. In addition to surveys, which may be administered verbally and informally by promotors or association presidents, it may be useful to get an indication of farmers' experience keeping systemized, up-to-date records. This can be observed in the *Cuaderno del Productor* that CenfroCafé provides to each cooperative member yearly for each member to maintain a history of fertilizer applications, farm upgrades, and a plethora of other information needed for various certifications and cooperative record-keeping and data collection. If farmers in a particular association are notorious for spotty record updating, then perhaps it is not a wise choice to implement this monitoring system in that association.

Another aspect to consider in launching a simple, user-friendly form for coffee farmers to complete is the literacy level of farmers who would fill out the form. Though we did not hear during our focus groups from any farmers that they have difficulty reading or writing, it is possible that some farmers were too shy to admit they would be unable to read or write in the form or that they did not have anyone (albeit family, friend, or neighbor) who could assist them in form completion. For semi-literate farmers, a form with graphics or images may be recommended.

Context

- **Varying Perception & Potential**

In the case of semi-literate and illiterate farmers, the promotion of an additional written form as a potential aid in pest management may be viewed less favorably. We strongly recommend the inclusion of illustrations to make this strategy more accessible to all producers. Images of what lesser known pests look like on coffee plants could increase the knowledge of all farmers and improve their recognition of such issues when they occur on the farm.

- **Access**

In implementing a monitoring system that individual farmers within a cooperative network system will conduct, knowledge about innovative and effective pest control techniques is a key part to be able to successfully control such issues once detected by monitoring. A potential barrier is the difficulty in information sharing due to a complex political structure. For example, INIA has a network of pilot projects for pest and disease control using varying techniques in different locations (this project was referenced in the human capital section). Each pilot project parcel is managed by an INIA researcher and at the end of the project, the results will be disseminated in a document recommending the best results from techniques, with several years' extension of the project to encourage coffee farmers to visit these demonstrative pilot plots and learn how to implement these techniques. There is a potential for remote, marginalized producers to benefit less than other farmers who may be more centrally located to the pilot plots or who may be more connected to those in power at such institutions.

Recommendations

We view the farmer auto-monitoring and record keeping with medium-low feasibility – the main barrier to implementation is the willingness and ability of farmers to record their observations on disease outbreaks on their farm in a timely and consistent manner. However, given producer feedback and information provided by key actors, we believe cooperatives will encounter difficulty in getting farmers to consistently write down their observations in a timely manner before they forget details. In order to ensure successful implementation of this strategy, we recommend increased capacity-building for the following capitals:

- **Human**: Additional training is suggested for producers who have expressed lack of knowledge of identifying certain pests and diseases, and for those farmers who may not know the appropriate control measures to take to combat them. Sustained follow-up training is essential to ensure continued success of the program. This training may be provided by cooperatives via technicians or *promotores*, or other organizations (such as regional or national governmental agencies; NGOs like Rainforest Alliance, Catholic Relief Services, PlantWise, Root Capital, among others; or private companies such as CCC, Twin Trading, or other coffee buyers).

Coffee producers also must perceive they have sufficient time to keep a written record of their observations of pest and disease occurrences in their coffee farms. If not, the likelihood of uneven or inappropriate implementation of this strategy increases. In some cases, motivation and perceived ability on behalf of the producers will be increased by training to raise awareness and promote thoughtful discussion of the utility of this approach in being better prepared to react in the face of increasing disease and pest loads as the climate continues to change.

- **Human/Social**: Sufficient interest on the part of producers is required to implement a self-monitoring and management program for pest and disease control; if the farmers are not interested in completing a simple short document at a determined periodic interval, this strategy becomes less likely to be carried out successfully to achieve its purpose/original aim. An important consideration to remember when designing the template for the form are the levels of literacy among the cooperative members, so as to ensure no one is excluded from the benefits of this approach. If farmers are not sufficiently literate to record their observations, they will either need to rely upon someone to help them fill out the monitoring sheet, or the monitoring form would have to heavily feature illustrations or graphics to allow semi-literate and illiterate farmers to completely fill out the form.

- **Physical**: Despite having plenty of notebooks and pencils, in our interviews and talks with cooperative leaders and key actors in various agricultural related government agencies, it was apparent that neither CenfroCafé nor major agricultural agencies had an easy to fill out form at their disposal to implement this strategy. Through cooperation and collaboration between the cooperatives and agencies such as INIA, the Ministry of Agriculture (MINAGRI), and SENASA, we believe that a comprehensive and useful form can be created for this use by all parties.

Please see Appendix L for more detailed information to consider when assessing the feasibility of implementing a self-monitoring and management project for pests and diseases.

WATER COLLECTION SYSTEMS

As discussed previously, the availability of water and seasonality of rain are of critical importance in coffee production. As precipitation become increasingly variable, a stable water source that does not rely upon weather patterns can help smallholders increase resiliency and adapt to such changes (NDF, 2013; UN Water, n.d.).

Essential to the production and processing of coffee, water has become a widely discussed topic within the coffee community as we experience global water scarcity and rain unpredictability (SCAA, n.d.). Water is used for irrigation of coffee plants; for fumigation and pesticides, to mix the solution for application; for wet milling, to remove the fruit pulp from the coffee bean; and for mucilage removal, by fermenting the beans in large tubs (Brando, 2013). For smallholder coffee farmers, depending on rainwater for their coffee crop can be a potential risk, since water is especially scarce during the dry season when most of the coffee washing and processing takes place (Fox et al., 2015, p. 79). It is also worth noting that there are competing efforts in terms of water usage: domestic household use versus agricultural use.

Water collection systems can range from small open-air tarps to massive subterranean concrete systems, which can be located throughout the coffee plantation. There is great variation in the types of water collection systems being implemented around the world depending on available materials and other contextual factors. For purposes of this study, we are looking at systems to collect rain water predominantly, if not exclusively, for agricultural use.

If the plot features a structure with a metal or plastic based roof, then gutters made of steel, timber, plastic, or other materials can be used to collect rain water, and then connect to a catchment system (Maldives MHTE, 2009). Most commonly, these consist of either homemade tanks or large manufactured metal barrels, plastic tanks, or pottery jars, any of which can be located underground (Soluciones Practicas, n.d.). Studies in Peru and the Maldives, among others, have found that such homemade collection tanks, which are generally quite large, are most commonly built with bricks or concrete, some of which even contain an internal metal

skeletal cage for support (Centre for Science & Environment, n.d.; Maldives MHTE, 2009; Soluciones Practicas, n.d.).

When a roof is not available, tarps can even be used to collect rainwater, either by suspending them or digging a ditch and lining it with a tarp (Churchill, n.d.). Some systems also consist of an isolated tank, which is manually filled with buckets of water from nearby natural water features in order to have a supply for when levels are low.

The implementation of water collection systems was selected as one of the three strategies in Guatemala for additional research. As water collection systems were not selected for further research in Peru, we are unable to provide much analysis in terms of capital available and feasibility.

Producer Experience

As expected, there was significantly more experience with water collection systems in Guatemala than in Peru.

- **Guatemala**

Individual pilot projects were mentioned in some of the interviews, a few of which we were able to visit to ask further questions. All experience was on an individual basis, with at least one tank or cistern per individual family. The systems discussed in interviews and field visits were all only up to about three or four years old. Some of these were open, solely catching rainwater directly. Others were coordinated with slanted roofs or integrated with gutter systems to capture the most rain water. Models in use include:

- Plastic tanks, commonly known as *Rotoplas*, for the common brand name
- Subterranean cement and/or cinderblock tanks
- Plastic tarps, either:
    - Placed on the ground after digging a depression or
    - Suspended above the ground by four posts, one in each corner

There is also growing concern amongst cooperative leaders and members regarding the *aguas mieles*, or honey water, which is left once the beans have been washed. Farmers currently just dump the water our, for the most part, which contaminates the water. When farmers downstream use this same water, it has a negative impact on the quality of their coffee. Therefore, even some members who do have access to water are interested in systems to collect rain in order to have uncontaminated water for processing.

Due to the fact that many farmers in this region only live on their parcel during harvest, if at all, there is a widespread concern regarding the security of investment plot infrastructure given farmers may not be there enough to maintain the structure and prevent theft or vandalism. Several communities mentioned shared water systems for drinking water and other domestic use; however, farmers in these communities are still interested in individual water collection systems for agricultural use, as agricultural use of the shared systems is prohibited.

- **Peru**

Based on interviews with cooperative leaders, the implementation of water collection systems is not of particular interest or priority to smallholder producers. There is little producer experience with this strategy, as water is relatively not as scarce in Peru as in other coffee producing countries. However, one of the focus groups reported that access to water has been a problem for their higher-altitude community members, some of whom now must carry their coffee harvest to a lower altitude in order to find sufficient water for washing.

Capital Assessment

Our assessment for water collection systems is based almost entirely on interviews from Guatemala, as this was not selected as one of the top three strategies for further research in Peru.

- **Financial**: The need for credit and loans was one of the top answers given by respondents; prices suggested by interviewees ranged from GTQ 1200–3000, or USD

$155–388[4]. While one cooperative unaffiliated with CODECH finances 30% of a water system for its members, many cisterns are funded by individual savings and loans from the cooperative or outside sources. One cooperative mentioned receiving a donation from the Minister of Economy for implementation of individual water cistern projects for agriculture, but the funding did not come close to covering costs. We did not hear any report of members being denied loans from the cooperatives, so it is unclear whether financial resources are available but underutilized, or unavailable altogether.

Two focus group participants suggested that cooperatives could try to place group orders for materials used in water collection systems – whether the *rotoplas* tanks or sand for cement – and receive wholesale prices. Financial resources were also mentioned, to a lesser degree, in the context of hiring a technician to train people on how to build catchment systems in addition to providing follow-up and visitation of individual plots and projects.

- **Human**: Producers need training on types of water collection systems and concepts of water management. Additionally, human capital is needed in terms of both labor hours to build and maintain the structure, and an individual with structural knowledge in order to ensure it is installed correctly. The only efforts, other than individual innovation, mentioned in interviews was that the *Ministerio de Agricultura, Ganadería, y Alimentación* (MAGA), or Ministry of Agriculture, tried to give ideas to coffee farmers on water collection systems.

- **Natural**: Two interesting natural assets were identified for successful implementation of water collection systems: land and water. The majority of the CODECH member plots are very small and on steep terrain, which makes it difficult to install water collection systems in some places where adequate flat space is not available. Two different interviewees also mentioned that installing water catchment systems

[4] Based on exchange rate of USD $1 = GTQ 7.75 as of March 2016.

wouldn't matter, because it doesn't rain much so they still would not be able to capture enough rain.

- **Physical**: There are multiple physical inputs required for construction of a water collection system, which depend on the type of system being installed. Building the tanks can include use of cement, cinderblocks, plastic tanks, nylon, wood, pipes, and/or a variety of other materials. Respondents did not indicate difficulties in obtaining materials for construction, with the exception of oversized nylon which can be difficult to find. One key actor suggested people in Huehuetenango may be going into Mexico to get materials for both ease and cost savings. Multiple interviewees also pointed out that a water collection system does not solely consist of the tank or cistern, but that materials for pipes, tubes, and buckets are also usually necessary for implementation both to fill the tanks and to use the stored water.

- **Social**: Several interviewees reported hesitation by some farmers in building water collection systems due to the fact that they don't live on their parcel, and their water and/or materials could be stolen, indicating a lack of social capital. Those systems which were of nicer quality were hidden and even included locked access to prevent theft. Two respondents identified a need to accustom people to water management in general in order to teach the cooperative members to implement systems individually. Two others identified need for integration amongst stakeholders working on water systems.

  There was a lack of consensus amongst respondents regarding the possibility of cooperative members sharing water collection systems. While this is of fairly common practice for drinking water, it is a less common practice for agricultural purposes.

Feasibility

The feasibility of implementing water collection systems is perhaps best summed up by one key actor, who reported that *"… es más un tema de opciones tecnológicas que sean lo más simples posibles y de bajo costo"* ("it is more an issue of technological options, what can be the easiest possible and of low cost") (Personal communication, July 2015).

- **Costs & Benefits**

The implementation of water collection systems is moderately capital intensive in terms of financial, human, and social resources. Some of the models we saw ran as high as $400, which are not the most expensive models in existence. However, the system using a tarp is significantly less costly, and affordable for more farmers.

Human resources in terms of installation would keep a farmer from tending to crops for as few as one day or as many as a full week, and potentially even require additional labor. Training, guides, and/or field technicians are also necessary to ensure proper installation. That said, there seems to be relatively few maintenance costs in terms of money or time. Having a steady supply of water would allow producers to continue their normal harvest schedule in the face of changing climate and precipitation patterns, potentially increasing efficiency of harvest. One key actor indicated that in his region *"las restricciones del pueblo, del municipio, es no usar el agua para el riego de cultivo […] es exclusivo para consumo familiar"* ("the restrictions of the village, the town, is to not use the water for irrigation [..] it is exclusively for family consumption") (2015).

Social resources are somewhat more difficult to analyze due to variation in responses from interviewees; yet social capital must be improved for either scenario. If cooperatives are to pursue a project implementing individual water collection systems, members must feel a high enough level of trust amongst their neighbors and community in order to invest in infrastructure on their parcels. Many individual farmers try to protect their water systems from theft by hiding pipes under foliage, burying tanks underground, and putting locks on the faucets. If cooperatives are to pursue systems at the sector or community level, which a couple of CODECH's sub-associations indicated seemed feasible, members would also need to feel a high enough level of trust in order to maintain faith that none of the other participants involved in their sharing group

would overexploit the resource. It is also worth noting that CODECH's members do not have irrigation systems for their coffee, they solely use rain. A behavioral shift would be required for members to implement water management practices in partnership with collection systems.

Some respondents cited lack of physical space as a concern; however, the *rotoplas* tanks come in a variety of sizes. In order to rival some of the subterranean systems, one may look to a plastic tank of approximately 8,000 – 10,000 liters; a comparable model of 2,000 – 2,600 gallons has a footprint of eight feet in diameter ("Water Tanks," n.d.), space in which four to six coffee trees could grow. However, some of the smaller collection systems were around 2,500 – 3,000 liters; a comparable *rotoplas* tank of 750 gallons has a footprint of only four feet in diameter.

There are several significant co-benefits associated with implementation of water collection systems, the most significant of which may be that it would reduce demand on existing water sources, and potentially eliminate people siphoning off water from the domestic supply. Those who are in a region where agricultural water use is restricted would have more flexibility in when they use water for producing their crops.

An increase in available water in their parcel may allow some farmers to grow additional coffee plants, or begin introducing more crops onto their land without having to worry as much about competing water needs. Producers who must carry the coffee cherries to their homes for processing could reap significant savings in terms of labor by harvesting in their parcel, therefore leaving the pulp in the field and only needing to transport the coffee bean.

An additional co-benefit for some could be an improvement in the quality of the water being used in coffee processing, moving from nutrient and runoff contaminated rivers to cleaner ran water. Two respondents reported that cleaner water in the harvesting and washing stages produces a higher quality coffee.

- **Information Required for Decision-making**

While there are many factors to consider in implementing any adaptation strategy, several specific factors should be explored before pursuing water collection projects. We provide a

summary below, but please see **Error! Reference source not found.** for more detailed analysis of factors to consider:

- In Peru and some parts of Guatemala, there is neither interest nor perceived need in implementing water collection system projects. Need may also vary from plot to plot, with those near streams and rivers perceiving less of a need. If this is the case, investment may be better allocated elsewhere.

- Some producers live in communities with either shared or individual water collection systems. These are usually restricted to domestic use. Therefore, when determining whether or not a producer could benefit from a collection system, one must take into account the current experience with and system of collecting water so as to ensure harmony amongst the systems and somewhat competing priorities.

- While not a common concern, some feared they would not have enough water to fill a water tank. It is important to assess annual precipitation and identify local, uncontaminated water sources in order to ensure these would provide sufficient water for storage and use in production.

- One must consider whether or not the plot has sufficient space and terrain on which to install a collection system. They can be implemented in most places, though may have limitations on which styles can be installed. For example, a *rotoplas* plastic tank, which is relatively small, on a small concrete slab may be more feasible on some plots than a large 8,000 liter subterranean cinderblock structure.

- Such projects have large upfront costs, so it is important to look locally at prices of materials. When budgeting for such projects, be sure to look at total costs, including pipes, buckets, and other tools to collect and use the water, not just the cost of materials for the tank itself. One must also consider whether these materials are easily accessible – either due to local availability or to the capacity of producers to transport materials from point of purchase to their plots.

- What is the lifespan of one of these tanks? Those in our study had all been installed in the past few years, so there was little experience with maintenance and costs once the tanks become dated.

Context

- **Varying Perception & Potential**

There is significant variation in perceived need amongst the various geographic locations. With relatively greater access to water, Peru did not identify water collection systems as one of the top issues requiring intervention. On the other hand, for smallholders in Guatemala who are experiencing decreased precipitation, there is great interest in water collection systems. Multiple key actors, cooperative leaders, and cooperative members suggested that Guatemala would benefit from improved understanding of water management amongst farmers.

- **Access**

The water collection systems in place with the CODECH farmers we interviewed were all on plots of relatively large size, belonging to farmers with relatively greater financial capacity and easier access to natural and physical capital. Nonetheless, regardless of income level, cooperative members were interested. As all members of the smallholder household are involved in the processing of coffee, a water collection system would benefit all members of the family, and not exclude any specific groups within the community.

Interestingly, there was little discrepancy in results amongst actors at different levels. Both government actors and cooperative members agree that Anacafé and other federal programs are insufficient to meet the needs of all of the coffee producers. Moreover, actors from across the board in Guatemala identified issues in water management, which should be addressed.

The only response which did not fit with the majority of respondent information on water collection systems was from a leader of a cooperative unaffiliated with CCC who suggested that a lack of financial capital is the main – and, potentially sole – barrier in implementation, stating

that *"el técnica alguien puede apoyar, en caso nuestro podríamos, pero la situación va a ser la parte económica. Qué tanto va a querer el productor apoyar?"* ("someone can support the technique, in our case, we could, but the situation will be the economic part. How much will the producer want to support?") (Personal communication, July 2015). While indeed, it seems financial resources are the main burden, a need for human capital in terms of instruction on how to build such cisterns was cited by numerous cooperative members.

Results

- **Guatemala**

This strategy has medium-high feasibility when considered amongst other strategies for Guatemala. Capacity for the following capitals would need to be improved in order to pursue implementation:

- **Human**: The water collection systems built by some of CODECH's members have been designed and built by the member themselves. We heard that MAGA gave ideas on designs to cooperatives, but many of the farmers themselves had not seen such designs; it may be worthwhile to follow up with MAGA in an attempt to acquire the designs they are sharing for water collection systems. CODECH and/or their sub-associations must offer training and/or distribute resources to members on the types of water collection systems that are possible, and practical, for their needs.

- **Financial/Physical**: The materials required for building a water collection system can vary greatly, from a simple tarp through to a system complete with cement water tank fed by gutters on the roof. While purchasing materials to start the project will be a burden regardless, this wide range of options could allow people to implement a system despite having few resources to devote. Members also suggested that they may be able to receive lower prices on materials if CODECH were to purchase them bulk for wholesale prices, which is worth pursuing.

- **Natural**: Some plots in Guatemala simply are not adequate for installing a water collection system, due to size, or terrain, or other factors. As such, research should be done to determine whether, in such circumstances, neighborhood groups could find shared space for a collective catchment system.

As all members of the family are involved in coffee processing and washing, this strategy would provide inclusive benefits to the family unit.

Please see **Error! Reference source not found.** for more detailed information to consider when assessing the feasibility of implementing a water collection system project.

OTHER RECOMMENDATIONS

There are several common themes that emerged from the interviews and focus groups at all levels. Although they are not specific to the climate change adaptation strategies we have discussed above, we provide the following additional recommendations:

The need for continued training was mentioned across countries, stakeholders, and cooperatives, with both CODECH and CenfroCafé severely understaffed in this area. As with any development project, it is necessary to have sufficient and iterative training for participants to successfully implement the targeted strategy and to sustain benefits. However, many times this does not occur in projects implemented through the cooperative or at the level of the base associations, and once a grant-funded opportunity ends, so does the project. Another issue was related to the difficulty in providing training due to issues of logistics and access. While farmer-to-farmer training and demonstration plots can work, cooperative members can always benefit from the consistent training and idea sharing offered by convening. Unfortunately, this can be very difficult to arrange due to limited capacity within the cooperatives; such an event would require funding for transportation and lodging for CODECH's many remote members, potentially as a SEEDS grant from CCC or with other support from buyers. Despite logistical costs, the need for training is crucial and cannot be stressed enough. One key actor even stated that, "if you don't have a good technical plan to go along with your financial plan, you're just going to be in the same problems

as three years ago" (Personal communication, July 2015). This reinforces the idea that financial capital alone cannot adequately provide for any strategy.

Even when producers are spread within a small geographic range, they still have varying needs and vastly different capital available – or access to capital. Many of the existing projects sponsored by various national and international organizations have exposed the lack of understanding the conditions and needs of members' communities. For example, in many focus groups, some producers identified a need for water collection systems due to lack of reliable water supply, while their neighbors perceived sufficient water supply due to their location next to a lake or stream. In order to resolve such issues, well-designed pre-implementation needs assessments should be applied proceeding implementation of any strategy discussed above. Such assessment may include inventorying perceptions of interests among producers, and assessing the urgency of needs amongst communities in terms of financial, natural, and social conditions. With such a protocol in practice, prior to introducing the strategies, the process could mitigate the knowledge gap among the communities, and correct the mismatching between resource allocation and resource need.

The other common recommendation for both countries is to increase the collaboration among stakeholders at all levels. As mentioned in the results sections, current pilot projects are unevenly distributed, which reveals the lack of communication and cooperation work among donors and other stakeholders within the coffee chain. It may be worthwhile to dedicate a staff member or office to stakeholder engagement in both cooperatives to facilitate and allocate ongoing and potential projects. Staff in such an office could communicate with existing project-supporting organizations and potential donors to collect ideas in order to create collaborative plans across multiple stakeholders, and to keep up with the recent research to circulate within cooperatives to update members with the agricultural news. Additionally, learning from another local cooperative in Peru, CenfroCafé staff could design an annual report including project information and financial statements for the cooperative to circulate among stakeholders to inspire collaborative actions. Although full collaboration of all stakeholders would seem unrealistic, a continuous conversation among different participants bridged by a Stakeholder

Engagement Office could offer opportunities to explore other joint actions to maximize the benefits to smallholders in increasing resiliency to climate change.

CCC, CODECH, CenfroCafé, and their sub-associations are already doing a lot to improve resiliency, including implementing coffee plant nurseries to promote renovation or funding infrastructure projects and research on coffee varietals. It is worthwhile to continue support for these efforts, which ensure sustained capacity at all levels so the various stakeholders are able to function. For example, CCC's role in connecting CODECH and CenfroCafé to the specialty coffee market is a major asset in increasing incomes, and potential resiliency, for smallholder farmers. One interviewee responded that:

> *creo que lo más importante es que como esos cafés son buenos, son de calidad, no compitan en el mercado internacional porque se los comen – el mercado brasileño nos come a todos, no podemos competir con 52 millones de sacos. Lo ideal es sacarlos de ese mercado mayorista, que tengan un mercado de café especial. Para favorecer eso, hay que buscar compradores directo* ("I think the most important thing is that these coffees are good, are of quality, [because] they cannot compete in the international market because it will eat them – the Brazilian market eats us all, we cannot compete with 52 million bags. The ideal is to take [the smallholders] from the wholesale market, to have a specialty coffee market. To facilitate this, you have to look for direct buyers") (Personal communication, July 2015).

For CODECH members in Guatemala, a general recommendation is that producers renew their plots and renovate their plants as they age out. Many producers have plants that are 30-40 years old, and bear very little fruit. This, coupled with the fact that many producers are hesitant to prune or otherwise intensively manage their plants for fear they won't adequately regenerate, has led their plots to not be as productive and robust as they could be. CODECH has already established two coffee plant nurseries using part of the fair trade price premium they receive on their coffee to support this effort to renovate member coffee plantations, though could use support in further scaling up this effort.

Unlike Guatemala, Peru is a relatively young player in global coffee market. Peruvian producers are still learning and obtaining information on agricultural technology and practices through observation and from foreign countries and organizations. As one of the largest cooperatives in

Peru, CenfroCafé has an abundance of ongoing programs and upcoming projects to increase member resiliency and improve livelihoods. Respondents mentioned financing programs (*e.g.*, credits for solar dryer credits), training projects (*e.g.*, Young Farmer Education Camp to provide technical training to the young farmers or sons of the members), and home renovation projects (*e.g.*, Better Kitchen Better Life to improve members' cook stoves thereby preventing indoor pollution). Therefore, one recommendation for CenfroCafé is to continually support and organize these projects by incorporating the suggested adaptation strategies. For example, CenfroCafé could facilitate pest monitoring and management training sessions as the part of young farmer camp and train them to be the new *promotor* in their community to help with self-monitoring implementation. Or when providing financing to members, CenfroCafé could provide a follow-up bonus in support of those who have made efforts to train for solar dryer operation and maintenance.

CONCLUSIONS

Through this project, we have confirmed several overarching concepts, and provide the following comments in conclusion:

First, as described in the first year's results and confirmed by our research, climate change is already impacting the livelihoods of smallholder coffee producers and other actors along the coffee supply chain (Fox et al., 2015). Variability in precipitation and shifting seasons have interrupted many traditional processes involved in production of coffee. The most vulnerable smallholders could increase their resiliency to such effects through adaptation strategies with support from a variety of stakeholders.

Second, and related to our recommendation for pre-implementation needs assessments: there are no "cookie cutter" or blanket solutions, as exemplified by the differences in feasibility for solar dryers amongst the two countries. While Peru has had numerous successful pilot projects, solar dryers in Guatemala are far less feasible due to their steep terrain, and small plots. Additionally, many farmers from lower altitude locations may have sufficient sunshine to dry coffee and prefer to practice the conventional coffee drying method, prioritizing their investments elsewhere. As

mentioned above, it is crucial to assess the needs of individuals before implementing projects across a wide geographic area. While some strategies may generally be more feasible than others, each is dependent upon a complex set of variables. Moreover, while there is variation in suitability, there are also significant differences in opinion amongst individual producers, based on the complex environmental, cultural, economic, and political factors which impact perceived, and actual, feasibility.

Third, no one strategy will sufficiently allow producers to adapt; therefore, multiple projects should be piloted and pursued. Further research and feasibility studies are encouraged to explore other adaptation strategies to increase smallholders' resiliency to climate change impacts. In general, farmers who had implemented one strategy were more keen on implementing a second; however, this acceptance of a need to adapt must become more widespread in order to truly shift producer communities to more resilient livelihoods.

In reference to our selected strategies for research, income diversification is of medium-high feasibility for CODECH in Guatemala, with significant up-front financial and human costs, but the potential for immense improvements in resiliency. Due to the terrain and financing required to implement solar dryers, they are of high feasibility for CenfroCafé in Peru; however, they are of low feasibility for CODECH in Guatemala due to inadequate terrain. Collective seed banks and nurseries are assessed as having low feasibility for CenfroCafé in Peru due to insufficient funding, labor, and social cohesion. Proactive pest and disease monitoring and management has the potential to significantly impact the resiliency of producers by allowing them to tend to their crops with more care; however, the immense lack of human knowledge leads us to assess the feasibility of this strategy as low for CenfroCafé. Collecting rainwater would allow producers to process coffee despite times of invariable precipitation, and can be implementing with a variety of materials; therefore, this strategy has high feasibility in Guatemala for CODECH.

Finally, CCC is an exemplary roaster making real impact by meeting their economic bottom line while committed to high social and environmental standards. CODECH and CenfroCafé, along with other producers from whom CCC sources coffee, are already implementing projects to improve farmer resiliency and adapt in the face of climate change, much of which is due to their

relationship with and support from CCC. Such exemplary efforts should be recognized, encouraged, and continued to be expanded upon.

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APPENDICES

Appendix A: List of 17 recommendations to CCC from the first masters group

(Fox et al., 2015)

1. Monitoring pests and diseases and how those impact different varieties.
To overcome pests and plant illnesses it is important to acknowledge the source of the detriment as well as what exacerbates the effects as well as mitigates them. Effective recording and registering of databases that allow producers to see trends of how varieties are affected in different altitudes or with different densities of shade trees could improve the resilience of producers when impacted by a plague. We recommend to have short, boilerplate documents that are straightforward to complete in order to record this information. Workshops or capacity building exercises are required in order to demonstrate to producers the importance of keeping those records organized, complete, and up to date. The data could be collected at the household level and aggregated by the local association leader before submission to the cooperative.

2. Local-level resource maps.
In our interactions with smallholder farming communities, we did not observe structured documentation of locally-based natural and agricultural resources. In the coffee association in San Miguel, Peru (of Cenfrocafé), the community had a self-drawn map that illustrated the town center and social resources, member farm locations, waterways and forests, and distances between these points. Similarly, the Grupo Autónomo para la Investigación Ambiental (GAIA) of Oaxaca, Mexico, led a community-level resource documenting initiative to illustrate shared and complementary resources between coffee farmers in the region (for more information, refer to the Comision Nacional Forestal (CONAFOR) website). We recommend that each smaller association and/or base cooperative create a map to inventory the resources within their own communities.

These maps would be created by the community and used within the community to identify locations of resources, potentials for sharing resources, and effective agricultural management strategies. Mapped resources may include locations of homes and farmland, town centers, communal/public land, waterways, forested areas, transportation networks, and distances between these resources. Additionally, these maps would illustrate the agricultural resources of each cooperative member's farm, such as the varieties of coffee cultivated or methods of shade management.
This information about local agricultural and natural resources is necessary to create baseline data used for tracking and monitoring changes in land use, climate patterns, coffee varieties, and diversification strategies. The data collected is critical for a variety of purposes, including:

- Strategically diversifying farms within the same locality to increase the variety of products and seeds for producer livelihoods as well as the connectivity of forested area for ecological diversity.

- Facilitating community-level exchange of local, high quality seeds selected from individual farms to augment production of trees for timber, fruit trees, vegetables, and coffee varieties.
- Promoting agricultural product trading among farmers in the same region. If neighboring farmers grow different subsistence crops they can trade with close neighbors even when the volume is not enough to bring to the market.
- Labeling hot-spots or zones of pest and disease events. Cooperative members in a community could report problem with a particular pest (e.g. roya) on their farm and an association leader could use the map to identify commonalities among affected farms. Attributes of interest on the maps would include location, coffee varieties, shade cover, altitude, and aspect. This could lead to better organized and more effective pest-fighting strategies for the farmers in that area.
- Instigate local research on varieties and coffee quality (see recommendation 4)

3. Cooperative-level data management of resources

We found that the cooperatives track basic information about individual producers in their network. However, cooperative leaders were struggling with two key issues, particularly in Guatemala and Peru. First, a limited number of technicians and second, difficulty in verifying which practices would guarantee consistent high quality coffee year over year on a specific farm. Building on the resource mapping from recommendation #3, cooperatives could pull together the community-level data to create landscape level planning across the regions where their members reside. Additionally, the cooperatives could organize their data in such a way as to systematically create baselines, track trends, and monitor changes in management strategies and cupping quality. Data could include coffee varieties, shade management, income diversification, cupping score, and issues with pests and diseases of each farmer. Improved data collection and management would allow cooperatives to understand and subsequently address the needs of their members, including how management practices relate to cupping score. Additionally, this could even help the local emergency networks and improve disaster relief mechanisms when severe weather events occur. In the long term, it could lead to programs of transferring credits and premiums to producers such as the ones implemented by the FNC in Colombia in which every producer has an ID card that allows them to use it as a credit card and buy farming materials.

4. Further research on pest-resistant varieties.

Cooperatives should exercise caution when promoting new pest-resistant varieties amongst their members. Especially in response to the roya epidemic, many farmers have felt pressure to renovate with roya-resistant varieties like Catimor and Colombia. Many participants in our study remarked that while these varieties were resistant to roya, they also resulted in a lower cupping score for quality. Research on coffee varieties and cup quality have shown mixed results, but generally demonstrate a decrease in quality with roya-resistant varieties, particularly with an increase in elevation (p. 12). However, there is controversy ab, and further research needs to be done.

We recommend that the cooperatives perform systematic sampling of coffee varieties at different altitudes to determine if coffee cupping quality of some varieties is significantly lower than others. Second, the cooperatives should have frank discussions with their coffee buyers and exporters about whether these new varieties have future market value or similar pricing. This

discussion between cooperatives and specialty coffee buyers, like Counter Culture Coffee, is necessary in maintaining positive commercial relationships and ensuring future contracts.

5. Coffee preparation training for producers.
Many coffee growers have never prepared or sampled their own coffee nor have a strong understanding of how the final consumer prepares his or her coffee, especially in Guatemala and Peru. Teaching farmers how coffee is roasted and prepared for consumption will aid in growing the domestic market for coffee. Furthermore, having trainings and tasting for farmers which allows them to personally compare the properties of the different varieties of coffee, distinct preparations of coffee, as well as how the quality of the end product is impacted by exposure to humidity, leaf rust, or improper cultivation or processing techniques. By exposing farmers to the outcomes of different agricultural inputs and practices, the farmers will be more strongly connected with their product and have a more comprehensive understanding on how actions taken on the farm during different stages of the coffee's lifecycle will promote more desirable qualities and therefore a more competitive price for the coffee.

6. Funding solar driers.
Many strategies to adapting to climate change focus on pre-harvest management issues, however, climate change can have an effect on post-harvest processing as well (p. 66). Drying coffee beans to a certain humidity level in the appropriate amount of time is difficult if there is unpredictable rain, humidity, and/or cloud cover. The timing of coffee drying can severely impact coffee quality (i.e. molding), which decreases the price per sack for the producer and lower the overall quality of the cooperative.

This is particularly a problem in Peru, and has potential to be a problem in Guatemala. Colombian farmers have addressed this issue by installing solar driers (secadores solares) on their farms. We recommend that the cooperative help fund the materials for solar driers for at least every association, so that farmers could share a communal space for drying coffee in case of poor weather conditions. The association could decide on a communal location for the solar drier, create a design plan and materials list, and apply to the cooperative for materials. In addition to materials, the cooperative could additionally provide the expertise of technicians or agricultural engineers to assist in the design and set-up process.

7. Local Tree Nurseries.
We found that as much as coffee-growing regions were being deforested, there were also plenty of reforestation efforts led by cooperatives, NGOs, and municipalities. For example, one of the base associations of CODECH had a reforestation program for their locality. Additionally, the Centro experimental del café y capacitación municipal of San Ignacio, Peru, created a nursery of tree seedlings for shade and riparian reeds for water control. One Peruvian farmer particularly inspired us with this quote:
There are many forested mountaintops and there are reforestation projects there, the authorities provide incentives. They make nurseries for all types of trees, but native to this region. Because if I -- here in this region there is cedar, and over there there are timber trees, and they collect the seeds from the best trees, get that seed, and incentivize.
Hay bastante montañas y allí hay reforestaciones, incentivan las autoridades. Hacen viveros de todas clases de árboles pero de la zona. Por si yo -- aquí en la zona hay cedro, allí el varejón

que llamamos maderables, y ellos sacan las mismas semillas de los mejores árboles, sacan la semilla, e incentivan (personal communication, May 27, 2014).
We feel that multiple local reforestation projects could greatly benefit smallholder farmers, especially when considering the protection watersheds, reduction of erosion and landslides, and ensuring future timber and firewood use.

Thus, we recommend that creating communal plots in the form of tree nurseries should be established in order to facilitate the development seed banks or even the installation of a subsistence crop system. This could lead to reforestation programs in which the cooperative designates a specific producer to lead the project. Farmers would to look within their region for (a) native forest trees, and (b) successful shade trees, to collect seeds/nuts, seed them in nursery, and when they are large enough distribute throughout community for farm shade trees and for reforestation with native and local species. Also, the communal work share brings the community together, increases social capital and could improve transfer of knowledge and open spaces for dialogue.

8. Farmer-to-farmer training programs.
Extension agents or technical assistants are one of the fundamental assets of cooperatives in increasing resilience and promoting adaptation strategies. However, in the case of CODECH, the cooperative has only one technical assistant for over 650 members who reside in large geographic area. As CODECH currently lacks the resources and capacity to work with the entire community of cooperative members, we recommend establishing a formal farmer-to-farmer training program. Many key actors in Guatemala explained how farmer-to-farmer trainings are one of the most effective ways of training smallholder producers and facilitating adaptation to climate change. This program at CODECH could improve the dissemination of knowledge and technical assistance and ensure the continuation of skills within the community.

This program could work many different ways, but we suggest that each base association of CODECH choose at least one of their best producers to be trained by their main technical assistant. After receiving training, this producer would return to his or her region and continue to disseminate knowledge of best management practices or adaptation strategies to other members of the base cooperative. In this way, a larger network of producers is captured and more producers are able to receive training. Furthermore, this system has the potential to unburden some of the workload of the technician, allowing him to focus more on researching new adaptation strategies, addressing special events such as natural disasters, or investigating new, useful technologies.

9. Branding and marketing training.
Counter Culture Coffee or other organizations on field could provide skills, workshops, and training in branding and marketing as a first step towards having a high quality marketing presence on each of the cooperatives. Furthermore, these cooperatives could use social media, such as Facebook, to improve reach to domestic and international buyers and consumers. This may be particularly useful for Peru in order to increase domestic market and promote the Cenfrocafé coffee shops in Jaén and Lima.

Each cooperative had different strengths as well as areas of improvement in terms of the branding and marketing of their product and of the cooperative itself. Below is a list of the most critical areas that each cooperative should address first address before moving forward with a more sophisticated marketing strategic plan:

- CODECH - the logo featured on CODECH's website does not make the name of the cooperative apparent and consumers. Furthermore there is religious undertones of the logo which could alienate some potential consumers. The logo must be redesigned, and better used, so that consumers can easily understand see what brand the coffee is coming from and so that the logo is inclusive of all demographics of consumers. Finally the cooperative needs search optimization as searching for "CODECH" or for "Guatemalan coffee" does not bring users to the CODECH website within the first page of search results.
- Cenfrocafé - has an established social media account on Facebook. That being said the page has not been updated for over a year. Cenfrocafé should revisit updating its Facebook page in order to foster its domestic market branding and presence their coffee shops. Cenfrocafé should also design a website that the social media accounts will drive traffic to in order to provide consumers with further information about their products.
- La Orgánica - La Orgánica does not have any online presence. The first action La Orgánica should take is designing a website. There is limited information about the cooperative online and it is exclusively on external websites. La Orgánica would benefit from a website because it will increase visibility of the cooperative to consumers and even coffee buyers as well as provide information about the practices and quality of the product.

CODECH's current website and the future sites for La Orgánica and Cenfrocafé should contain at least information regarding variety, exportable containers, number of members, and contact information so those in the coffee industry will be able to inquire about potential orders.

10. Water collection systems.

In Colombia and Guatemala producers report to have difficulty in obtaining sufficient water for their farms (p. 79), especially in times of high rain (infrastructure failure) and no rain (drought). Additionally, water was especially scarce during times of coffee washing and fermentation. Plus, climate change models suggest changes in precipitation which could reduce water resources in the future.

Supporting water infrastructure would increase climate resilience of cooperative members, especially in regions where rain water availability is highly variable or is predicted to decrease with climate change. We recommend this infrastructure, coming in the form of equipment such as rain barrels or tanks that may be able to supply a constant volume of water throughout the year, including the dry season. These collection facilities could be located throughout the coffee plantation. The water collection could support both crop cultivation in the form of irrigation as well as post-harvest processing in the form of washing.

11. Rainforest Alliance.

Rainforest Alliance is an organization currently present in all the three countries, but only certifying Cenfrocafé coffee. However, key actor interviews found that Rainforest Alliance is

one of the most helpful providing training and technical assistance to smallholder coffee producers (see more about certification on p. 13 and p. 45). We recommend that CODECH and La Orgánica pursue Rainforest Alliance certification for their product to take advantage of these partnering opportunities.

12. Partnering with non-governmental organizations and other stakeholders.
There is a constant need of creating new partnerships to downgrade transactional costs and to improve the network of coffee cooperatives in each country. We found that cooperatives have strong links with some of these organizations but we recommend a continuous search of establishing effective partnerships with new organizations. Specifically in Guatemala the cooperative should look to connect with new organizations like Sustainable Commodity Assistance Network, Catholic Relief Services, Rainforest Alliance and Technoserve.

13. Cooperative partnerships.
In contrast to CODECH and Cenfrocafé, La Orgánica is a small cooperative (~120 members). At that size it is hard to execute higher level programs and long term goals. We recommend to find a second level or umbrella organization that is suitable for La Orgánica and can allow them to improve in their level of governance and social networks. However, it is important to ensure that there are benefits of all members of the cooperative.

14. Income diversification through value added products.
Based in field observations there is a potential in alternative processed products. There is an opportunity for the cooperative and its members to earn alternative income by offering processing of certain agricultural products to members. In Jaén, the municipality offered farmers training in beekeeping and honey harvesting. Similarly, the cooperatives could process fruits and herbs to produce jams or juices, dried fruit, medicinal teas or tinctures, in order to provide the communities with a new income stream that could improve and add a shared value to the community. In addition, coffee farmers operating between 600-1,200 meters where the quality, and thus price, of coffee is not as favorable as that in higher altitudes could transition to grow cacao if the cooperative offered training as well as processing services for the cacao syrup. With alternative streams of income, the coffee farmers will be more resilient to crop failures and the total incomes of the cooperative community as a whole will be more insulated from the price volatility of coffee.

15. Establish cooperative coffee seed banks.
We found that limitations on finding new seeds from different varieties introduce several constraints on the renovation programs and restricts the ability of producers to apply the adaptation strategies of using other coffee varieties as a way to control pests and diseases (p. 56). In the three countries, the national governments have imposed some type of regulations to restrict the trade of new varieties. Therefore, as a long term recommendation and at each cooperative, it could be beneficial to establish seed banks in which members can access and purchase seeds. Opening a channel for seed exchange between producers and the central cooperative system could improve the capabilities of farmer to renovate with new coffee varieties. Also, the development of those seed banks could be aligned with a program in which producers save seeds from their better suited trees and provide distribute those along the producers.

16. Cooperative leader conference.
The cooperative leaders from the three countries (and possibly others) should meet at an annual conference in order to share experiences about pest control, varieties, shade tree densities and other agricultural adaptations as well as programs for improving producer livelihoods. This program could improve the transition of knowledge and would promote best practices among the cooperatives.

17. Establish or continue supporting programs for women and youth.
In Guatemala and Peru, the cooperatives had programs promoting coffee production for women and youth, respectively. CODECH supports women's participation in production in two ways: one of the base associations of CODECH is a women's group, and CODECH sells Café de Mujeres (women's coffee) and explicitly markets it as such. Many women attend the trainings and workshops offered by the technical assistant, and women are part of the board. In contrast, women participate less in the cooperative in Colombia and Peru, and there are no programs specifically targeting women's membership and involvement. We recommend that La Orgánica and Cenfrocafé encourage more women to join the workshops and training events. This action could be in the form of establishing an organization similar to CODECH's, or simply promoting women's participation in the cooperative.

In Colombia and Peru, participants often cited generational transition (p. 84) as a critical issue for the future of coffee production. Cenfrocafé is currently addressing this issue through a program specifically designed to target the youth of member producers. These youth receive general education about the coffee industry and production, as well as take field trips to coffee-related locations such as processing facilities. This youth program in Peru improves the sustainability of coffee production by promoting the transition to the next generational and encouraging the vertical flow of knowledge. Since participants in Colombia also cited issues with generational transition and youth moving to other professional careers we recommend that La Orgánica establish a similar program among their cooperative members.

Appendix B: Interview Guide for Key Actor Interviews

There will be quite a bit of variation in the specific topics covered in each interview since it will be highly dependent on the sphere of influence and expertise of each interviewee. Some of the questions you will want to cover in these interviews are:

Does the interviewee think that the particular adaptation strategies we are studying are viable? Why or why not? What other adaptation strategies do they think might be effective for smallholder coffee producers in Guatemala/Peru? Why?

What are some of the barriers that exist (i.e. political, policy, financial, environmental technical, etc.) for implementing these types of adaptation strategies in Guatemala/Peru? What might some means that cooperatives could employ to overcome these barriers?

What organizations in Guatemala/Peru are already working on these types of adaptation strategies, in what ways and in what regions of the country? What other sources of support are available (i.e. political, policy, financial, technical, capacity building, knowledge transfer or training, etc.) in Guatemala/Peru?

Are there any documents or websites that the interviewee would recommend we review to that would help us better understand the feasibility of the adaptation strategies we are studying or the context in which they will be implemented?

Who else would the interviewee recommend you speak with about these adaptation strategies?

Appendix C: Interview Guide for Cooperative Leader Interviews

What do you think of the idea of developing ??? in your cooperative?

What would be some of the benefits of developing ??? in your cooperative?

What would be some of the barriers that would need to be overcome if ??? were to be implemented in your cooperative?

What resources does the cooperative or its members already have that could be used to implement ??? in your cooperative?

What other resources would be necessary in order to implement ??? and can you think of some sources where the cooperative or their members could secure those resources?

What kind of training would the cooperative leadership and/or members require in order to implement ???

What further information would it be helpful to have in order to make a decision about whether or how it would make sense to implement ??? in your cooperative? Where do have any ideas where we could find that information?

Appendix D: Interview Guide for Focus Groups & Community Asset Mapping Exercise

Focus Groups:

What do you think of the idea of developing ??? in your community?

Do you think it would be better/easier to develop ??? at the level of the community/sub-coffee association level or with individual households? Why?

What would be some of the benefits of developing ??? in your community?

What would be some of the barriers that would need to be overcome if ??? were to be implemented in your community?

What resources does this community or the individual households already have that could be used to implement ??? in your community?

What other resources would be necessary in order to implement ??? and can you think of some sources where the community or individual households could secure those resources?

What kind of training or further information would this community require in order to implement ???

Community Asset Mapping: *Community asset mapping exercises will be held directly after each of the focus group discussions and can be seen as an extension of that dialogue. The idea is to bring the power of the group together to think about the type of assets (e.g. capital) that are currently available in the community that they could draw on to implement the potential adaptation strategies. Steps are as follows:*

1. If there are enough people in the group, divide them into sub-groups, with each one focusing on one of the adaptation strategies. If there are not enough people, work as a single group, but produce a separate asset map for each adaptation strategy.

2. Give each group a piece of big tablet paper and 5 different colors of markers (good to have multiple markers of each color for each group so that multiple people can participate).

3. Ask each of the groups to draw a very basic map of their community in BLACK marker with the major landmarks (most important places) marked on them.

4. Ask them to draw with BROWN marker the infrastructure (e.g. buildings, roads, open spaces, machinery, tools, etc.) or the natural resources (good soil, water, forested areas, they already have available that could help in implementing ???

5. Ask them to draw with GREEN marker the natural resources (e.g. good soil, land/space for developing, water sources, forested areas for timber or other products, animals, etc.) they already have available that could help in implementing ???

6. Ask them to draw with PURPLE marker the people or organizations (this represents both knowledge held by individuals, organizations in the community that could help to organize people, or connections they have to other people or organizations that might supply needed resources) they already have available that could help in implementing ???

7. Ask them to draw with RED marker the financial resources (e.g. sources of credit, savings, subsidies from the government, income generating activities, etc.) they already have available that could help in implementing ???

8. Have each group come to the front of the room to present and describe each category that is represented on their maps. Be sure to both write on the map the names of the different things they have represented (ask them first!) AND take very detailed notes as they are talking. As important, be sure to take multiple, well-lit, high resolution photos of the maps when you are finished. It would be good to take the maps themselves with you when you go, unless the focus group members would like to hold on to them.

9. Facilitate a discussion with the entire group about what resources, other than those that the community already has access to, they might need implement ??? in their community, and where/how they think they might be able to access them.

10. If there is enough time and energy and the weather is good, ask folks from the focus group to show you some of the areas they drew on their maps. Have further discussions with them as you are at the sites about the questions discussed in the focus group.

11. Remember to write-up your notes in a cohesive fashion as soon as you can after each focus group.

Appendix E: Interview Guide for Cooperative Members

1. Why do you envision this approach working?
    a. What possibilities do you perceive in implementing this approach?
2. What kind of costs would that imply for you and/or your family? (e.g. time, financial resources, human capital, etc.)
    a. What are the potential risks associated with these costs?
3. What would you be willing to contribute for the implementation of this strategy? (e.g. collaborating with other members, financial resources, human capital, time, etc.)
4. How do you perceive yourself in terms of resources relative to other members of the cooperative? (e.g. credit, savings, labor, etc.)
5. What additional (savings) resources do you think you will have to contribute relative to the other members?
6. How do think your experience in income diversification different from other members of the cooperative?

7. Do you think the way benefits are shared among CODECH members based on their level of effort/production?
8. Do you feel represented in your cooperative?
9. Do you feel represented in your community?

Appendix F: Coding Guide

Theme A: Context under which smallholder coffee farmers are operating

1. IN-COUNTRY CONTEXT

Consists of discussion or description about the local context respondents mentioned about political, economic, social, historical or environmental context.

- POLITICAL: The the political aspects of the environment that are relevant to the situation/action, including aspects such as the distribution of power, the range of organizations involved and their interests, and the formal and informal rules that govern interactions.

- ECONOMIC: The environment in which businesses operate; this includes things like income, employment, presence of commerce/industry, distribution of resources.

- SOCIAL: the immediate physical/social setting in which people live and things happen, including culture, education, people, and institutions.

- HISTORICAL: the moods, attitudes, and conditions that existed in a certain time.

- ENVIRONMENTAL: the physical/natural world, including perceived climate changes, the landscape, environmental conditions, etc.

2. PERCEIVED CHANGES IN COFFEE PRODUCTION

Includes any reference to impacts of climate change on coffee production. For example, the cupping quality, the quantity harvested.

- QUALITY: the attributes and characteristics of the coffee harvest

    - INCREASED: increased in coffee production quality, cupping quality, and coffee market price

    - DECREASED: decreased in coffee production quality and cupping quality, and negative impacts on coffee market prices.

- QUANTITY: the volume of the coffee harvest

    - INCREASED: an increase in the volume of coffee production

    - DECREASED: a decrease in the volume of coffee production

- NO IMPACTS: unaffected, steady production quotas and quality

- NA / OTHER: perceived changes in coffee production without specifying the outcome of the impacts

Theme B: Previous experience in implementation of projects

1. CURRENT EFFORTS / ADAPTATIONS

Includes information about what efforts or adaptations producers have attempted, or are attempting, to implement in order to improve and/or secure the quality and quantity of their coffee production.

- DIFFERING VARIETIES: growing multiple varieties of coffee in the same parcel

- INTERCROPPING: growing two or more crops in the same area

- FERTILIZERS, PESTICIDES: application of fertilizers, pesticides, herbicides, etc

- IPM: integrated pest management - use of labor-intensive integrated methods to eliminate pest damage while minimizing the use of pesticides

- EROSION CONTROL: preventing or controlling land degradation from wind or water

- SOLAR DRYERS: constructed systems which amplify the heat of the sun to more effectively, evenly dry coffee

- WATER COLLECTION SYSTEMS: infrastructure allowing for the collection and storage of water

- INCOME DIVERSIFICATION: the practice of having multiple sources of income in order to reduce risk of external shocks

- SEED BANKS OR NURSERIES: the practice of storing seeds as a source for planting in case others are destroyed or participating in group nurseries to germinate seedlings for use

- OTHERS: other practices related to climate change adaptation strategies

2. PRODUCER EXPERIENCE

Includes information on previous producer's experiences in implementing related adaptation strategies. It also includes the information the respondents could have mentioned that can help determine the source of success and/or failure.

- SUCCESS: previous efforts including former projects, innovative agricultural practices has resulted in positive changes in coffee production and producers' livelihood.

- FAILURE: previous efforts leading to negative changes or no change in coffee production or producers' livelihood

- LESSONS LEARNED: conclusive statement or comments by respondents on previous experience from projects and agricultural practices

- NO EXPERIENCE: no previous project or practice with selected climate change adaptation strategies

3. LEVEL OF IMPLEMENTATION IN FORMER PROJECTS

Includes any mentions to the the level of the implementation of previous experiences.

- FEDERAL/NATIONAL: projects or practices were adapted on national scale or more than one state/province.

- STATE: strategical practices were implemented within one state/province.

- LOCAL/MUNICIPAL: projects or practices were conducted within one municipal region.

- COMMUNITY-LEVEL: specific projects or strategies were adopted in certain communities.

- COOPERATIVE-LEVEL:

    - BASE: associations formed by a group of cooperative members, not necessarily within one community

    - MID: Specifically for CenfroCafé, which has 12 management networks under the top level
    - TOP: cooperative level (CenfroCafé and CODECH)
- INDIVIDUAL FARMER: at the level of individual cooperative member
- OTHER: not specified by respondents

4. FORMER STAKEHOLDERS INVOLVED

Any mentions to the stakeholders involved in implementing previous experiences.

- GOVERNMENT: governmental agencies and organizations
    - INTERNATIONAL: international governmental agencies
    - FEDERAL/NATIONAL: national governmental agencies (Peruvian National Government and Guatemalan National Government)
    - STATE: State governmental agencies
    - LOCAL/MUNICIPAL: Municipal or local governmental agencies
- COOPERATIVES
    - BASE: associations formed by a group of cooperative members, not necessarily within one community
    - MID: CenfroCafé was organized and divided into 12 network regions
    - TOP: cooperative level (CenfroCafé and CODECH)
- PRIVATE COMPANIES: coffee buyers, roasters and retailers
- NGOs
    - INTERNATIONAL: international non-governmental or non-profit organizations (e.g. Rainforest Alliance, Fair Trade USA)
    - FEDERAL/NATIONAL: national non-governmental organizations (e.g. National Coffee Board in Peru)
    - LOCAL: local non-governmental working groups

Theme C: Feasibility of the strategy

1. STRATEGIES
Include the five adaptation strategies and other strategies that are mentioned by respondents.

- INCOME DIVERSIFICATION: the practice of having multiple sources of income in order to reduce risk of external shocks

- Pest Monitoring & Management: initiation of a farmer-implemented monitoring system where producers record noteworthy problem areas in their coffee farm, the information is collected periodically (perhaps at the association level by association presidents or CenfroCafé technicians; perhaps weekly/biweekly/monthly), the data is aggregated, and sent to Cenfro's main office (or other, smaller network-level office) for analysis by technicians. Then feedback and suggestions are provided for improving pest management via IPM (integrated pest management) - use of labor-intensive integrated methods to eliminate pest damage while minimizing the use of pesticides

- SOLAR DRYERS: constructed systems which amplify the heat of the sun to more effectively, evenly dry coffee

- SEED BANKS: the practice of storing seeds as a source for planting in case others are destroyed or participating in group nurseries to germinate seedlings for use

- WATER COLLECTION SYSTEMS: infrastructure allowing for the collection and storage of water

- OTHER: other adaptation strategies suggested by respondents

2. CAPITAL NECESSARY FOR IMPLEMENTING

Includes the resources the community has and also current efforts in implementing a similar adaptation strategy that could be scaled.

- FINANCIAL: availability of funding and access to credit and income, household finances, and remittances

- HUMAN: formal and informal education, work experience, and employment

- NATURAL: access rights, climatic conditions, and land, water and other natural resources

- PHYSICAL / MANUFACTURED: household assets, , tools (shovels, machetes, boots, notebooks, etc), supporting infrastructure, road and transportation, and reliable water supply

- SOCIAL: shared trust between members, cultural norms, networks and conditions that affect access to livelihood assets

3. EXISTENCE OF CAPITAL

Includes any discussion on the policies, government programs, technical skills, etc. that the participants perceive as available, and could potentially be used for implementing the strategy.

- AVAILABLE: capitals listed in the previous section are perceived as available
    - UTILIZED: available capitals are used in the previous or current projects/practices.
    - UNDERUTILIZED: unused capitals that respondents know and have the access to
- NON-EXISTENT & NEEDED: capitals listed in the previous section are perceived as necessary and unavailable or lack of accessibility/information.

4. LEVEL OF IMPLEMENTATION

Includes any mentions to the the level of the implementation of previous experiences.

- FEDERAL/NATIONAL: projects or practices were adapted on national scale or more than one state/province.
- STATE: strategical practices were implemented within one state/province.
- LOCAL/MUNICIPAL: projects or practices were conducted within one municipal region.
- COMMUNITY-LEVEL: specific projects or strategies were adopted in certain communities.
- COOPERATIVE-LEVEL:
    - BASE: associations formed by a group of cooperative members, not necessarily within one community
    - MID: Specifically for CenfroCafé, which has 12 management networks under the top level
    - TOP: cooperative level (CenfroCafé and CODECH)
- INDIVIDUAL FARMER: at the level of individual cooperative member
- OTHER: not specified by respondents

5. POTENTIAL SUPPORT, PARTNERS, AND STAKEHOLDERS

Any mentions to the stakeholders involved in implementing previous experiences.

- GOVERNMENT: governmental agencies and organizations
    - INTERNATIONAL: international governmental agencies
    - FEDERAL/NATIONAL: national governmental agencies (Peruvian National Government and Guatemalan National Government)
    - STATE: State governmental agencies
    - LOCAL/MUNICIPAL: Municipal or local governmental agencies
- COOPERATIVES
    - BASE: associations formed by a group of cooperative members, not necessarily within one community
    - MID: Specifically for CenfroCafé, which was divided into 12 network regions
    - TOP: cooperative level (CenfroCafé and CODECH)
- PRIVATE COMPANIES: coffee buyers, roasters and retailers
- NGOs
    - INTERNATIONAL: international non-governmental or non-profit organizations (e.g. Rainforest Alliance, Fair Trade USA)
    - FEDERAL/NATIONAL: national non-governmental organizations (e.g. *La Junta Nacional de Café*/ National Coffee Board in Peru)
    - LOCAL: local non-governmental working groups

6. EXPECTED/ POTENTIAL IMPACTS

Includes information on how respondents perceive the outcomes of implementing selected adaptation strategies. It also includes the information the respondents could have mentioned that can help determine the perceived impacts as positive or negative.

- CO-BENEFITS/ EXTERNALITIES: benefits or externalities that indirectly relate to coffee production.
    - POSITIVE
    - NEGATIVE
- DIRECT IMPACTS TO COFFEE PRODUCTION: benefits or externalities that directly relate to coffee production.
    - POSITIVE
    - NEGATIVE

Theme D: Other

- **MEMORABLE QUOTATIONS & USEFUL FACTOIDS**

Useful or potentially significant themes, quotations, or facts which may be useful in writing the MP paper.

- **UNCLEAR OR BIASED CODING**

Due to difficulties in transcription, or incomplete/compromised sound recording leading to unclear/unsure coding.

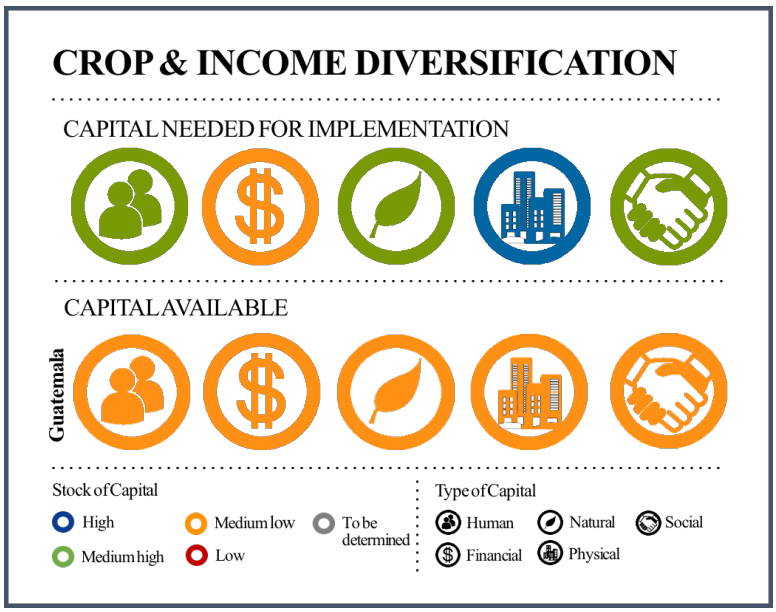
- **POSSIBLE MISINTERPRETATION**

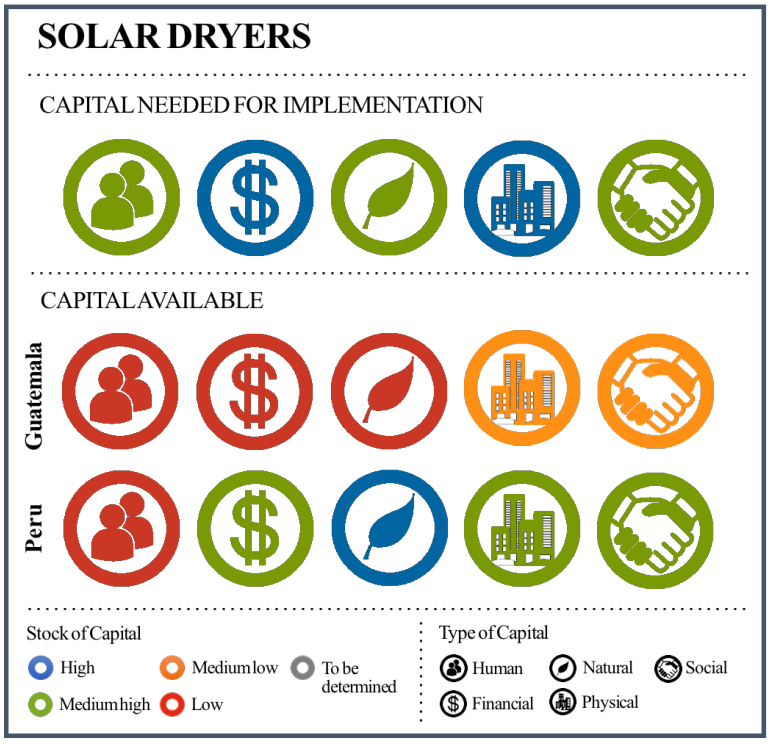
Difficulty understanding Spanish; potentially compromised or misunderstood translation from local language to Spanish; or difficulty of clients to understand questions.

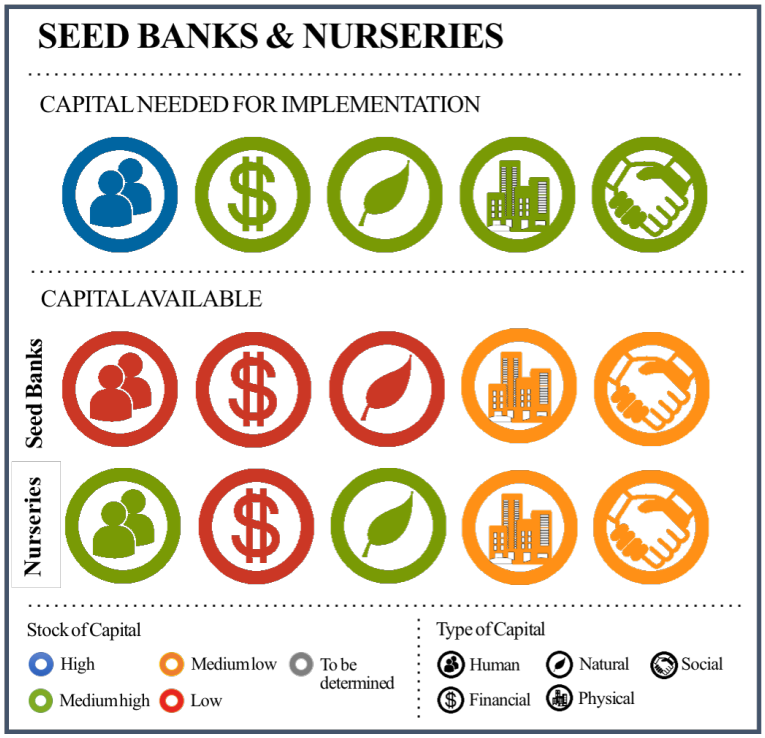
- **INTERESTING INFO FOR CLIENT**

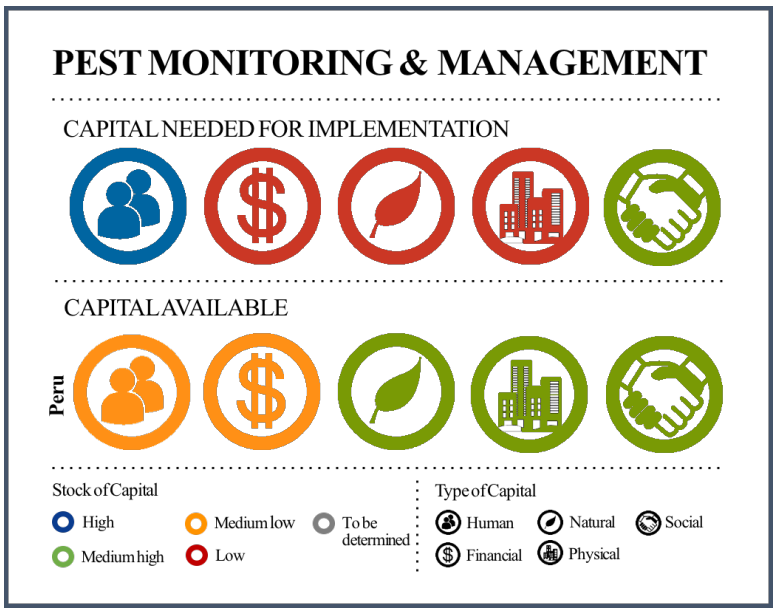
CCC is also quite interested in knowing what farmers are doing in general to improve their harvest quality. As this is not directly related to our RQ, some of it may be collected in other nodes (in particular, XX) but many interesting tidbits for them may not fall under other categories.

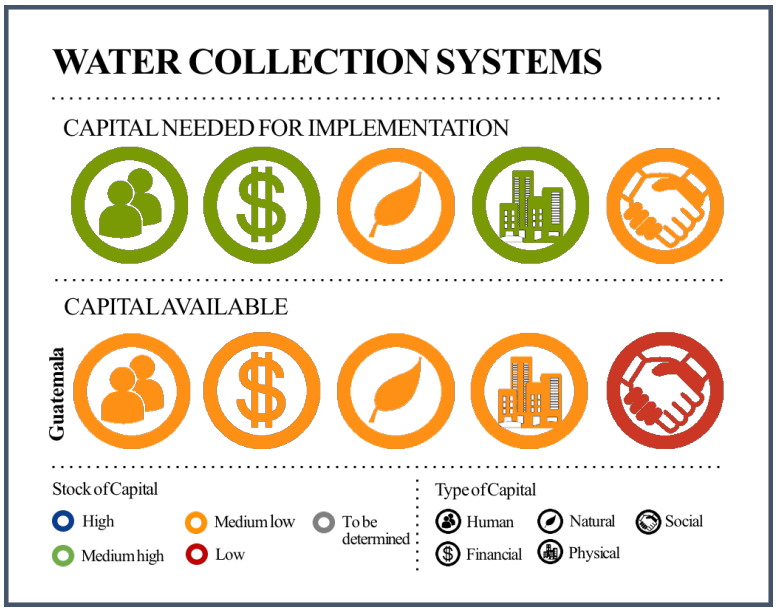
Appendix G: Feasibility Graphics per Strategy




SOLAR DRYERS
CAPITAL NEEDED FOR IMPLEMENTATION
CAPITAL AVAILABLE
Guatemala
Peru
Stock of Capital
High
Medium high
Medium low
Low
To be determined
Type of Capital
Human
Natural
Social
Financial
Physical


SEED BANKS & NURSERIES
CAPITAL NEEDED FOR IMPLEMENTATION
CAPITAL AVAILABLE
Seed Banks
Nurseries
Stock of Capital
High
Medium high
Medium low
Low
To be determined
Type of Capital
Human
Natural
Social
Financial
Physical

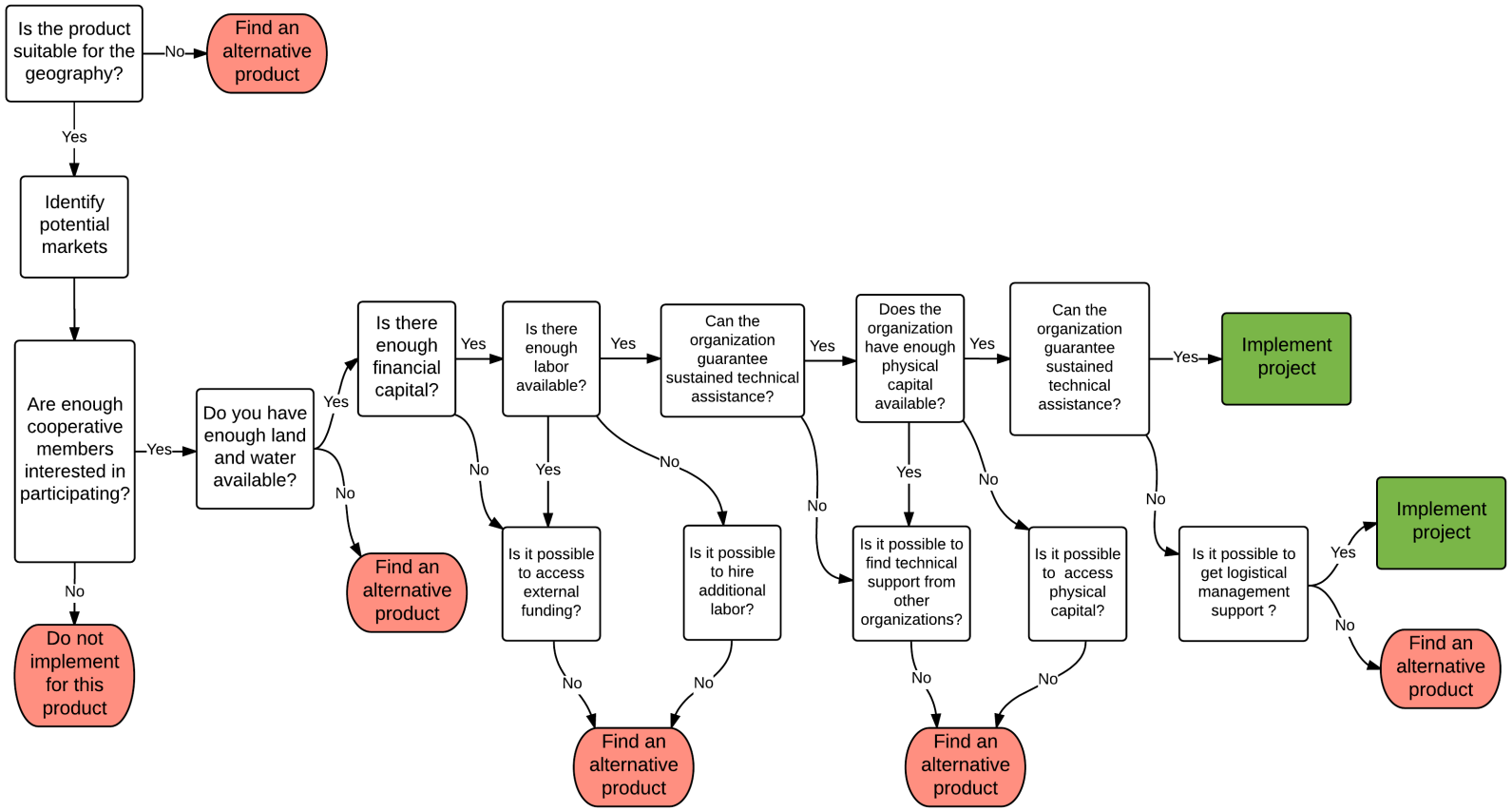




Appendix H: Products Mentioned for Diversification

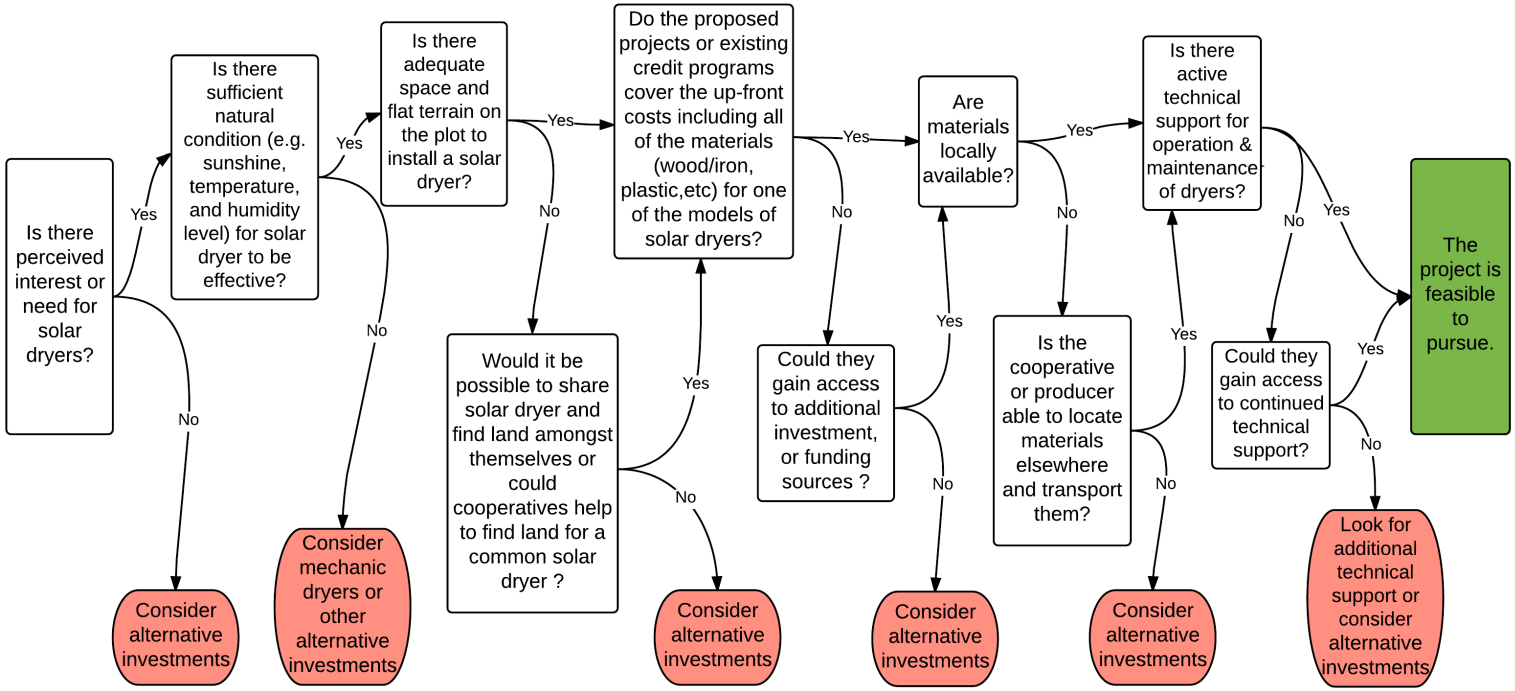
apple
avocado
banana
beans
bees (honey)
beet
broccoli
cabbage
carrot
cauliflower
chard & other greens
cherries
chickens
chili
corn
grains & flours
herbs (various)
hibiscus flowers (for cooking)
lemon
mango
mushrooms
nectarine
onion
passion fruit
peach
peanuts
pepper
plums
potato
radish
sheep
squash
sweets (from coffee)
tomato
wine (from coffee)

Appendix I: Decision Tree for Income Diversification

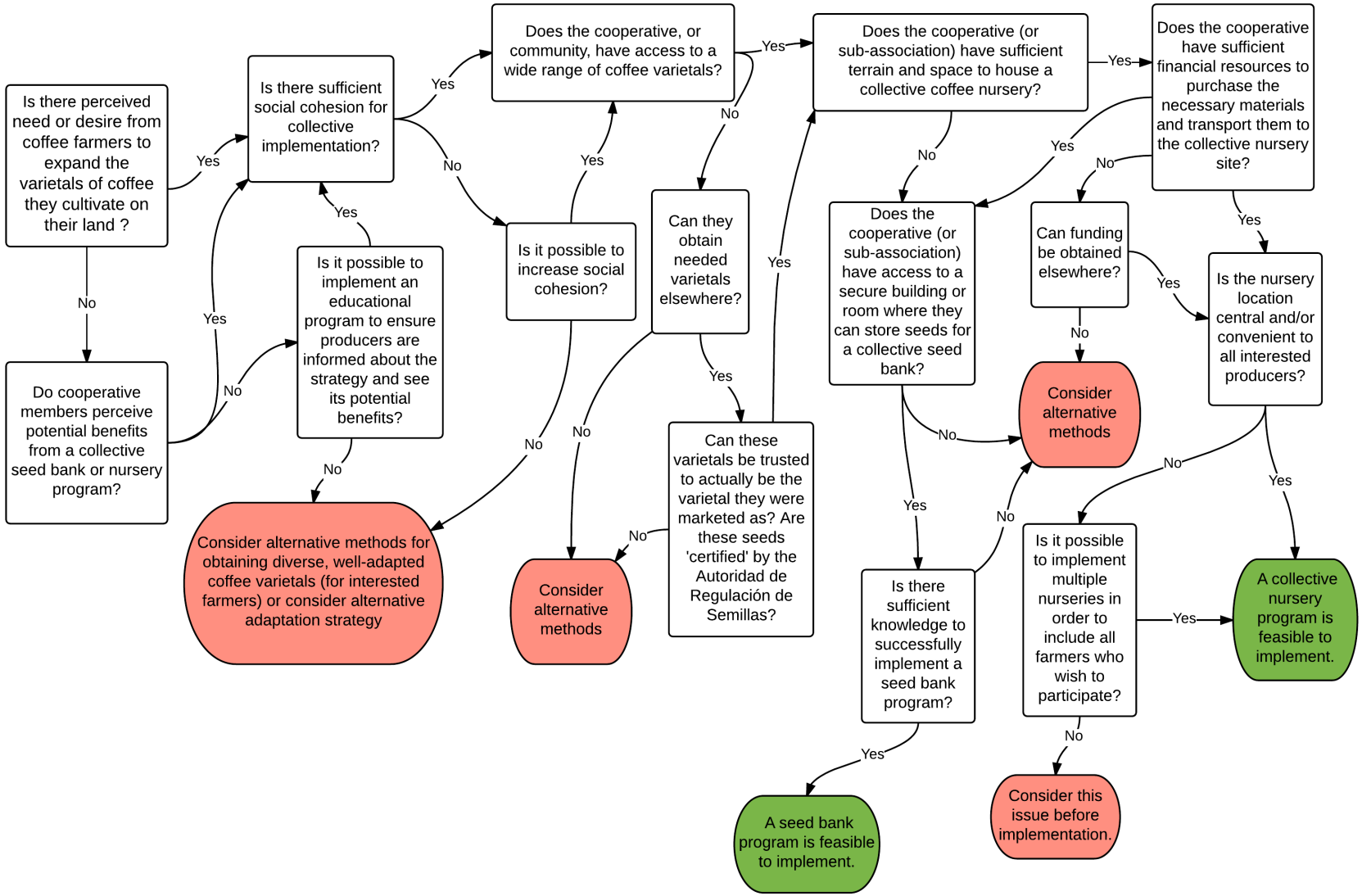


Source: (Rivera Aguierre, 2016)

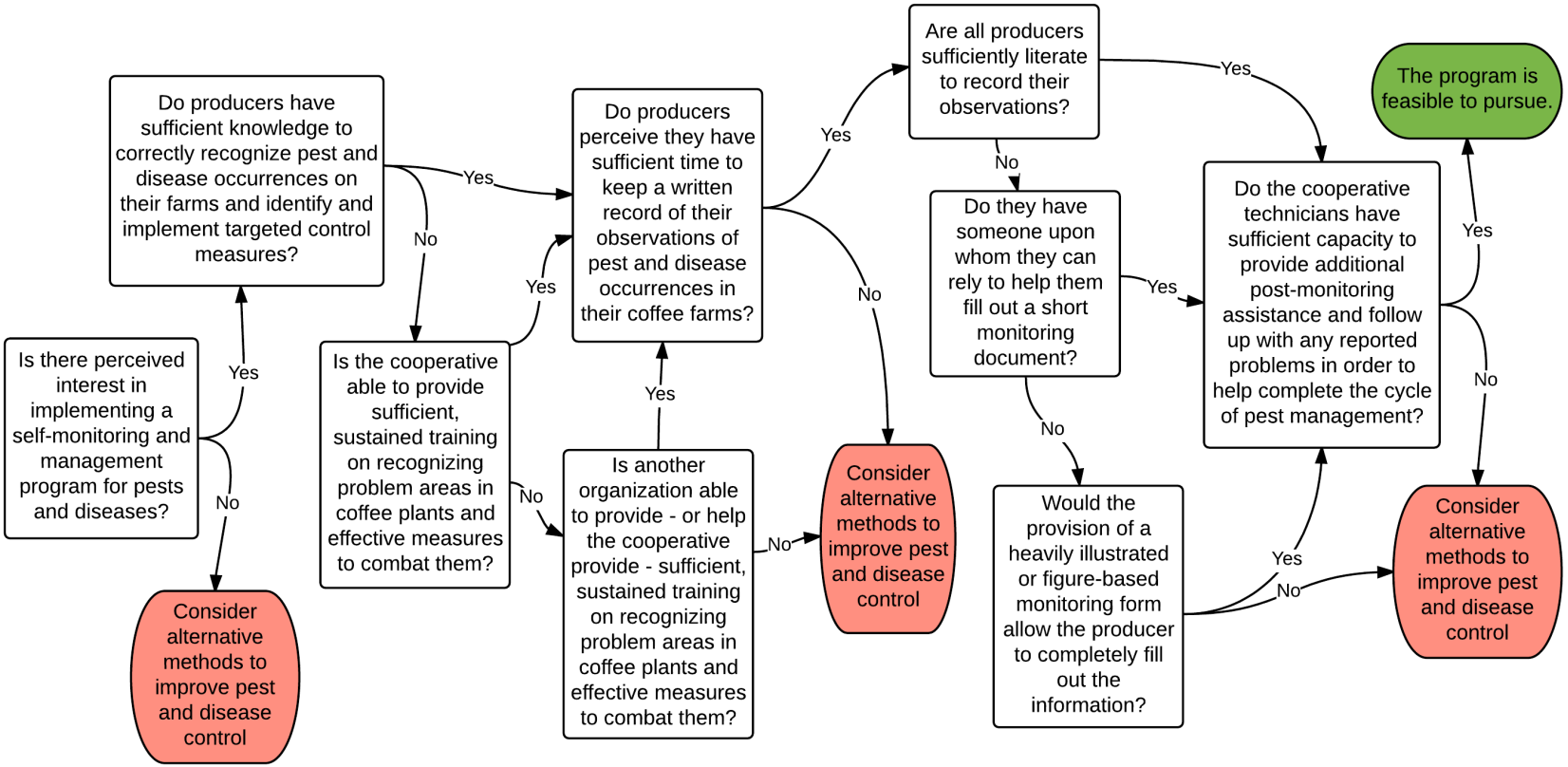
Appendix J: Decision Tree for Solar Dryers



Appendix K: Decision Tree for Seed Banks & Nurseries



Appendix L: Decision Tree for Pest Monitoring & Management



Appendix M: Decision Tree for Solar Dryers