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Analysis of climate change vulnerability and adaptive capacity of small coffee producers in Turrialba, Costa Rica

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***MAGISTER SCIENTIAE* IN AGROFORESTRY AND SUSTAINABLE AGRICULTURE**

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With much love and appreciation to my patient, supportive and loving family -
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Acronyms

CA	Central America
CATIE	Tropical Agricultural Research and Higher Education Center
CC	Climate Change
ECLAC	Commission for Latin America and the Caribbean
FAO	Food and Agriculture Organization
ICAFE	National Institute for Coffee
IICA	Inter American Institute for Cooperation on Agriculture
INDER	Rural Development Institute
IPPC	Inter Governmental Panel on Climate Change
MAG	Ministry of Agriculture and Livestock
MIDEPLAN	Ministry of National Planning and Economic Policy
NOP	National Organic Program
PROCOMER	Promoter of Foreign Trade of Costa Rica
PROMECAFE	Regional Cooperative Program for Technological Development and Modernization of Coffee Cultivation of Central America, the Dominican Republic and Jamaica
PROCAGICA	Central American Program for Integral Management of Coffee Rust
RCCP	Regional Climate Change Program
TVAAC	Tool for vulnerability analysis and adaptive capacity of coffee farms
UCR	University of Costa Rica
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VAC	Vulnerability and Adaptive Capacity
WHO	World Health Organization

Abstract

In 2015, the Tropical Agricultural Research and Higher Education Center (CATIE) and the Regional Climate Change Program (RCCP) developed a rapid assessment tool to help technicians and producers in Central America measure the vulnerability and adaptive capacity of coffee (*Coffea arabica*) farms affected by climate change. Supporting this initiative, the Central American Program for Integral Management of Coffee Rust (*Hemilia vastatrix*) (PROCAGICA) provided support to develop a reference manual guiding the process in Costa Rica, where coffee is mainly cultivated by small producers who represent 97% of the total coffee producers (ICAFE, 2018).

The present study was conducted between October 2018 and May 2019, and focused on applying the rapid assessment tool on 26 coffee farms (Organic, Agrosustainable and Conventional Systems) that belong to members of the Apoya Naturalba Coffee Association situated in Turrialba, Costa Rica. The purpose of the study was to determine the vulnerability and adaptive capacity of the farms using the rapid assessment tool, farm surveys and a participatory workshop. The data which was gathered, tabulated and analyzed with the use of features in Microsoft Excel and INFOSTAT (2012). Frequency tables, Contingency tables and Correspondence Analysis were used to analyze the data.

Youth involvement in coffee activities was low to absent. The producers planted 8 or more traditional and improved varieties as well as diverse crops; and had a few small stock animals. The findings demonstrate that the farms are in 4 categories; Critical vulnerability and adaptive capacity; Average critical vulnerability and adaptive capacity; Regular vulnerability and adaptive capacity; and lastly, Moderate vulnerability and adaptive capacity. The most important limitations to coffee production were temperature increase (100%) and irregular rainfall (100%). Statistical analysis demonstrated that based on the sample size used; there was no association between the Category of Vulnerability and Adaptive capacity and the number of practices implemented on the farm. Neither were there any association between the number of practices and the type of system implemented by the producers.

Key Words: Coffee (*Coffea Arabica*), Climate Change, Vulnerability, Adaptive Capacity, Impact

1. Introduction

Coffee production provides an important livelihood for many small producers in the tropics; however, its production is heavily threatened by the impacts of Climate Change (Verberg, et al., 2019). This growing situation has had major socioeconomic impacts to farm families and has reduced economic growth in Central America. Coffee is a climate sensitive crop (Bunn, 2015), which means that it requires specific climatic conditions during its entire growth and development stages. Otherwise, climate variability can easily intervene in its quality and productivity (Coffee and Climate, 2015). If coffee producers in the region do not respond to the effects of CC immediately, not only will they risk having competitiveness in the world markets, but they will become increasingly vulnerable to the irreversible threats and consequences that affect everything related to agriculture and food security (UNDP, 2018).

It is estimated that a total of 25 million small producers from at least 60 countries around the world produce coffee on 11 million hectares of land (Waller et al., cited by Läderach et al., 2016). In Costa Rica, a total of 88,901 hectares are grown on 1.6% of the country's national territory. Small producers represent 97% of the total growers and 51% of the coffee exports are destined mainly to the United States (52.35%), Belgium (14%) and Australia (4.2%) (PROMECAFE, 2018). A total of 134,280 persons are either directly or indirectly employed by the coffee sector, which makes it a very significant agricultural crop at the national level. In 2016, coffee ranked seventh with respect to agricultural and economic importance for the country. In 2018, it generated a value of 305.6 US million dollars in export value (PROCOMER, 2018).

In Costa Rica and around the globe, small producers are particularly challenged with agronomic and socioeconomic problems due to unstable climate patterns. Climate variability makes it difficult for them to plan or determine which farm practices can best facilitate a successful and profitable harvest. Some participative studies conducted in the region demonstrated that producers are becoming increasingly vulnerable to the effects of CC. This situation stimulates a debate among producers as to whether they should continue to expand their coffee plantations or not. Some of the common questions among producers have been whether they should abandon existing plantations that no longer look promising, invest in adaptation techniques/practices, or diversify into new crops or livestock production systems which may adapt easier to new climate conditions. Unfortunately, there are no definite responses to these questions from either the technicians or the experts; since the response can be either one, or a combination of all options, depending on the producer's farm plans, objectives, economic capacity and availability of support system(s), which can guide them through the process (Coffee and Climate, 2015).

Verberg et al (2018) suggest that climate change adaptation measures are particularly becoming a serious focus in coffee systems. However, an essential first step must take place, it involves gathering and analyzing information on how the farmers are currently experiencing and preparing to respond to future climate change impacts. The information gathered could be the basis for programs and strategic responses that are more targeted to address the specific needs and limitations which the small coffee producers face (Harvey et al., 2018). It is in this same light, that the present study aims to describe the components of 26 coffee farms and analyze implemented practices to determine their influence on production, and the vulnerability and adaptive capacity of the producers.

The main tool used to conduct the analysis was a rapid assessment tool to determine vulnerability and adaptive capacity (TVAAC), developed by Virginio Filho (2015). The tool used 25 guiding questions for producers with respect to their perceptions for three main variables (Exposure, Impacts and Adaptive Capacity) related to climate change. Besides the farm survey, the descriptive data gathered allowed for the categorization of each farm and the producers were asked to prioritize limitations considered fundamental to increase adaptive capacity to climate change.

2. Objective

2.1 General Objective

To determine climate change vulnerability and adaptive capacity of small coffee producers in Turrialba, Costa Rica.

2.2 Specific Objectives

1. To describe the association of small coffee producers from APOYA-Naturalba and their productive units.

2. To compare vulnerability and adaptive capacity results from farms which were evaluated in 2016 with new information from 2018.

3. To determine which climate change adaptation measures (practices) have been implemented and adopted by members of APOYA-Naturalba in 2018.

3. Research Questions

3.1 Objective No. 1

1. What are the characteristics of small coffee producers who are members of Apoya Naturalba?
2. Which types of management systems do the small producers implement on their farms?
3. What does the productive unit comprise of in each type of farming system?
4. Apart from coffee, which other crops are important to association members?
5. What type of trainings do producers receive and what type of support system do they have?

3.2 Objective No. 2

1. Are there any evidence/significant changes in the vulnerability and adaptive capacity of small coffee producers 2018 compared to the findings encountered in 2016?

3.3 Objective No. 3

1. What category of vulnerability and adaptive capacity best describes the farms?
2. What type of management activities do the producers implement during each growing cycle?
3. Is there any evidence that the practices implemented can affect production? If so, which ones?
4. Does the type of system and number of practices implemented affect the vulnerability of the farms?
5. What are possible limitations as to why farmers have, or have not, implemented practices to adapt to climate change?
6. Who do the producers perceive as possible entities, institutions, etc., that can provide technical assistance for adaptation to climate change?

4. Referential Framework

4.1 History of Coffee in Costa Rica

Costa Rica is the first country in Central America to have formally cultivated and expanded coffee production in the 1800s, after it was first introduced to the Americas. The country gained independence in 1821 and the national assembly began to promote coffee as a potential crop for income generation (ICAFE, 2019). The government at the time created specific policies to incentivize producers through the distribution of free coffee plants and tax exemptions on inputs. If coffee producers demonstrated that they grew the crop for five years or more, they automatically qualified for titled property of the parcel of land.

By the 1830s coffee was referred to as the "Golden Grain" and producers began to explore its processing. At first, it was sun-dried and manually peeled in their yards, later, the humid process technique was adapted. Eventually, the use of innovation and machinery were incorporated into the process, and this significantly improved the quality of the coffee beans. Despite the coffee crisis at the end of the 19th century, Costa Rica still managed to produce high quality coffee beans and gained access to niche markets in Europe. The green revolution is said to have contributed greatly to the transformation of the industry, especially in the areas of crop nutrition (fertilization). The first varieties of *Coffea arabica* introduced were Caturra and Catuai. The first coffee exports were sent to Panama in very small quantities (200 kg), but greater exports ensued in the 1840s when coffee was traded for merchandise from Europe (ICAFE, 2019).

By 1933, the crop was given high priority at the national level, so much, that the country instituted its first non-state public institution responsible for the coffee industry. It was given the name of Coffee Institute of Costa Rica (ICAFE). This institute still exists today and is governed by a specific law of the republic, No. 2762 whose mission is to regulate, promote and defend the industry so that all producers can earn fair income through sustainable practices and excellent quality grains. To promote the crops potential, the Ministry of Agriculture (MAG) developed a strong coffee program focused on: crop nutrition, genetic improvement, pest and disease control, weed control, cultural practices (adjusting planting distances, plant management and shade regulation), as well as strengthening technical assistance and the distribution of information to farmers by the 1950s (Perez,1977). Interestingly, today these areas remain a priority for the MAG, the ICAFE, and other stakeholders involved in coffee production.

4.2 Economic Importance

Banana, pineapple, coffee and beef hold strong economic importance in Costa Rican exports despite the agronomic, climatic and marketing challenges. In 2012, coffee production reduced by 60% due to two factors: Coffee Rust (Hemileia vastatrix) and extremely low international coffee prices (Statistical Compendium of Costa Rica, 2018). However, Costa Rica's agricultural census of 2014 indicates that there are still 84,133 hectares of existing coffee plantations. A total of 41,339 producers grow the crop on 26,527 farms distributed throughout the country (ICAFE, cited by the USDA (2019)). Interestingly, small producers represent approximately 97% of the total growers and it is estimated that at least 134, 280 persons are either directly or indirectly employed by the coffee sector PROMECAFE (2018).

Regarding consumption, Costa Rica's population of five million inhabitants (INEC, 2018) have been gradually increasing coffee consumption. Since the country cannot balance the production for trade over the last ten years, on occasions, there has been importation of coffee from Honduras, Nicaragua and Peru to fulfill the quota for local consumption and complement local coffee purchase. In terms of trade, coffee exports reached 1,219,087 bags in 2017/2018 (value = US$314.2 million) when compared to 1,112,510 bags in 2016/2017 due to the slight increase in production. It is a fact that the premium prices afforded to Costa Rican coffee producers have been the main reason why producers can remain in the industry despite the challenges of high input costs USDA (2018), pests, diseases and other adversities of climate change. Clearly, coffee remains a significant agricultural crop from an economic, cultural and food security standpoint in the country.

4.3 Coffee and Family Agriculture

Coffee production has historically been a family activity for many years. Costa Rica is one of the first countries in Central America to develop a policy specifically for family agriculture. The said policy aims to promote at least five different key instruments specifically designed for rural territorial management and family agriculture; differentiated technical assistance for family agriculture, commercialization, financing, food and nutrition security, and gender (Sabourin, et al., 2015). This policy is a commendable achievement for Costa Rica because it particularly favors small coffee producers who would otherwise be unrecognized and less supported. Small producers face the challenges of climate change and fluctuating coffee market prices, but they remain involved in the industry. This type of activity is considered a fundamental pillar for integrated rural development. The World Rural Forum cited by Platero et al. (2012) suggests that family agriculture is more than a model for farming economy; it is the basis for food production towards food security and sovereignty.

According to Bouroncle et al (2017), climate change is the most significant threat for rural livelihoods in Central America, especially for small and medium-sized producers. Even though population growth seems to be stabilizing over the past years (World Population Review, 2019), it is evident that many low income and poor farm families will be increasingly affected by climate change. This situation will make them vulnerable with lesser chances of adapting to new climate conditions (Thomas et al, 2018). Small coffee producers and their families are undoubtedly a part of this vulnerable group. Therefore, it is vital that the coffee industry continues to be supported intently so that producers can live sustainably. Vermeulen et al. (2012) and Ricketts et al. (2004) cited by Hannah et.al. (2016), suggest that it is important to try to clearly understand the impacts of climate change on small producers. This will allow for more adequate adaptation strategies to be developed using integrated approaches involving family participation and the ecosystem for livelihood improvement.

4.4 Coffee Production Systems, Trends and Certification

Costa Rican coffee only represents 1% of world coffee production and the country is renowned for its wide range of flavors and aroma. This is possible because the country has eight regions with distinct conditions of altitude, temperature and rains (ICAFE, 2016). Coffee is grown by two methods, shaded agroforestry systems, or full sun using conventional methods and practices (Schnabel et al., 2017). In Costa Rica, both methods are used. Traditionally, the norm is to plant the trees below native forest canopies which imitate the natural way in which Arabic coffee was originally grown in Ethiopia where coffee is believed to have originated (Alemayehu, 2015). Shade trees serve as a source of nutrients (from tree litter), habitat for biodiversity, weed suppressant and as an important alternative for income generation through the sale of wood (Pratt and Harner, 1997). According to Bote and Struik (2010), shaded coffee provides a heavier and more enhanced flavor with greater quality. Most organic coffee is grown under shaded systems in Costa Rica. Organic coffee is said to be more sustainable because it eliminates the use of synthetic products, produces a competitive product, promotes conservation and protection of natural environments and biodiversity and involves a certification process. In contrast, conventional coffee is usually grown in full sun and utilizes modern technology and hybrids. This system provides higher yields and profits to producers when compared to shade grown coffee. However, studies demonstrate that conventional practices shorten the life cycle of the crop and produce adverse effects to the natural ecosystems as a result of high input use and unsustainable practices (Schnabel et al., 2017). According to consumers, the flavor of coffee produced in this system is less distinct than shade grown coffee.

Kilean et al. (2005) suggest that sustainable coffee production systems and certification are two logical methods that can lessen the impacts of low coffee prices for producers. Differentiation of coffee has generated improved income for producers since it involves a shift from conventional approaches to more sustainable techniques affecting productivity and quality in a positive way. However, it is projected that even though producers receive better prices for sustainable coffee, the effect may only be short term as the market becomes more developed, and there is a constant increase in demand and supply. Similarly, fairtrade certification which demands high retail costs without premium quality will also reduce in time. In the short term, this strategy will function effectively, but with time, when the markets grow and develop, competition is expected to occur and the only way to remain in the market will be to improve agronomic practices, productivity and exports of coffee.

The crop can be grown under at least three production systems using different methods. However, coffee producers relate that income from coffee is not enough to sustain families, so many of them have incorporated other agricultural activities such as fruit trees, root crops, grains, herbs and even livestock to complement earnings. Deudg (2003), cited by Damiana

(2005), express that small coffee producers in Costa Rica have diversified into other crops on their own without any assistance from the government or ONGs. The reason for this is because producers realized that instead of focusing on the replanting of random shade species, leguminous species could not only provide shade, but they enhance soil quality as well. Fruit trees and other crops complimented earning significantly, and it is for this reason that the diversification initiative has been growing.

4.6 Climate Change and how it affects Coffee Production

Climate Change affects coffee both directly and indirectly (Table 1). When there is excessive heat, coffee berries ripen fast and coffee quality is reduced significantly over time. High temperatures reduce the capacity of the plant to photosynthesize and grow adequately, resulting in plants stressed with abnormal leaf, stem and flowers growth. On the contrary, when there are excessive rains and strong winds, this can damage tree stand and increase fruit fall. This condition also gives rise to indirect problems such as soil erosion, contamination by agrochemicals and road damage. If the rains are unseasonal, the rate at which flowering occurs is more frequent, as is the case of Turrialba (CITE). Unstable weather promotes increase in disease occurrence and can complicate the drying process at harvest. If the rain is prolonged, there are fewer flowers, less fruits, and lower photosynthetic activity due to lack of enough sunlight. Increased humidity favors fungal diseases and a possible reduction in Coffee Berry Borer (CBB). In contrast, extended dry periods weaken the trees and make them more susceptible to pests. In small plants it can destroy young trees (Coffee and Climate, 2015).

Table 1. Direct and indirect effects of extreme or unusual weather events on Coffee Arabica.

Climate Hazard	Direct Impacts on the Trees	Indirect Impact
High Temperatures	- Above 23oC: Fruit ripening accelerates, leading to progressive quality loss - Above 25oC: Photosynthetic rate is reduced - Above 30oC: Tree growth is depressed - High Temperatures can cause leaf, stem and flower abnormalities and abortion	- Pests and diseases may increase
Heavy rains, hail and strong winds	- Tree damage, increase fruit fall, especially near harvest	- Soil erosion, landslides, subsidence, wash-away of agrochemical applications - Damage to roads and other infrastructure increases costs
Intermittent and unseasonal rains	- Greater flowering frequency	- Possible increase of diseases - Post-harvest drying difficulties
Prolonged rains	- May reduce flowing, affect fruit set, lower photosynthesis because of continual cloudiness	- Increase humidity may favor some fungal diseases; may increase mortality of some insect pests such as Coffee Berry Borer (CBB)
Prolonged drought	- Weaker trees, wilting, increased mortality of young trees	- Stressed trees more susceptible to some pests

Extracted from: A step-by-step guide to supporting coffee farmers in adapting to climate change. Coffee and Climate, 2015.

4.7 Regional Coffee Price, Production and Climate Change

Coffee production in Costa Rica increased significantly in the year 2017-2018 (USDA, 2018). Global production reached 163.51 million bags, which represents a 4.8% increase when compared to the previous year. This increase directly affected coffee prices, causing them to lower as much as US$111.51/pound (15.8% lower) when compared to the average US$132.43/pound in 2016-2017. This change in price also generated a visible effect on the income of small producers who are particularly struggling to survive in an unstable industry (ICO, 2018a). Even though coffee consumption is increasing by at least 2%, coffee growers are still not receiving better proceeds.

In the last two years, the price of coffee has reduced by over 30%, making it difficult for producers to cover the cost of production. As a result, global initiatives were implemented to address important factors affecting producers in areas such as lower investments in crop management by producers (which directly affects quality and quantity), food insecurity of producers, poverty and migration to urban areas and developed countries, where producers believe there are better opportunities to provide for their families (ICO, 2019).

As seen in Table 2, Honduras remains the largest producer in Central America, even though production decreased by at least 2% in 2018. This reduction can be attributed to the effects of Coffee Rust (Hemileia vastatrix) which has greatly affected the industry since 2012/13 (USDA, 2019). In Guatemala, Coffee production was affected by droughts, diseases, low prices and the volcanic eruption which affected more than 3000 hectares of coffee in the Acatenango Valley (Palacios, 2018). According to the USDA (2019) GAIN report, coffee production in Nicaragua was reportedly "good" in 2018/2019 due to favorable rainfall distribution, homogenous coffee fruit ripening, and access to financing by some producers and renovations of 20,000 hectares of coffee plantations. The corresponding figures are expected to reduce in 2019/20 due to scarce financing, poor management (due to lack of funding and labor) as well as the socio-political crisis the country is facing. Even though ICO suggests in Table 2 that there was a slight increase in coffee production for Costa Rica in 2018, the country's Institute for Coffee (ICAFE) reported that there was a 10% reduction due to factors related to Climate (intense rains, water stress in some areas), flower, fruit and leaf drop and diseases, including Coffee Rust. El Salvador and Panama face similar challenges as other countries in the region.

Table 2. Total Production by all producing countries (in thousands 60K bags)

Country	Production 2016/17	Production 2017/18
Honduras	7560	7450
Guatemala	3734	3900
Nicaragua	2617	2500
Costa Rica	1561	1595
El Salvador	760	760
Panama	105	100

Source: International Coffee Organization. July, 2019.

Killeen and Harper (2016) suggest that even though world coffee consumption is predicted to continue to experience a strong growth in the next 30 years, there are still some important issues to consider regarding coffee demand, type, location and management for both Robusta and Arabica varieties. Regions such as East Asia, South Asia and Sub-Saharan Africa are expected to set the trend on trade, but the tendency is specifically towards the consumption of intensely managed Robusta and Specialty coffees from Arabica, which is shade grown and manually picked. While this may be encouraging for Central America, the issue of climate change is extremely critical to consider, because predictive models indicate that in the next 40-50 years coffee-producing areas in CA will experience a significant topographical shift influencing good quality coffee production. Traditional areas where coffee is currently grown are expected to become warmer and more prone to periodic droughts, which will affect coffee plant growth and development. In terms of forest cover, this situation will produce a strain on natural resources and the delicate ecosystems, which we now have because farmers will move to more suitable areas resulting in deforestation. As demonstrated in Figure 1 (2010/2013) and Figure 2 (2010/2050), it is projected that coffee suitability areas in Central America for both Arabica and Robusta varieties will gradually shift between 2010 and 2050.

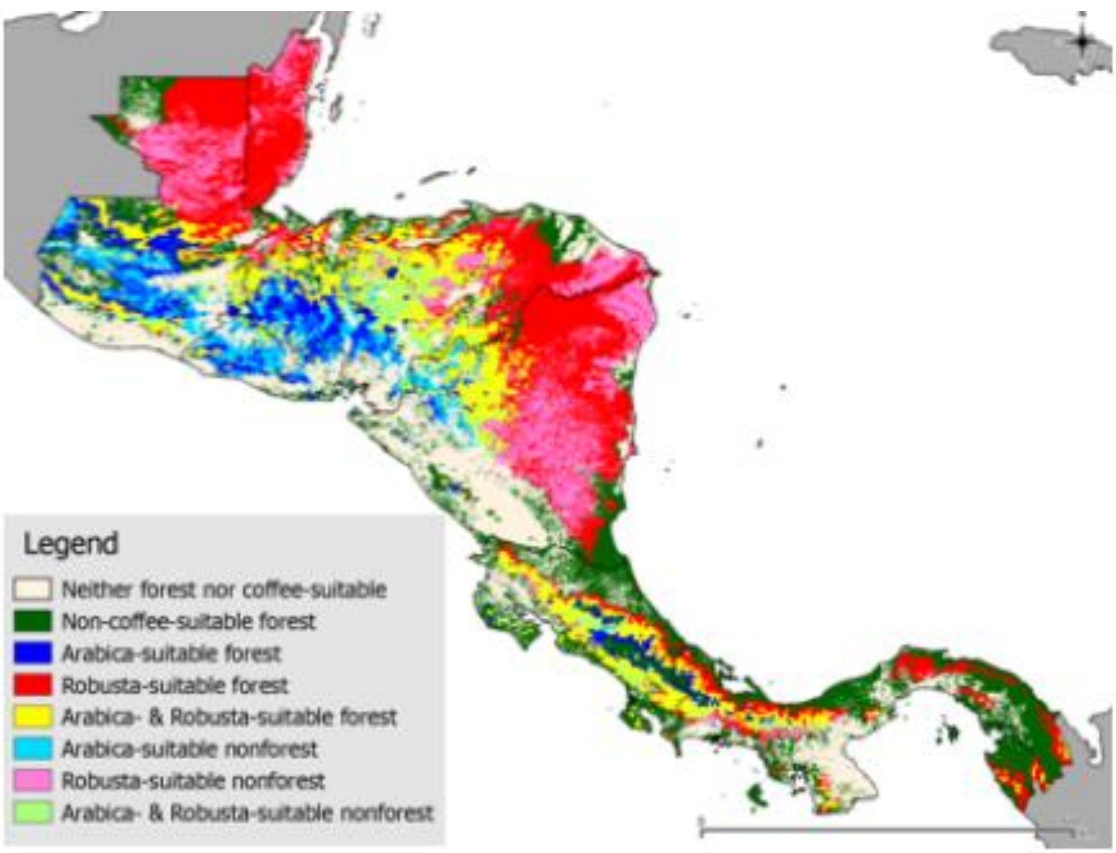
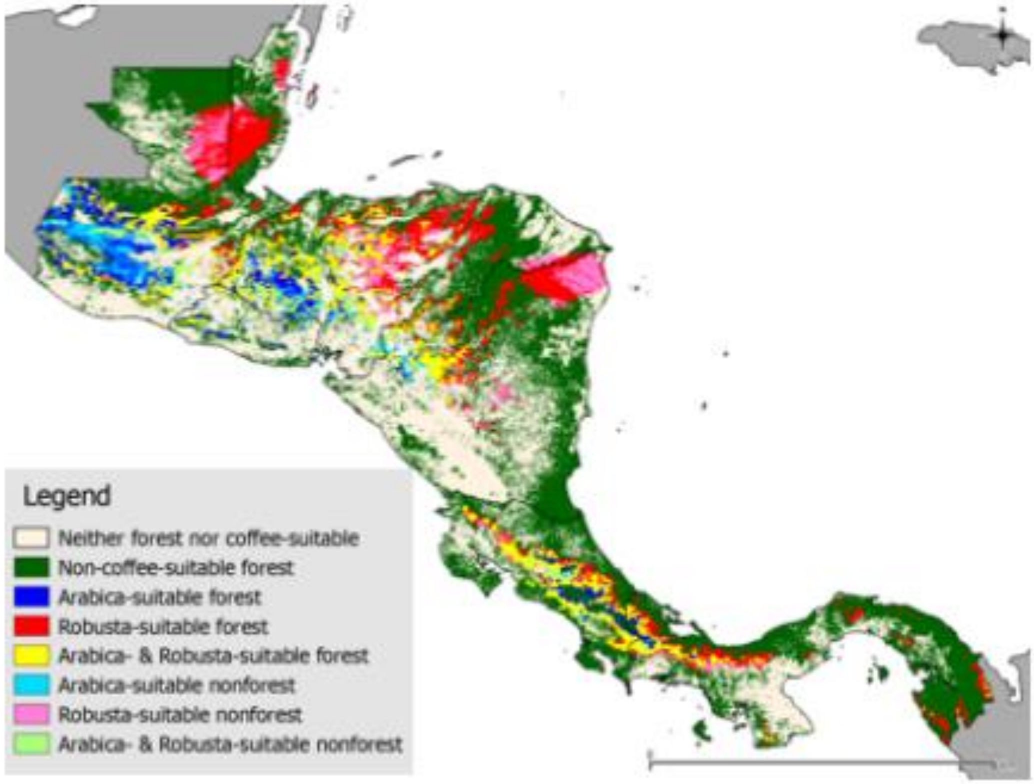


Figure 1. Central America 2010 Coffee Suitability and 2013 Forest Cover.
Killeen and Harper. 2016.



Central America	2010	2050	
Suitable Area Forest (km2)	185,749	112,622	The impact of climate change on suitable area affects forest and non forest areas approximately equally, but for Arabica to expand to meet demand under a HCHY-DS Scenario some deforestation would be almost inevitable
Arabica	88,348	52,667	
Robusta	154,914	74,014	
Suitable Area Non forest(km2)	99,467	13,826	
Arabica	47,989	18,645	
Robusta	73,827	25,578	

Figure 2. Central America 2010 Coffee Suitability and 2050 Forest Cover.
Killeen and Harper. 2016.

4.8 Nationally Appropriate Mitigation Actions (NAMA – Café)

In an effort to reduce the growing environmental challenges faced by coffee producers in Costa Rica, a new and unique approach was attempted to ensure that coffee production does not intensely contribute to global warming. The country has developed Nationally Appropriate Mitigation Action (NAMA), whose primary objective is for the country to become carbon neutral by 2021 through the application of various policies and strategies. This effort originated from an agreement made at the Conference of the Parties (COP) in Bali in 2007 that the NAMA policy should aim to stimulate change within the economy through the incorporation of technology, financing and capacity building, by developing countries who have voluntarily committed to reducing greenhouse gas emissions by 2020. Costa Rica has so far led the implementation of the first ever agricultural NAMA in the world (specific to coffee production) through collaboration with public, private, financial and academic sectors set to reduce greenhouse gas emissions by coffee plantations and mills. The main actions to be implemented by NAMA are:

- Reduction of fertilizer use.
- Efficient use of water and energy in coffee processing.
- Promotion of financial mechanisms to support agroforestry systems in coffee.
- Determination of carbon footprint at coffee mills.
- Differentiation of coffee through new and creative strategies.
- Development of feasibility and project design studies for the implementation of low-emission technologies.

A total investment of US$30 million was set aside for this initiative; and if successful, this national effort will not only reach its aim to reduce carbon emissions, but it will also be fundamental in developing NAMAs for other agricultural crops that also require the same efforts (ICAFE, 2019). Five other important initiatives related to climate change that the country has developed and/or participated in are:

- The National Climate Change Strategy.
- Program on Carbon Neutrality.
- The National Development plan 2015 – 2018.
- State Policy for the agricultural sector and the rural development of Costa Rica 2010-2021.
- ESAC (Regional Strategy).
- The Regional Program for Climate Change (USAID).

4.9 **Key definitions related to Climate Change**

To understand this research´s context and the coffee production dynamics, it is important to know some concepts associated to climate change. For example, the term "weather" and "climate" have two distinct definitions according to the factor of "time". Weather refers to the atmosphere over a short period of time; whereas climate is the way the atmosphere "behaves" over relatively long periods of time (NASA, 2017). The term "Climate Change" is defined by the United Nations Framework Convention (UNFCCC, 2019) as the result of human activity combined with natural climate variability over comparable periods of time and which alters the global atmospheric conditions. It is a persistent change in the state of the climate over decades or more. These combinations can either increase or alter the global atmospheric conditions (IPPC, 2014).

"Climate variability" refers to changes that occur over shorter periods of time (usually less than a year). Common terms such as the rainy season, dry season, drought periods or cold fronts (Coffee and Climate, 2015) are often used to describe these conditions. Some of the most commonly discussed agricultural threats resulting from climate variability are: unavailability of adequate and essential water sources for human, crop and livestock survival, increased crop failure, food scarcity, animal mortality, higher pest and diseases incidence, loss of soil fertility, erosion, and loss of key biodiversity components necessary for the provision of important ecosystemic services (FAO, 2016). The problem with climate variation is that it produces unstable weather patterns which make food production very challenging. Short term variations can cause hazardous effects such as excess humidity, flooding, droughts and even forest fires in extreme heat periods; these can affect many aspects of agriculture. When microclimates are affected by these factors, or when there are changes in the earths system, phenomena such as El Niño and La Niña are more likely to occur (NASA, 2017). Consequently, coffee producers, like many other types of producers in Central America, become vulnerable and exposed to scenarios that directly affect their food production systems, food security, and general economic stability and development.

Vulnerability may be defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change (IPPC, 2014). It is a function of exposure, sensitivity and adaptive capacity (FAO, 2016). Villareyna el. al. (2016) define "exposure" as the changes in climate and climate variability (increase in temperature, changes in rainfall and patterns of hurricanes and tropical storms, which can affect coffee production). "Sensitivity" is the extent to which a system is affected by external stimulus, and in the coffee context, this refers to quality, production, expense and profits among other important factors.

"Adaptive Capacity" is the capacity of a system to adjust to the changes in climate with the objective of mitigating potential damages to the crop. Producers can make good use of the positive opportunities that may be presented, or they can respond to the challenges brought forward by climate change. In the case of this study, producers can gain enough useful knowledge and resources to make important decisions related to building on-farm CC resiliency which directly affects their livelihoods (Coffee and Climate, 2015).

"Resilience" is a term used to explain the capacity of a social or ecological system to absorb alterations (changes in climate) without losing its basic structure, functionality, capacity to auto-organize or ability to adapt to stressful conditions caused by changes in climate (Vallejo et al., 2016). Building resiliency of coffee plantations is an important focus of institutions such as CATIE, whose work aims to promote integrated systems combining high productivity and profitability, taking into consideration the environment and its resources, which constantly needs to be conserved (CATIE, 2018).

4.10 Climate Change Concerns and Initiatives in Central America

Climate instability significantly affects coffee production and presents a huge threat to Central America's ability to produce enough high-quality coffee for the world market. To be able to assess the extent of the situation, specific attention must be given to measuring vulnerability and the producers capacity to either mitigate or adapt to current variations in climate. In this respect, the question of whether producers need to mitigate or adapt are equally important in responding to climate change.

However, one must consider that these two strategies are quite different; while mitigation refers to actions that will prevent the impacts of climate change, adaptation anticipates the possible effects and appropriate actions necessary to prevent or minimize damage while taking advantage of new opportunities that may arise as a result of the changes (European Commission, 2019). In a report generated by the Economic Commission for Latin America and the Caribbean (ECLAC, 2012), DARA's Climate Change Monitor (2012) has established five levels of vulnerability as it relates to Climate Change: acute (most vulnerable), severe, high, moderate and low (least vulnerable). Based on these levels, Central America was categorized as follows in the year 2010; "Moderate for Costa Rica, Nicaragua and Panama; high for the Dominican Republic; severe for Guatemala, El Salvador and Honduras; and acute for Belize. The monitor predicts that there will be an increase in vulnerability towards 2030: "High for Costa Rica, Guatemala and Nicaragua; severe for Panama; acute for Belize, El Salvador Honduras and the Dominican Republic."

Consequently, many sectors (academia, state, private sectors, research institutions, NGOs and communities, among others) have attempted to respond and prepare using an integrated and interdisciplinary approach to confront the situation of climate change. So far, a series of decisions and recommendations has been proposed for the way forward by experts in the region, however, they constantly need to be revisited, reassessed and improved with time, incorporating new knowledge and information about climate change. Efforts contemplating human and environmental systems are necessary because it is only by this means that researchers will be able to properly plan and monitor climate change effectively (National Research Council, 2010).

According to Vignola et al. (2015), ecosystem-based adaptation practices (EBAP) are a part of a larger strategy taking into consideration factors of biodiversity and ecosystemic services. The original use of this concept was mainly focused on conservation and restoration of natural habitats, and had absolutely no specific emphasis on the relationships or benefits of biodiversity, ecosystemic services and ecological processes as it relates to agricultural production systems. This has changed in recent years. The objective of EBAP forms a strategy designed primarily to assist producers in learning how to adequately adapt to the adversities of climate variability and climate change. EBAP has proven to be an excellent option for building resiliency. Practices are geared towards improving livelihoods through diverse systems that help generate income for farm families. Nonetheless, it requires at least three conditions for it to work efficiently: 1) We need to explore and learn how to implement adequate practices that will result in developing more resilient farming systems that respond to climate variations and climate change; 2) We need to focus on improving and developing policies that will favor agroecosystems and their services, which will in turn enhance the livelihoods of small producers; and 3) Promote EBAP and invest in participatory-type learning processes such as those provided through extension services, farmer field schools and research institution and other technical support systems.

4.11 Tool for vulnerability analysis and adaptive capacity of coffee farms

Central America and the Dominican Republic (Figure 3) have been participating in The Regional Climate Change Program (RCCP) concerning coffee and climate change, which was established for the period 2013 – 2019. The program's lead implementer was The Tropical Agricultural Research and Higher Education Center (CATIE). One of its most valuable achievements has been the development of an evaluation tool used to measure vulnerability and adaptive capacity of coffee farms. The tool, which is still considered to be a work in progress, took at least 15 years to develop through integration of experience and knowledge of producers and coffee experts from within the region. A preliminary test was conducted in the city of Turrialba, Costa Rica, in 2016, with 13 small coffee producers participating. Subsequently, Guatemala, Honduras, and Nicaragua also applied it on a larger scale.

Figure 3. Geographical scope of the Regional Climate Change Program.

Source: USAID Climate Change Program. CATIE, 2018.

The tool incorporates both the biophysical and socioeconomic factors related to coffee production. The focus is on three aspects: Exposure, vulnerability (exposure + sensitivity/impact) and adaptive capacity of coffee producers (CATIE, 2018). It promotes the use of participatory methods allowing a clearer understanding of the vulnerability degree and adaptive capacity of coffee producers and their farm families. It also suggests the necessary framework and organizational support for farmers to engage in sustainable production that will reduce vulnerability.

The method is participatory and the primary focus is the producers observations on climate variability, impacts of extreme climate phenomenon, agroecological interactions in production, design and shade management, soil and fertility management, fertilizer and chemical use, pest and disease management, stability of production and the learning capacity of producers. The model's design is highly interactive and permits verification and comparison of the various productive units that are in line with adaptation practices that present resiliency and adaptive capacity for farmers in each country (Acuña, R. et al., 2017).

The “highly interactive” idea suggests that the application of the “tool” requires the involvement of various stakeholders to collect information, analyze it and chart the best way forward to ideally confront the challenges of climate change. The participatory approach permits a continuous process that requires constant adaptation. It is a process through which persons become involved to a lesser or greater extent in the development process (Geilfus, 2008). Since confronting Climate Change requires a global, international, regional, national, and local effort, this suggests that there is not a single sector that can solve all the problems related to the impacts of climate change (WWF, 2018).

In conclusion, it is valid to point out that Central America cannot continue to focus only on productivity and yields. The interests and views of farmers and their families who depend on the industry for survival must be considered. A wide spectrum of adaptation levels and strategies must be considered to achieve proper adaptation goals. The adaptive capacity ranking and characterization are complementary to the prioritization and identification of adaptation strategies in specific areas where support is most needed (Bouroncle et al., 2016). Therefore, the proposed approach from the RCCP is expected to ensure that information drawn from the tool can serve as a guide for technical personnel and policy makers, so that they can provide fundamental support for improvement through more specific, strategic and meaningful intervention.

More recently, CATIE followed up on field validations based on the methodology of vulnerability analysis and adaptive capacity within the framework of PROCAGICA (Regional Program for the integral management of coffee rust), coordinated by IICA and financed with the European Union funds. In coordination with the RCCP, a coffee and climate manual for Costa Rica was prepared (Villareyna et al., 2018).

The present study will provide a resourceful indication of the producer’s knowledge and prospects, which in effect will prove useful for institutions, and state policy makers responsible to make important and strategic decisions as to which aspects of coffee production require technical support and funding.

5. Methodology

5.1 Location and description of the area of study

The present study is based on information gathered from the canton of Turrialba, Costa Rica, between October 2017 and May 2018. Turrialba measures approximately 1,642 km2 and lies in the humid tropics, longitude West: 83º 34' 03", latitude North: 9º 47' 14" between the Central and Atlantic regions of the country. The región has 12 districts: Central Turrialba, La Suiza, Peralta, Tuis, Pavones, Santa Teresita, Santa Cruz, Tayutic, Santa Rosa, Tres Equis, La Isabel and Chirripó (MIDEPLAN, 2016). The study was only conducted in Pavones, La Suiza, Jabillos, Grano de Oro, La Isabel, Tres Equis and Central Turrialba, where producers from the association Apoya Naturalba were found. Historically, in this region the rainy periods run between June and December with an average rainfall of approximately 2854 mm per year; however, in the months of June and July rain can reach up to 315 mm. The least rainfall generally occurs between January and May. In March, as little as 93 mm can be expected. The temperature typically ranges between 24° C in April and 22° C in December. The annual average temperature is 22.9° C with variations of approximately 2° C throughout the year (Climate-data.org, 2018).

There are approximately 8,000 hectares of coffee plantations in the region grown at altitudes of 600 m to 1300 m in Turrialba. According to ICAFE (2017), the coffee industry in this region employs at least 2,385 registered producers who were responsible for the production of 9, 043, 600 kg of coffee fruits (berries) in 2016 – 2017. This production represented a fairly significant increase of 5.3% when compared to the previous year's production. Even though there was an increase in production, the department responsible for national statistics in Costa Rica have reported that the number of farms and coffee plantations have decreased in the last years due to the high incidence of Coffee Rust Hemileia vastatrix and other pests and diseases problems. Despite the great losses in production over the last years, some coffee producers in the canton remain hopeful and continue to grow the crop.

5.2 Description of the Association Apoya – Naturalba

The present study was conducted with Apoya Naturalba, this was originally two separate associations which merged interests, efforts and resources to form a single association "Apoya – Naturalba". It presently has a membership of 40 active coffee producers who operate on an administrative contract clearly defining the role of each one. The association's focus has been mainly social development and the promotion of diversified sustainable and organic practices. In the last three years, coffee producers replanted improved varieties resistant to coffee rust (*Hemileia vastatrix*), a disease that can severely affect the plants development. Due to the recent plantings, much of the farms do not expect a significant harvest until the end of 2019 and 2020. Apart from Apoya - Naturalba, there are four other coffee mills in the region: Santa Rosa, Aquiares, Café Mission and Atirro who also buy coffee from small producers for processing.

5.3 General Description of the Research Process

The study was divided into four phases corresponding with each objective (Figure 4). The first two phases were conducted on-farm with the producers, and the third phase involved the analysis of the data collected in phase one utilizing both Microsoft Excel and the statistical software Infostat. Lastly, a focal group was organized with members of Apoya-Naturalba and other stakeholders.

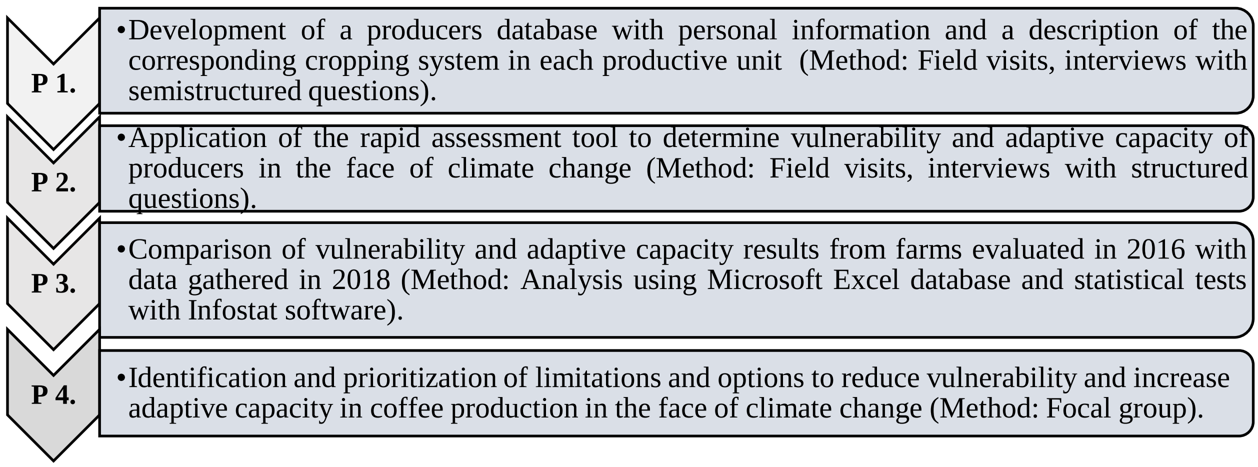


Figure 4. Sequence of phases used to conduct analysis of vulnerability and adaptive capacity of small producers from APOYA – Naturalba, Turrialba, Costa Rica.

5.4 Farm Selection Criteria

The association administrator provided a list of producers, with general information about the members. The list was reviewed and updated. To participate, producers had to agree to provide their valuable time and farm information as part of the study. Producers who were not interested in the study and/or no longer produced coffee were eliminated from the study.

5.5 Calendarization of Farm Visits

Of the 40 active farms in the association, a total of 26 farms met the abovementioned criteria and were assessed. Field visits were programed by telephone and then the visit was done. Each interview lasted an average of 2 ½ - 4 hours, depending on the producer’s interest in the discussion, time availability and farm size. Table 3 shows the number of farms visited and their respective locations by district.

Table 3. Number of interviews conducted by district in Turrialba, Costa Rica. 2018.

District	No. Interviews/Farm
Pavones	11
La Suiza	1
La Isabel	3
Chitaria	3
Tres Equis	1
Turrialba Centro	4
Grano de Oro	2
Cachí	1
Total	**26**

Objective No. 1 *Description of producers and small productive units*

5.6 Participatory Interviews and Farm Survey

Data collection was divided into two parts according to suggestions by Virginio Filho (2018) and Geilfus (2008) for the use of participatory tools and methods. First, a conversation was conducted with the producer to gather information on general management practices implemented on the coffee farm. Then, a farm survey was carried out to quantify and describe the components of the farm by species and type.

Semi-structured interviews were used to gather personal information, production quantities and farm management practices. The information recorded includes: producer name, gender, occupation, location, age, family size, coffee and crop experience, number of trainings received, training areas or workshops in which he/she participated, number of people working in farm activities, type of activities in which they participate, daily additional labor cost, primary sources of income and technical support networks, among others (Annex 1).

After the interview, a walk through the property with the producer was done to visually observe and verify the activities on the farm. A list of the number of crops and animal species observed, along with their respective quantities and common names, were recorded on a data sheet (Annex 2). A second list with coffee varieties and associated crops was also recorded (Annex 3). The descriptive variables used to quantify and analyze the farm can be observed in Table 4.

Table 4. Descriptive variables for farm diversity used in evaluation 2018.

Variables for **Coffee**	Variables for **Other Crops**	Variables for **Animals**
Acreage	Type of Crop	Type of Animal
Variety	No. of plants	No. of Animals
No. plants		
Production		
Destination		
Shade		

Forest species and service trees were recorded in the database as either “present (1)” or “absent (0)” for each farm. Other important data collected included: land tenure, crop priority, crop spacing and association of crops, agronomic practices, yields, value adding initiatives and commercialization of crops both inside and outside the coffee parcel.

5.7 Analysis of Producer Information and Farm Survey

Descriptive statistics were used to characterize and describe each productive unit. To demonstrate the components of the farm, the data was tabulated and processed using Microsoft Excel. Graphs and tables were generated, and the data was transferred and analyzed with the statistical software, INFOSTAT® (2012). A cluster analysis was done to separate the population into two groups; high and low coffee production.

Objective No. 2 *Comparison of vulnerability and adaptive capacity 2016 vs 2018*

5.8 Analysis of Responses for variables of exposure, impacts and adaptive capacity (2016 vs 2018) – 8 farms

The 25 guiding questions from the TVAAC (Tool for Vulnerability Analysis and Adaptive Capacity) were applied to 8 producers, who represent 31% of the total producers. The responses were first analyzed individually to determine changes in vulnerability and adaptive capacity in the year 2016, and then in 2018. Of the 8 producers, 2 implemented conventional coffee practices, 2 implemented Agrosustainable practices (in transition to organic) coffee and 4 implemented organic practices. The total points and category for each farm during 2016, and the new results from 2018, were recorded and compared using frequency tables to demonstrate the percentage responses (average) for variables of Exposure, Impacts (sensibility + exposure) and Adaptive capacity. The data was then transferred to Microsoft Excel and presented in a table form.

5.9 Comparison and identification of principal limitations (2016 vs 2018)

The limitations for the eight farms were highlighted to demonstrate the factors that affected vulnerability and adaptive capacity. The values (points) which were highlighted corresponded to the responses in which more than 50% or more of the producers perceived that the variable was a problem (-1). Each limitation was discussed to further explain the possible reasons for increase in vulnerability and reduced adaptive capacity. The comments and opinions of the producers which were mentioned during the interviews, was also taken into consideration for the discussion of the results.

Objective No. 3 *Identification of adaptation measures implemented by producers in 2018*

5.10 Analysis of Responses for variables regarding Exposure, Impacts and Adaptive Capacity (2018) – 26 farms

The 25 guiding questions established for the TVAAC (Tool for Vulnerability Analysis and Adaptive Capacity) were also used to gather information on vulnerability and adaptive capacity for the 26 producers in this objective, for both 2016 and 2018 (Annex 4). The average responses were obtained using frequency tables generated by INFOSTAT® (2012) and transferred to Microsoft Excel to generate the table presented.

5.11 Farm Categorization based on Vulnerability and Adaptive Capacity

After all the interviews were completed, the questionnaire responses with all the values (points) were tabulated and processed in Microsoft Excel using basic arithmetical sums to determine the category where each farm belonged based on the reference in Table 5.

Table 5. Guide for assigning categories of vulnerability and adaptive capacity to coffee farms. Extracted from Manual (Villareyna et al., 2018) and Virginio Filho, E (2015).

Reference Category	Points Obtained in The Valuation
1. Vulnerability practically absent, excellent adaptive capacity.	From 20 to 25 Points
2. Low vulnerability, high adaptive capacity.	From 15 a 19 Points
3. Vulnerability and moderate adaptive capacity.	From 8 a 14 Points
4. Vulnerability and regular adaptive capacity.	From 1 a 7 Points
5. Vulnerability and adaptive capacity moderately critical.	From -6 a 0 Points
6. Vulnerability and critical adaptive capacity.	From -13 a -7 Points
7. Vulnerability and adaptive capacity very critical.	From -20 a -14 Points
8. Totally vulnerable and without any adaptive capacity.	From -25 a -21 Points

5.12 Identification of principal limitations (2018)

The limitations for the 26 farms were presented to show the factors affecting vulnerability and adaptive capacity in 2018, using contingency tables and correspondence analysis in the Infostat software. The values (points) highlighted corresponded to responses in which more than 50% or more of the producers perceived that the variable was a problem (-1). Each limitation was discussed to further explain the possible reasons for an increase in vulnerability and reduced adaptive capacity by the producers during the last 2 years.

5.13 Identification and Description of practices adopted by small producers of Apoya-Naturalba

The number and type of practices implemented by the producers were listed and described for each system. Subsequently, based on the description of practices described by the producers, the frequency of each implemented practice was presented for each production system.

5.14 Analysis of association between practices and production systems (2018)

The principal limitations of the 26 farms were presented for all three categories (Exposure, Impact and Adaptive Capacity). Subsequently the limitations were presented independently per system (Organic, Agrosustainable and Conventional). Frequency tables were generated in Infostat to obtain the average response for each category (-1, 0.5 and 1) by systems. The data was then transferred to a database in Microsoft Excel, where each variable with a value of (-1) which gained more than 50% response was highlighted and explained.

Table 6. Numeric representation and definition of responses to the rapid assessment tool (Villareyna et al., 2018).

Response	Representation	Indication
Yes	-1	A problem exists on the farm
More or less	0.5	A slight problem exists on the farm
No	1	A problem does not exist on the farm

5.15 Participatory Workshop for identification and prioritization of limitations on coffee farms

During the workshop session, each of the 25 variables was discussed among the producers. The responses were recorded similarly to how it was conducted in the fields, to indicate whether a problem existed or not on the farm. This workshop was guided following recommended steps to assess vulnerability and adaptive capacity of the coffee producers (Figure 5).

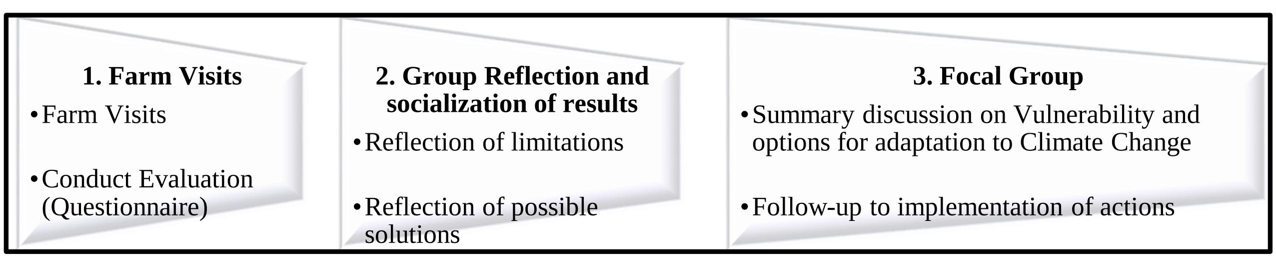


Figure 5. Recommended steps to implement and assess vulnerability and adaptive capacity of coffee producers (Villareyna et al., 2018).

5.16 Focal Group reflection and socialization of preliminary results

All the producers who were part of the study were invited to attend the participatory workshop.

The objectives of the workshop were to:

1. Reflect on the preliminary data, which was collected to categorize and describe each farm.
2. Discuss types of agronomic practices encountered in each production system.
3. Identify and list limitations that producers face in their coffee production systems.
4. Prioritize each limitation to be addressed based on practicality, support available from related entities, financial availability and technical support agencies.

An agenda (Annex 5) and a guide (Annex 6) to facilitate the workshop were elaborated prior to the event. As recommended by the methodological toolbox for the agricultural sector developed by the InterAmerican Institute for Cooperation on Agriculture (IICA, 2017), the participants were divided into three groups of 3 – 4 participants. The producer's ideas, emotional state, perceptions, experiences and reactions to the specific topics of coffee and climate change were recorded. One technical person who is familiar with the use of the TVAAC was assigned to guide each focal group discussion. The principal goal of the discussion was to identify responses for the information demonstrated in Table 7. Invitations to attend workshops were made via telephone and WhatsApp messages on two separate occasions, the first was an initial invitation emphasizing the importance of the event, and the second was to confirm participation.

Table 7. Format for identification and prioritization of adaptation and mitigation options.

Possible Measures or practices by limitations identified	Who can possibly contribute towards implementing the measures suggested?						
	The producer family	The producer family with the help of: (Mark with X)					
		Association of local producers	Cooperative	Local or National NGOs	National Coffee Entity	Ministry of Agriculture	Other (Indicate)

*Extracted from Costa Rica Manual (Villareyna et al., 2018).

After the group discussions, the results of 10 of the most frequent limitations were presented and prioritized (Annex 7). Thereafter, a discussion was conducted to identify recommended practices/actions that could be used as possible measures to reduce climate change vulnerability and increase adaptive capacity. Subsequently, the results were presented and shared by a producer from the working group. The information gathered from the entire session was recorded and presented on writing material.

6. Results and discussion

Objective 1. Description of producers and small productive units

6.1 Description of Small Coffee Producers

In this study a total of 35 small coffee producers were interviewed. Of those, 9 were eliminated because they no longer participated in the association, did not have availability to participate in the study, or no longer managed coffee plantations. The 26 small producers who participated represented 65% of the total membership, 2 were females, and 24 were males. The average age of the producers was 58 years. The eldest producer was 74 and the youngest was 35 years old. Collectively, they had an average of 22.5 years of experience in coffee production and management. The majority of the producers (85%) who were interviewed were married and had at least 3 children.

The participation of youth in coffee production resulted extremely low to absent in every aspect of the crop's management based on the producer's responses. This affirmation coincides with the Rural Territorial Development Plan for Turrialba (2015 – 2020), which highlights that many young people migrated to the cities to do further studies, or seek employment with little or no interest in returning to participate in traditional agriculture. The plan also mentioned that the population of older people in Turrialba has significantly grown over recent years (INDER, 2015). These two concerns demonstrate that there is a growing need to promote youth engagement in agriculture in the region. Ripoll et al., (2017) suggest that if youths are to be an active part of any agricultural activity, it must first become more attractive, productive, profitable, modern and less labor intensive. In a positive effort to create interest and incentivize youths from coffee families, ICAFE and the Ministry of Education signed an agreement in 2019 to train up to 4700 youths in Barismo[1]. This effort was aimed at fostering professional development and creating new market opportunities for high quality coffee producers in the country (ICAFE, 2019). Another example of youth involvement according to Stiftung (2018) is an initiative implemented in Guatemala and Nicaragua to involve youths in the coffee value chain. In communities where coffee is the principal activity, not only have they established demonstration plots in the schools, but the government has incorporated topics related to sustainable coffee production into the school's curriculum.

Consistent with the findings of Harvey et al. (2018), 99% of the producers who were interviewed have legal ownership of their parcel of land. They generally do not live on the actual coffee farms, but they live in small nearby communities and travel to the coffee plantations at least two times per week. The lands where they produce were either inherited from family or

[1] Specialized studies in high-quality coffee which focuses on creating new and different drinks with creative presentations.

acquired from the state, which is referred to as "asentamientos[2]". Figure 6 demonstrates the producer's source of income, which is primarily the sale of coffee, followed by employment in other agricultural activities, odd jobs in the community, or from a pension. Some producers also engaged in the buying and selling of other fruits and vegetables transported from other communities near Turrialba. Other producers depended on contributions from the state, children or other family members.

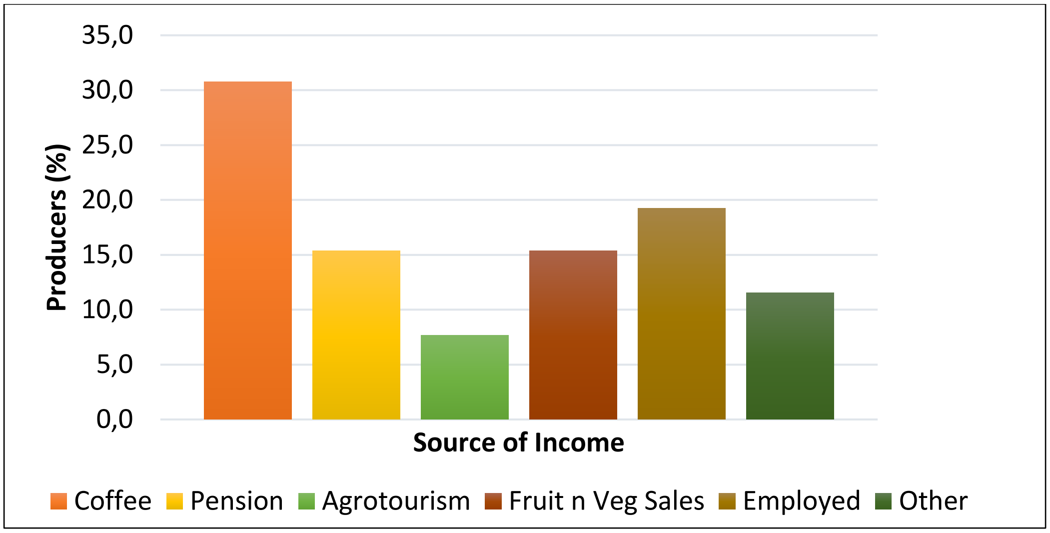


Figure 6. Source of income of small coffee producers from Apoya Naturalba, Turrialba, Costa Rica (2018).

6.2 Technical Assistance

Technical assistance was received by 46% of the small producers at least once, or twice per year from either the Ministry of Agriculture (62%) and/or Apoya Naturalba (58%) (Figure 7). The trainings were mostly in the area of coffee production, pest control, fruit tree management, cacao and the production of organic amendments for coffee farms. Many of the producers expressed that it was difficult for them to participate in the available trainings due to lack of time, and in some instances, lack of motivation, and poor communication between members.

[2] Asentamientos are lands acquired by the state and provided to farm families for use and development. They are usually supported by governmental or non-governmental institutions that foster socio-economic development in rural areas in Costa Rica.

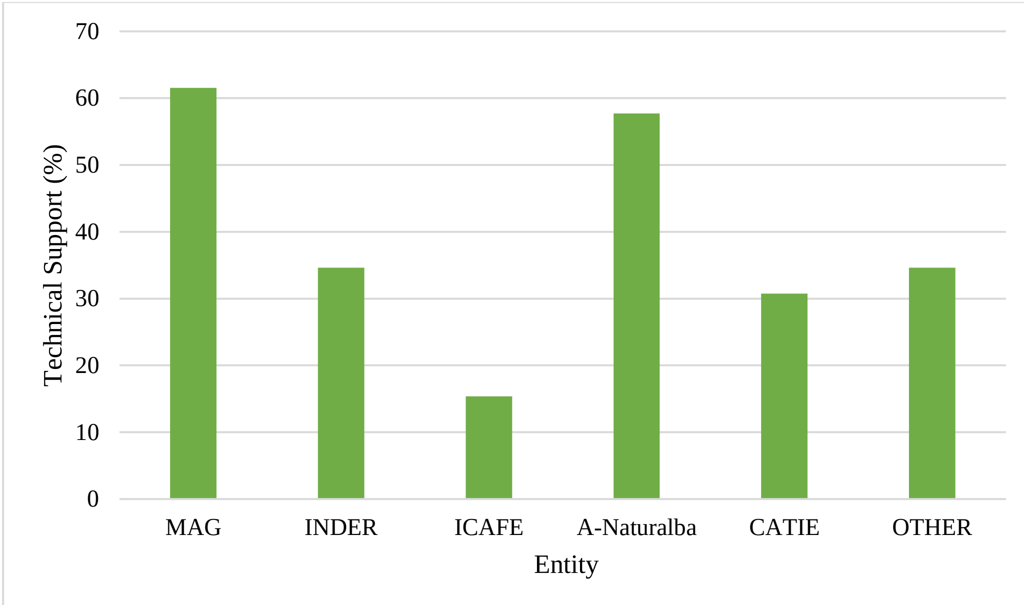


Figure 7. Sources of technical assistance provided to small coffee producers from Apoya Naturalba, Turrialba, Costa Rica (2018).

6.3 Description of Farm and Farming Systems

Overall, the producers who were interviewed work on 133.85 hectares of land (Figure 8). A total of 59.15 hectares (44.2%) is dedicated solely to coffee production and the remaining 74.7 hectares (55.8%) were used to produce a variety of other crops. Similar to findings by Viguera et al. (2015) and Harvey et al. (2018), the average size of the individual coffee parcels was 2.3 hectares; meanwhile the average total farm size was 5.2 hectares. 50% of the producers planted at a distance of 2 m x 1 m, while others used varied spacing and particularly wider spacings in plots with older trees.

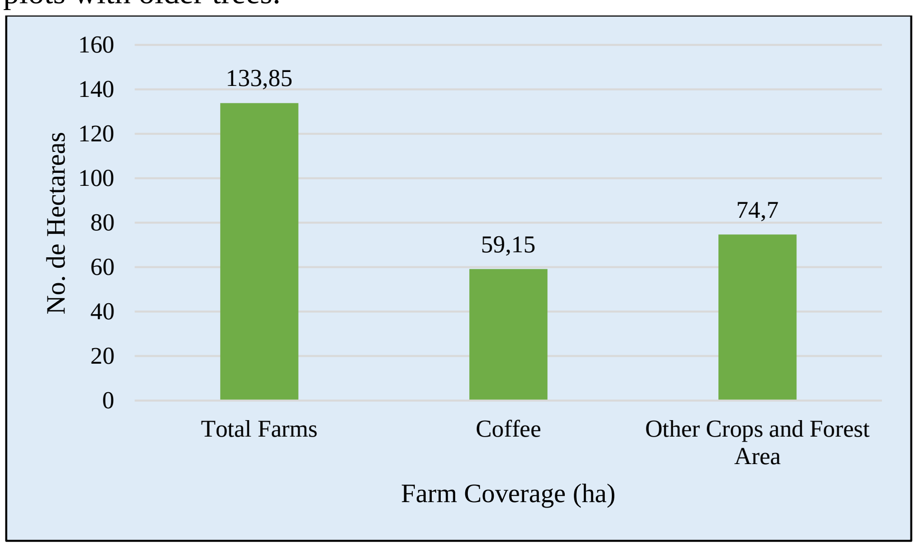


Figure 8. Distribution of Farms according to land use from Apoya Naturalba, Turrialba, Costa Rica (2018).

Producers from the association grew coffee using three types of farming systems: conventional, agrosustainable and organic. Figure 9 demonstrates that the majority of the farms evaluated were conventional (58%), followed by agrosustainable (27%) and organic (15%). Many of the farmers who implemented agrosustainable practices were either interested in, or already making progress to transition to organic. Organic coffee production was attractive for small producers who were gradually becoming interested in targeting a niche and specialty markets. However, organic coffee production demands consistency, quality, direct sales and promotion for it to be successful. According to Giovannuci (2003), organic coffee can be a viable opportunity for small producers since it fosters strengthening of production skills and focuses on sustainable practices that can protect the industry. However, the issue of high cost certifications remains a challenge for the producers. In the case of Apoya Naturalba, they have managed to make certification affordable and available for all of its members.

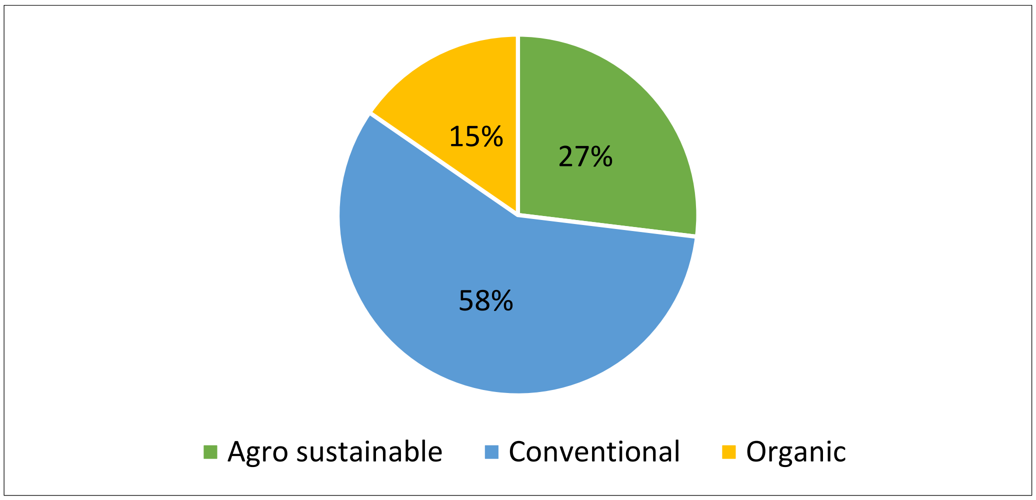


Figure 9. Distribution of of coffee farm systems from Apoya Naturalba, Turrialba, Costa Rica (2018).

Based on the information provided by the producers, at least 8 coffee varieties are grown, Figure 10 demonstrates their distribution. The most commonly grown variety was Caturra (32%), Costa Rica 95 (15%) and Catimor[3] (14%). The average age of the total population of varieties was 22 years. The age range of Caturra, CR95, Catimor and Catuai was between 15 – 60 years. Meanwhile, younger varieties (Obata, Milenio, Esperanza) were planted in the last 5 years to replace older, lesser productive and disease susceptible varieties. These three varieties have an average of only 1.2 years. They were originally introduced because of their resistance to important coffee pests and disease, high productivity and satisfactory taste with potential to attract specialty markets. A more detailed description of each variety is provided in Table 8.

[3] Producers referred to the varieties on-farm as Catimor, therefore it was the term used in the study.

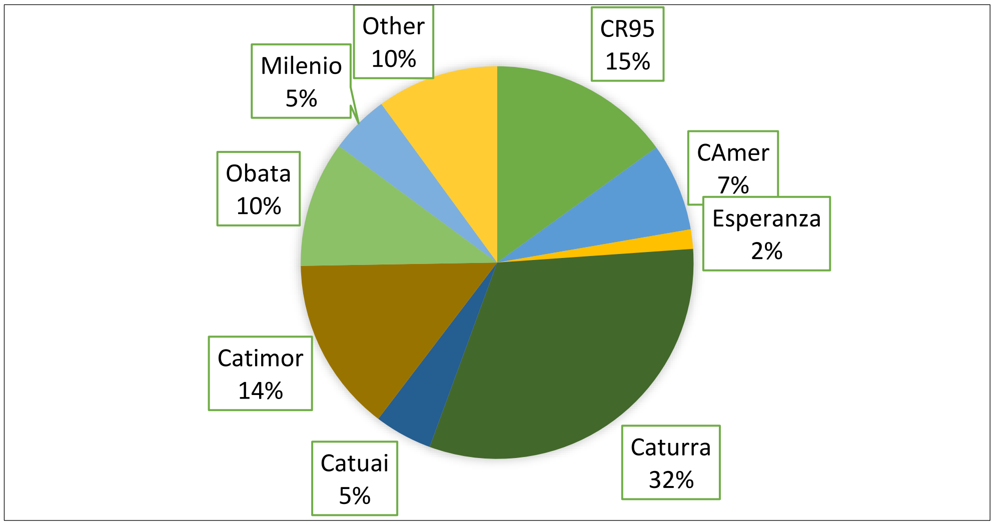


Figure 10. Coffee varieties grown by small producers from Apoya Naturalba, Turrialba, Costa Rica (2018).

Table 8. Description of coffee varieties from Apoya Naturalba, Turrialba, Costa Rica.

Characteristic	Caturra (32%)	CR95 (15%)	Catuai (5%)	Obata (10%)	Milenio (5%)	Esperanza (2%)
Productive Potential	Medium	High	High	High	High	High
Resistance to Pest & Disease	Low	Medium	Medium	Medium	High	High
Cup Quality	High	Medium	High	High	High	High
Yield in Benefit	Medium	Medium	Medium	Medium	Medium	Medium
Vigor	Medium	Medium	Medium	Medium	Medium	Medium

Source: The coffee variety wheel. ICAFE, Costa Rica (2019).

19% of the coffee plots were found to be in monocropped arrangements, in full sun and conventional systems. On the contrary, 42% of producers associated coffee with bananas (Figure 11). This system provided at least two benefits: additional income for families and a balance for the high management cost of coffee production (especially in conventional production). These findings coincided with Alves et al. (2015), where coffee production in Brazil turned out to be more expensive than the production costs of bananas. For many producers, the monthly income from banana production offsets the costs of coffee production, thereby generating a positive cash flow for producers. Asten et al. (s.f.) suggest that coffee-banana systems are particularly beneficial for farmers who have young coffee trees. The juvenile period for coffee development is 3 -5 years, during which no income is generated. If the coffee is associated with bananas, which can be harvested within one year; this can generate income for producers meanwhile the coffee plantation grows and develops. PROMECAFE (2018) suggests that the cost of production for conventional coffee during this research period was at US$175.43. Cocoa (Theobroma cacao) was also commonly found in the parcels due to the constant increase for opportunities to add value and earn additional income[4]. Some producers expressed interests in replacing older coffee trees with cacao to also increase income for the farm.

The species of service trees on the coffee farms were primarily Poro (*Erythrina poeppigiana*), Guava (*Inga edulis*) and/or a variety of native trees from natural regenerated forest (23%) in all three farming systems. Though the producers recognized the value of trees and shade, the pruning practice was rare, in some cases primarily because the producers had physical constraints (they were not able to reach and cut the high branches). However, in October of 2018, they actively participated in a workshop to learn to calculate adequate shade. The training also involved discussions regarding the use and benefits of a telescopic mechanical machine as an alternative to effectively manage pruning.

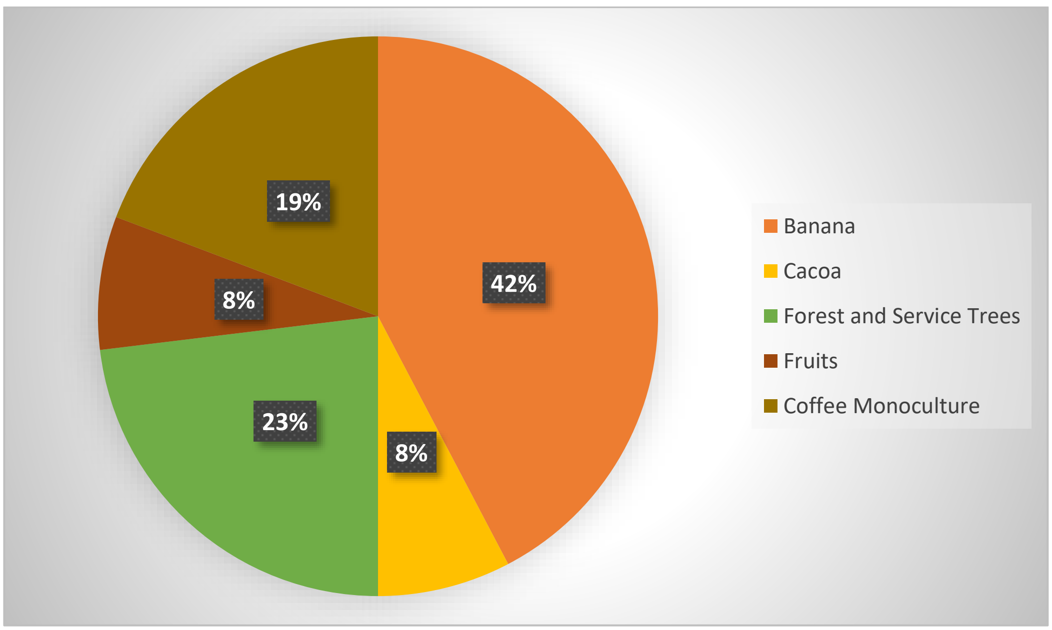


Figure 11. Distribution of crops associated with coffee varieties on farms from Apoya Naturalba studied in Turrialba, Costa Rica (2018).

Table 9 shows the results of a survey of fruit tree varieties (n= 26) observed. These crops were either found in association with coffee (8%) or dispersed throughout the farms. The survey also demonstrates the frequency of other plants and animal species on the producer's farm: native forest trees (85%), service trees[5] (77%), varieties of vegetables and herbs (38%), roots and tubers (23%), citrus (15%), sugarcane (4%) and improved pasture (12%). There were also animals such as chickens, cattle, sheep and pigs (27%).

[4] Ramírez, M. 20/05/19/. Personal communication. Pavones, Turrialba, Costa Rica.

[5] **Service trees** provide a complementary function in agroforestry systems (commercial or domestic). They can provide for example; wood, food, shade, medicine, construction material, etc., even though farmers are rarely rewarded for them.
Beer et al. 2003. Service functions of Agroforestry systems. Consulted 16 July. 2019. http://www.fao.org/3/XII/MS20-S.htm

Table 9. Number of individuals and frequency by fruit species in coffee farms of Apoya Naturalba studied in Turrialba, Costa Rica (2018).

Common Name	Scientific Name	Family	No. Individuals	Frequency	% of Farms
Avocado	*Persea Americana*	Lauraceae	28	5	19
Banana	*Musa acuminata Cavendish Sub group*	Musaceae	8895.5	23	88
Breadfruit	*Artocarpus altilis*	Moraceae	4	2	8
Cacoa	*Theobroma cacao*	Malvaceae	7802	7	27
Caimito	*Chrysophyllum cainito*	Sapotaceae	1	1	4
Cas	*Psidium friedrichsthalianum*	Myrtaceae	11	3	12
Cashew	*Anacardium occidentale*	Anacardiaceae	1	1	4
Chirimoya	*Annona cherimola*	Annonaceae	1	1	4
Coconut	*Cocos nucifera*	Arecaceae	38	4	15
Craboo	*Byrsonima crassifolia*	Malpighiaceae	3	1	4
Granadia	*Passiflora incarnata*	Passifloraceae	1	1	4
Guava	*Psidium guajava*	Myrtaceae	85	3	12
Hot pepper	*Capsicum chinense*	Solanaceae	500	1	4
Jew plum	*Spondias dulcis*	Anacardiaceae	6	2	8
Kiwi	*Actinidia deliciosa*	Actinidiaceae	1	1	4
Rambutan	*Nephelium lappaceum*	Sapindaceae	5	2	8
Rose apple	*Syzygium malaccense*	Myrtaceae	8	4	15
Membrillo	*Averrhoa bilimbi*	Oxalidaceae	1	1	4
Naranjilla	*Solanum quitoense*	Solonaceae	1	1	4
Loquat	*Eriobotrya japonica*	Roseaceae	3	1	4
Papaya	*Carica papaya*	Caricaceae	31	2	8
Plantain	*Musa × paradisiaca*	Musaceae	90	4	15
Soursop	*Annona muricata*	Annonaceae	33	5	19
Suriname Cherry	*Eugenia uniflora*	Myrtaceae	1	1	4
Zapote	*Matisia cordata*	Bombacaceae	7	1	4
Grapefruit	*Citrus x paradisi*	Rutaceae	6	2	8
Lime	*Citrus x aurantifolia*	Rutacea	76	11	42
Mandarin	*Citrus reticulata*	Rutaceae	45	9	35
Oranges	*Citrus x senensis*	Rutaceae	34	7	27
Others					0
Sugarcane	*Saccharum officinarum*	Poaceae	7	1	4
Pasture (ha)*			19	3	12
Forest Trees**				22	85
Service Trees***				20	77

*Improved grass types. **Assortment of naturally regenerated native species (Laurel, Cedro, among others). ***Principally *Erythrina poeppigiana* (Poro), Inga spp. (Guava) and Madero Negro (Madre de Cacao).

It is noteworthy that, besides bananas, limes and mandarins were also frequently planted by producers outside of the coffee plots. Each farm had an average of 3 to 5 of each type, mainly used for home consumption. When there was an excess, producers sold small amounts in the community establishments or shared with family and friends. Producers in the region became interested in planting citrus since 2007, when the Ministry of Agriculture first introduced and made available planting material from 67 new cultivars of table oranges, grapefruit, limes and mandarin (CEDAR, 2010) to producers. Regarding the production of root crops, at least 3 coffee producers grew a total of 6 varieties (Table 10). Most were used for home consumption, except for one producer who sells small amounts of each variety at the organic fair in the Las Palmas farmers market situated in Turrialba Center, and the organic market in CATIE.

Table 10. Number of individuals and frequency by root crop species in coffee farms of small producers of Apoya Naturalba studied in Turrialba, Costa Rica (2018).

Common Name	Scientific Name	Family	No. Individuals	Frequency	% of Farms
Araza	*Eugenia stipitata*	Myrtaceae	1	1	4
Peanuts	*Arachis hypogaea*	Fabaceae	100	1	4
Taro	*Colocasia esculenta*	Araceae	129	2	8
Cassava	*Manihot esculenta*	Euphorbiaceae	310	7	27
Ginger	*Zingiber officinale*	Zingiberaceae	50	1	4
Curcuma	*Curcuma longa*	Zingiberaceae	500	1	4

Vegetables were not traditionally grown in the communities studied; instead, much of the produce was brought from nearby communities in the province of Cartago. Interestingly, besides Culantro coyote (Coriandrum sativum), one coffee producer was responsible for the production of the 10 crops listed below (Table 11), but they were used for home consumption only.

Table 11. Vegetable production in coffee farms of small producers of Apoya Naturalba, Turrialba, Costa Rica (2018).

Common Name	Scientific Name	Family	No. Individuals	Frequency	% of Farms
Tomato	*Solanum lycopersicum*	Solanaceae	30	1	4
Beans	*Phaseolus vulgaris*	Fabaceae	120	1	4
Cabbage	*Brassica oleracea*	Brassicaceae	137	1	4
Celery	*Apium graveolens*	Apiaceae	110	1	4
Chayote	*Sechium edule*	Cucurbitaceae	2	1	4
Cucumber	*Cucumis sativus*	Cucurbitaceae	21	1	4
Pumpkin	*Cucurbita pepo*	Cucurbitaceae	800	1	4
Corn	*Zea mays*	Poaceae	150	1	4
Culantro coyote	*Coriandrum sativum*	Apiaceae	-	3	12
Herbs*				1	4

*various herbs used in home food preparation and medicine.

Six species of small stock animals were found on 4 coffee farms (Table 12). Except for cattle, which are used by one producer to produce milk and cheese, they are all used for home consumption.

Table 12. No. of individuals and frequency of animals on coffee farms for small producers of Apoya Naturalba, Turrialba, Costa Rica (2018).

Common Name	Scientific Name	Family/Class	No. Individuals	Frequency	% of Farms
Cattle	*Bos taurus*	Bovidae	116	4	15
Chicken	*Gallus gallus domesticus*	Phasianidae	122	4	15
Ducks	*Anas Platyrhynchos*	Anatidae	4	1	4
Pigs	*Sus domesticus*	Suidae	16	4	15
Goats	*Capra aegagrus hircus*	Bovidae	9	2	8
Tilapia	*Oreochromis niloticus niloticus*	Actinopterygii	4	4	15

6.4 Farm Labour

Figure 12 demonstrates that farm activities were mostly conducted with the use of part time labor (69%). The people hired were not usually from within the family, since family participation and interest is low in coffee production. Hiring was mostly done during the harvest period when the small producer requires extra help to harvest coffee. Producers sell and deliver their coffee harvests directly to the association without any intermediaries. The average wage paid daily is ₡8040.00 per day (6 hours = 1 day).

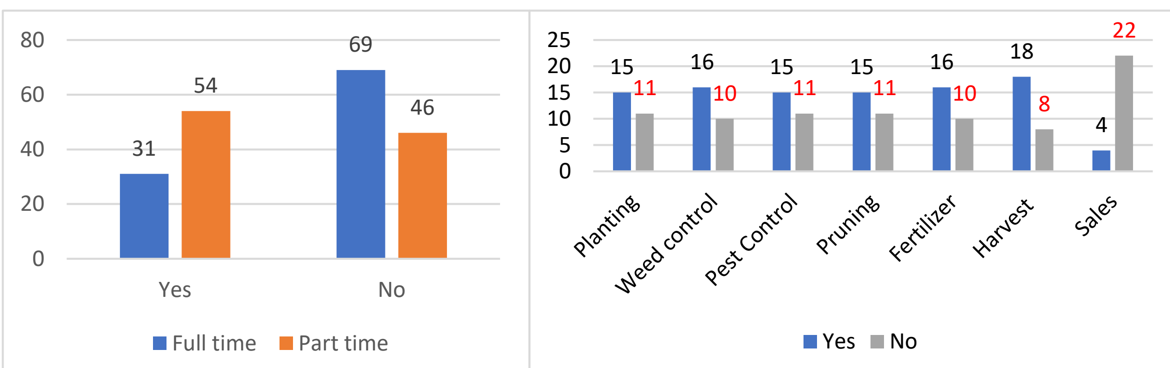


Figure 12. Additional employment and distribution of management activities on coffee farms of small producers of Apoya Naturalba, Turrialba, Costa Rica (2018).

6.5 Coffee Production

Figure 13 shows that the total annual coffee fruit production by participants was higher in 2017/2018 than in 2016/2017. The yield went from 276 fanegas to 538 fanegas respectively. The monetary benefit for each year was ₡50,267.23 (conventional) and ₡92,845.55 (organic and agrosustainable) in 2016 – 2017. In 2017/2018 the liquidation benefit was slightly higher,

₡52,068.80 (conventional) and ₡95,346.63 (organic and agrosustainable) in 2017- 2018, respectively. Based on the data provided, there are four distinct productive small coffee producers in the association who implement conventional practices. The average production among producers is 8.3 fanegas per hectare, a significantly low value when compared to 18 fanegas per hectare, which is considered the average production in the area for conventional coffee[6].

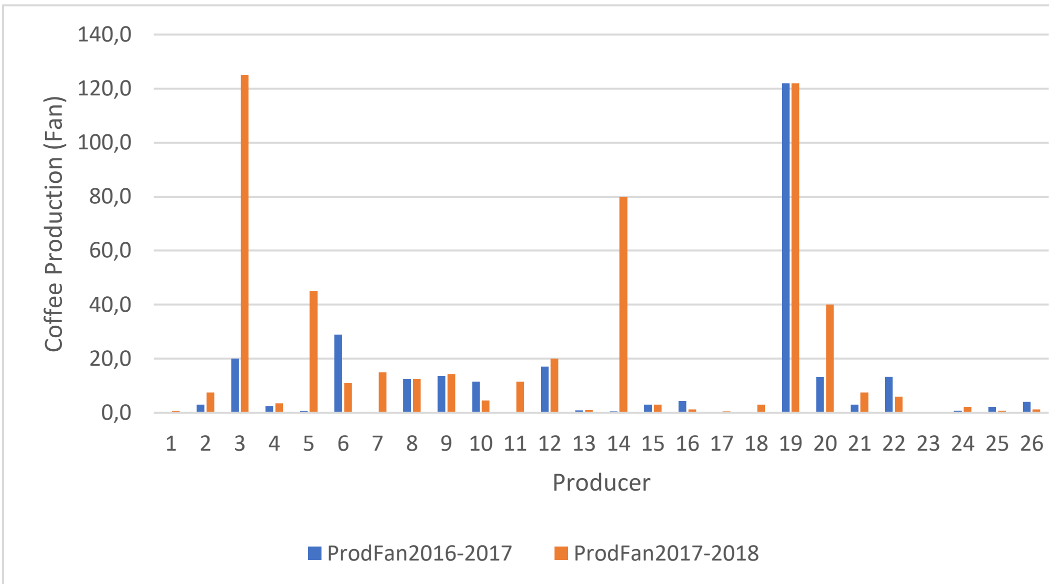


Figure 13. Comparison of annual coffee fruit production by active members of Apoya Naturalba, Turrialba, Costa Rica in 2016 – 2017 and 2017 – 2018.

6.6 Coffee Processing, Certification and Distribution

Members of the Apoya-Naturalba delivered their harvests personally to the mills for processing. When they were not able to transport the coffee fruit on their own, the administration collaborated to facilitate the necessary transport of the product to the mill. The mill is equipped with all the necessary machinery to perform both the wet and dry coffee process. The processing and supply of processed coffee (café oro)[7] is done on a supply and demand basis each year. In December of 2018, the association reportedly purchased 39.4 fanegas of organic coffee and 49.3 fanegas of conventional coffee from its members to meet demands. Five producers delivered only a portion of their harvests to the association. They used the remaining coffee harvests for home use and added value by traditional means of processing in their homes. Some producers sold portions of their harvest to other mills in Turrialba in pursue of better prices.

[6] Borjas, C. 21/09/19. Personal Communication. La Suiza, Turrialba, Costa Rica.
[7] Café oro (Dry coffee grains) = 1 sack 60 kg (international Coffee measurement)

All the members of the association contributed a small yearly fee towards coffee certification. This helped to reduce high certification costs that would not be obtainable on individual basis. The certification scheme for production and marketing is called Eco-Logica®. According to Eco-Logica© (2012), they inspect and certify the production and processing of organic products using the norms established by the National Organic Program (NOP) of the USDA and the National norms established by Costa Rica, Canada, Switzerland and Europe. In the case of Costa Rica, the norm is called National Organic Norms (No29782) of the Ministry of Agriculture. Small quantities of processed coffee were also sold to buyers from Germany, France and recently, Canada; but the majority of product was for the national market.

6.7 Workforce, Structure, Installation and Equipment

The association is managed by only four of persons: 1 responsible for roasting, 2 for administration and 1 for packaging. Throughout the year, however, assistance is provided by interns who arrive to the mill to learn, investigate and contribute with ideas for the members.

Currently, the association not only markets three types of coffee (organic, sustainable and natural), but they are also diversifying and exploring new products such as chocolate powder made from organic cacao, chocolate sweets, banana vinegar, organic sugar and green coffee (Figure 14). Apoya-Naturalba is equipped with a crusher, solar dryers, selector, grinder, storage tanks and other necessary equipment for coffee processing.

Figure 14. Coffee products processed and developed by Naturalba, Turrialba, Costa Rica.

<u>Objective 2 -</u> To compare vulnerability and adaptive capacity results from farms evaluated in 2016 with new information from 2018.

6.8 Analysis of Responses for the variables of Exposure, Impact (Sensitivity + exposure) and Adaptive Capacity of Producers (2016 vs. 2018)

A total of 8 small producers from the original 13 whose farm was initially assessed with the TVAAC in the year 2016 by Escárraga et.al (2016) participated in this analysis. Two farms were Conventional coffee, two were Agrosustainable and four were Organic. As demonstrated in Table 13, none of the producers demonstrated a significant increase or change in practice(s) in 2018. Instead, two of the coffee farms remained the same, Category (4 and 6), meanwhile 6 farms increased vulnerability from varied categories (1, 3, 4, 5, 6) to categories 4, 5 and 6.

Table 13. Comparison of results of 2016 and 2018 vulnerability and adaptive capacity results for small producers from Turrialba, Costa Rica.

ID	System	Vul2016	Vul2018	Cat2016	Cat2018	Vulnerability
		Points	Points	Category	Category	
CF	Conv	9.5	-4.5	3	5	Increased
FR	Conv	4.5	-3.5	4	5	Increased
VR	ASos	7.5	6.5	4	4	Same
HA	ASos	-13	-7.5	6	6	Same
VM	Org	8.5	3	3	4	Increased
LO	Org	21	-2.5	1	5	Increased
AS	Org	-1	-9.5	5	6	Increased
JS	Org	-1	-7	5	6	Increased

Conv =Conventional, ASos = Agrosustainable, Org = Organic

The values of the TVAAC from 2016 were first analyzed (Annex), then the data in Table 14 was generated by incorporating the new findings of 2018. Table 14 shows a comparison of the variables, and highlights the major limitations perceived by producers in the year 2016 and 2018 in terms of **Exposure** to climate variation. Findings concluded that 88% of the producers interviewed perceived an increase in both temperature and irregular rains in both periods. This perception precisely coincides with research findings by Harvey et al. (2018), also conducted in Turrialba. Harvey et al. reported that 98.6% of the producers perceived an overall change in climate (n=144). 97.1% of the producers specifically reported that they perceived an increase in temperature increase, meanwhile 66.7% perceived less rainfall during the course of the year in 2018.

Table 14. Comparison of results from TVACC 2016 vs 2018 for variables of Exposure.

Questions	Variables	2016			2018			**Average**			**Average of limitations** 16/18 (%)
		-1.00	**0.50**	**1.00**	**-1.00**	**0.50**	**1.00**	**-1.00**	**0.50**	**1.00**	
Variables (Exposure)											
1	Temperature	0.75	0.25	0.00	1.00	0.00	0.00	0.88	0.13	0.00	**88**
2	Irregular Rains	0.75	0.13	0.13	1.00	0.00	0.00	0.88	0.07	0.07	**88**
3	Increase Precipitation	0.25	0.25	0.50	0.25	0.25	0.50	0.25	0.25	0.50	25
4	Hurricanes and Tropical Storms	0.13	0.13	0.75	0.13	0.00	0.88	0.13	0.07	0.82	13
5	Droughts and Water Scarcity	0.38	0.38	0.25	0.50	0.13	0.38	0.44	0.26	0.32	44
6	Strong or increased winds	0.13	0.25	0.63	0.50	0.13	0.38	0.32	0.19	0.51	32

Table 15 shows a comparison of responses related to limitations of **Impacts (sensitivity + exposure)** by climate variation. This analysis shows that more than 75% of the producers indicated they perceived losses in production during the last 5 to 10 years. A report distributed by ICAFE (2018) provided evidence that of the 8 coffee producing zones in the country, the region of Turrialba experienced the highest reduction of coffee harvest by -29.3% during the last 5 years. A similar reduction in harvest occurred in Perez Zeledon (14.8%) and Coto Brus (4.2%). Pest and Disease problems (63%) were also perceived by the producers. This event prompted a statement by CICAFE (2018) that the Turrialba area was particularly endangered for in 2018, when climatic conditions highly favored the development of Coffee rust (*Hemelia vastatrix*). Consequently, it was recommended to apply at least four fungicides in scheduled moments to suppress the development of the disease. If farmers did not follow the recommendations, coffee farms were possibly affected even to this day. Other limitations perceived by the producers included irregular flowering (76%), loss of soil fertility (63%) and increase in leaf, flower and fruit drop (51%). These variables are directly affected by variation in climate.

Table 15. Comparison of results (% response) from TVACC 2016 vs 2018 for variables of Impact (Sensitivity + exposure).

Questions	Variables	2016			2018			Average			Average of limitations 16/18 (%)
		-1.00	**0.50**	**1.00**	**-1.00**	**0.50**	**1.00**	**-1.00**	**0.50**	**1.00**	
Variables Impact (Sensitivity + Exposure)											
7	Signs of Erosion	0.13	0.13	0.75	0.38	0.25	0.38	0.26	0.19	0.57	26
8	Loss of Fertility	0.50	0.25	0.25	0.75	0.00	0.25	0.63	0.13	0.25	**63**
9	Irregular coffee blooms	0.63	0.38	0.00	0.88	0.00	0.13	0.76	0.19	0.07	**76**
10	Increase in flower, leaf and fruit Fall	0.38	0.25	0.38	0.63	0.00	0.38	0.51	0.13	0.38	**51**
11	Increase in Pest and Disease	0.63	0.38	0.00	0.63	0.13	0.25	0.63	0.26	0.13	**63**
12	Decrease in Production	0.75	0.25	0.00	0.88	0.00	0.13	0.82	0.13	0.07	**82**

Finally, Table 16 presents the comparison of limitations regarding adaptive capacity by producers. Old coffee trees were a limitation for 51% of the producers, lack of shade management of existing trees (51%) and lack of drought resistant varieties (63%). At the national level, in 2018, these same factors were the reason for a national credit program for coffee tree renovation and pruning. The cost of renovation, including technical assistance for producers, remains very high. Producers are estimated to need at least ₡ 4,065,795.96 (US$7005.52) per hectare (ICAFE, 2018) to renovate coffee farms. Without financial support to assist these producers with renovations, many remained with old varieties highly susceptible to pests and disease.

Table 16. Comparison of results (% response) from TVACC 2016 vs 2018 for variables of Adaptive Capacity of coffee producers.

Questions	Variables	2016			2018			Average			Average of limitations 16/18 (%)
		-1.00	0.50	1.00	-1.00	0.50	1.00	-1.00	0.50	1.00	
Variables (Adaptive Capacity)											
13	Lack of Soil Conservation	0.38	0.13	0.50	0.63	0.13	0.25	0.51	0.13	0.38	51
14	Lack of Soil Cover	0.13	0.13	0.75	0.75	0.00	0.25	0.44	0.07	0.50	44
15	Lack of Diversity	0.25	0.13	0.63	0.00	0.13	0.88	0.13	0.13	0.76	13
16	Shade Management	0.38	0.25	0.38	0.63	0.13	0.25	0.51	0.19	0.32	**51**
17	Old Coffee Trees	0.63	0.25	0.13	0.38	0.25	0.38	0.51	0.25	0.26	**51**
18	Lack of Drought and Disease resistant varieties	0.50	0.38	0.13	0.75	0.00	0.25	0.63	0.19	0.19	**63**
19	Lack of Pruning and Tree formation	0.00	0.25	0.75	0.13	0.13	0.75	0.07	0.19	0.75	7
20	Lack of Replanting	0.50	0.25	0.25	0.50	0.13	0.38	0.50	0.19	0.32	50
21	Use of Synthetic Fertilizer	0.13	0.13	0.75	0.38	0.00	0.63	0.26	0.07	0.69	26
22	Use of Organic amendments	0.25	0.13	0.63	0.50	0.00	0.50	0.38	0.07	0.57	38
23	Lack of water source cover	0.13	0.13	0.75	0.75	0.00	0.25	0.44	0.07	0.50	44
24	Lack of Tree presence	0.00	0.13	0.88	0.75	0.00	0.25	0.38	0.07	0.57	38
25	Lack of organizational processes for mitigation and adaptation to climate change	0.25	0.25	0.50	1.00	0.00	0.00	0.63	0.13	0.25	**63**

The limitations presented in this section are a clear statement of why the farms either remained in the same category or increased vulnerability during the last 10 years. These challenges are not only evident in the region of Turrialba, but are also seen in other regions where coffee is also an important crop. The respective points used to assign the categories can be seen in Annex 8.

6.9 Identification of principal limitations according to Systems (Organic, Agrosustainable and Conventional) 2016 vs 2018

To further analyze the farms, Table 17 provides a list of the principal limitations perceived by the producers according to each system. For the variable of **Exposure**, producers who implemented Agrosustainable and Conventional systems did not perceive any limitations. However, those who had Organic systems indicated that Temperature increase (88%), Irregular rainfall pattern (88%) and Strong winds (63%) affected organic coffee production. Considering that the natural climatic conditions in Turrialba are highly variable, producers recognized that one solution to this limitation lies in improved varieties tolerant to the zone's conditions.

In terms of **Impact**, Organic producers (63%) perceived a decrease in production. This was due to the fact that many of them had recently eliminated older trees, replanted improved varieties and younger trees. Additionally, many parcels were significantly smaller than the other systems. Producers who used Agrosustainable systems reported that they were affected by at least 4 limitations: Loss of fertility (75%), Irregular coffee blooming (75%), Increase in pest and disease (100%) and Decreased production (100%). Soil fertility problems are usually consistent with coffee production systems whereby producers attempt to recuperate conventional soils and improve them. Findings from a study conducted by George (2006) in the same areas of Turrialba demonstrated that soils of conventional coffee plantations resulted to be very compact when compared to organic coffee plantations. This condition is not favorable for any type of system because it obstructs the absorption of nutrients and water to the plants. Furthermore, producers (51%) reported a lack of soil conservation and 38% perceived a lack of organic matter in the soil. Furthermore, they also reported pest and disease problems (100%). Collectively, all these conditions are directly associated to the decrease in production (100%) perceived by producers. Conventional Coffee producers also found limitations regarding reduced soil fertility (75%), irregular Coffee blooming (100%) and decreased production (100%).

One of the principal limitations perceived by producers in both Organic and Agrosustainable coffee production systems regarding **adaptive capacity** was shade management (63% and 75% respectively). This practice, however, was common in both systems. In the farms where shade trees were present, producers were mainly elderly people with limited time to invest on the farm and limited physical abilities to regulate the shade trees. In the early development of the coffee plantations, they managed to regulate the service trees, which were in many instances natural regeneration, but as they grew taller, it was harder and almost impossible to control them. This challenge was found in many other countries in the region, despite the fact that shade management have been proven to be essential to achieve optimal production. In Guatemala, a report by Technoserve (2017) mentioned that while producers were initially hesitant to adapt shade management practices, eventually 73% adapted the practice after perceiving the benefits. In conventional production systems, the two principal limitations were lack of replanting (75%) and lack of trees on the property (75%). Many of the producers perceived the lack of replanting problem caused by unavailability of credit to replace older coffee trees. Many of the conventional coffee systems were grown in full sun. In earlier years, producers removed all the trees because they considered that it hindered production. Today the situation is on the contrary. The 25 limitations studied for this section can be found in Annex 9.

Table 17. Principal Limitations by System (Conventional, Organic, Agrosustainable) 2016 vs. 2018

Variable	System	Limitation	%Average Response (-1) >50%
Exposure			
	Organic	Temperature Increase	88%
		Irregular rainfall pattern	88%
		Strong winds	63%
	Agrosustainable	None	-
	Conventional	None	-
Impacts (Sensitivity + Exposure)			
	Organic	Reduced production	63%
	Agrosustainable	Loss of soil fertility	75%
		Irregular coffee bloom	75%
		Increase in pests and diseases	100%
		Decreased production	100%
	Conventional	Loss of soil fertility	75%
		Irregular Coffee bloom	100%
		Decreased production	100%
Adaptive Capacity			
	Organic	Shade Management	63%
		Lack of drought and disease resistant varieties	75%
	Agrosustainable	Shade Management	75%
	Conventional	Lack of replanting	75%
		Lack of presence of trees	75%

Objective 3 - To determine which climate change adaptation measures (practices) have been implemented and adopted by members of APOYA-Naturalba in 2018.

6.10 Analysis of Responses for the variables of Exposure, Impact (Sensitivity + Exposure) and Adaptive Capacity of Producers (2018) (inclusive of farms evaluated in 2016).

Table 18 shows a comparison of the perception by farmers regarding the variable of "Exposure" to climate variation in both 2016 and 2018. Changes in temperature were perceived by 100% of the producers in 2018. They also mentioned that they perceived irregular trends in rainfall, which were particularly intense during shorter periods throughout the year in Turrialba; a natural phenomenon that presented the greatest risk to coffee production in the zone. The response to these two variables increased significantly between the two years.

According to Camargo (2010), an increase in temperature alone can greatly affect the metabolism of the coffee plants due to overheating of the leaves and excess energy that the plant cannot use. This can also result in poor quality fruits, if any at all. DaMatta et al. (2008) also suggest that abundant rainfall throughout the year is often responsible for scattered harvest and low yields – this is the particular case of the Turrialba region. These factors call attention to the topic of altitude as well, because according to Cerdas et al. (2017) altitude is strongly associated with temperature and rainfall issues in coffee production. These factors are out of the producer's control and must be prioritized and considered in order to reduce the risk of production losses. 38% of the producers indicated that they perceive threats of drought conditions in the zone. 42% indicated that strong winds and increases in rainfall with floods and landslides are a problem. 69% perceived that they are not affected by hurricanes or tropical storms.

Table 18. Responses (%) by small producers for the variables of exposure[8] to climate change during the last 10 years in Turrialba, Costa Rica. 2016/2018.

N°	Guiding Questions	2016			2018		
		Yes (%)	**+/- (%)**	**No (%)**	**Yes (%)**	**+/- (%)**	**No (%)**
	Variables (Exposure)	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**
1	Have there been changes in temperature in the last 10 years? (Exposure)	62	38	0	100	0	0
2	In recent years (5 or 10 years) have the rains been irregular? (Exposure)	77	8	15	100	0	0
3	Is there an increase in rainfall with floods and landslides (5 or 10 years)? (Exposure)	23	31	46	42	23	35
4	Is there a risk of hurricanes and tropical storms? (Exposure)	15	8	77	23	8	69
5	Have there been (last 5 or 10 years) droughts, decrease or absence of water on the property? (Exposure)	39	38	23	38	12	50
6	Are there strong winds and/or increases of these in recent years (5 or 10 years)? (Exposure)	15	23	62	42	12	46

[8] Exposure refers to the changes in climate and climate variability that can impact coffee production.

Table 19 shows that regarding the "Impacts" of climate change, 73% of the small producers perceived that the greatest problem they experienced was the irregular blooming of coffee farms – a condition very typical of the zone of Turrialba. Furthermore, 65% mentioned that the coffee trees showed problems with defoliation, fruit and flower drop, which were associated to nutrition (limited access to soil amendments and fertilizer). Soil conservation practices were lacking in 69% of the coffee farms. 50% of the farmers perceived problems with erosion even though 65% of them had evidence of ground cover.

Table 19. Responses (%) by small producers for the variables of Impacts (Sensitivity[9] + Exposure) to climate change during the last 10 years in Turrialba, Costa Rica. 2016/2018.

N°	Guiding Questions	2016			2018		
		Yes (%)	**+/- (%)**	**No (%)**	**Yes (%)**	**+/- (%)**	**No (%)**
	Variable Impacts (Sensitivity + Exposure)	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**
7	Do most of the soils in coffee plantations and other land uses on the farm show signs of erosion? (Impacts)	8	15	77	23	19	58
8	Has the fertility of the soil decreased in the last years? (Impacts)	54	15	31	50	4	46
9	Is there irregular coffee bloom? (Impacts)	62	38	0	73	8	19
10	Is there an increase in the fall of flowers and coffee fruits? and / or Is there an increase in defoliation of coffee plants? (Impacts)	46	23	31	65	4	31
11	In the last 5 or 10 years has there been an increase in pests and diseases damage in coffee plantations? (Impacts)	62	23	15	42	4	54
12	Has production been decreasing in recent years (5 or 10 years)? (Impacts)	77	15	8	38	8	54

The third component of the TVAAC concerning "Adaptive capacity" showed that the most significant problem perceived by producers (73%) was the lack of diversity in the farms. In general, the farms collectively demonstrated high diversity, but the individual frequency of species in each farm was lower. Pest problems were not an issue for 54% of the producers, however many indicated that they required knowledge, inputs and support to protect the crop. 85% of the farms had shade grown coffee and 50% of the producers had trees more than 15 years old. 46% were improved varieties planted during the last 10 years and 12% were not sure of the trees age. Many of the producers (65%), however, were either in the process of removing old trees or expanding the farm with younger trees. The practice of pruning was lacking in 69% of the farms, even though farmers acknowledged the importance and efficiency of the practice (Table 20). The average size of the farms was 5.2 ha., in half of them, coffee associated with bananas or service trees, the remainder of the farm generally presented dispersed tree arrangements. In most cases, there were random trees left behind for shade and lumber.

In many farms, the water source was mainly from the community water system. Some producers had streams but had no tree coverage to protect the water source. More than 60% of

[9] Sensitivity with respect to the impacts of CC refers to the degree by which a system is affected by extreme events. Usually, these "impacts" are reflected in coffee quality, production, costs, profits, etc. (IPCC, 2007)

the producers experience difficulties in acquiring synthetic fertilizers to provide nutrition to the plantations. Consequently, the impact of all these challenges led to the perception (54%) that coffee production was significantly affected and decreased in the last 10 years. Since climate change has been an important topic among the producers, 88% perceive that there are organizational processes in place to mitigate and adapt to it, however this has not been sufficient to make any significant progress on strengthening adaptive capacity (Table 18).

Table 20. Responses (%) by small producers from Turrialba, Costa Rica, for the variables related to Adaptive capacity[10] to climate change. 2016/2018.

N°	Guiding Questions	2016			2018		
		Yes (%)	+/- (%)	No (%)	Yes (%)	+/- (%)	No (%)
	Variables (Adaptive Capacity)	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**
13	Are soil conservation practices lacking in most of the area? (Adaptive capacity)	23	8	69	69	8	23
14	Is grass cover and leaf litter absent in coffee plantations (between rows of plants)? (Adaptive capacity)	8	8	84	27	8	65
15	The diversification (timber, fruit trees and other crops of food security), the diversity of birds in the coffee or farm is low or does not exist (adaptive capacity)	16	15	69	73	0	27
16	Are the coffee plantations areas in full sun or with less than 20% shade coverage or with excess> 70%? (Adaptive capacity)	23	38	38	12	4	85
17	Are the coffee plantations old (more than 15 years old)? (Adaptive capacity)	46	23	31	50	8	42
18	Are coffee varieties resistant to drought, high temperatures absent? and / or Are varieties resistant to important diseases such as rust, crow's eye? (Adaptive capacity)	54	23	23	42	12	46
19	Is the annual practice of pruning and de-suckering of coffee trees absent? (Adaptive capacity)	0	15	85	69	0	31
20	Is the replanting of coffee trees absent every year? (Adaptive capacity)	54	31	15	27	8	65
21	Is more than 140 kg of Nitrogen / mz / year (200 kg of N / ha / year) of synthetic origin (chemical) fertilizer applied? (Adaptive capacity)	0	8	92	38	0	62
22	Is the practice of applying organic fertilizers and / or managing pulp and honey water in coffee plantations absent? (Adaptive capacity)	31	15	54	62	4	34
23	Are most streams and water sources without forest cover? (Adaptive capacity)	0	15	85	69	0	31
24	Are most areas of other uses of the farm without association with trees? (Adaptive capacity)	8	15	77	69	0	31
25	Are organizational processes missing regarding mitigation and adaptation to climate change? (Adaptive capacity)	31	23	46	12	0	88

[10] Adaptive capacity is the ability or potential that a system (in this case, coffee) has to adapt to events, effects or impacts of climate change (IPCC, 2007).

6.11 Categorization of Vulnerability and Adaptive Capacity of coffee farms

The responses of the producers on the TVAAC were analyzed both individually and collectively by variable (exposure, impacts and adaptive capacity) to determine the vulnerability and category of the farms. The results represented graphically in Figure 15 are based on the category reference; which is described in the research methodology (this information was taken into account throughout the analysis in both objectives): 27% of the producers obtained -13 to -7 points which represented critical vulnerability and adaptive capacity; 31% of the producers received - 6 to 0 points which represented average critical vulnerability and adaptive capacity; 27% of the producers received 1 to 7 points which was regular vulnerability and adaptive capacity; and lastly, 15% of the farms obtained 8 to 14 points which is moderate vulnerability and adaptive capacity. This categorization provided a clear picture of the vulnerability of the farms and served as a reference for recommending necessary actions that could reduce the impacts of climate change.

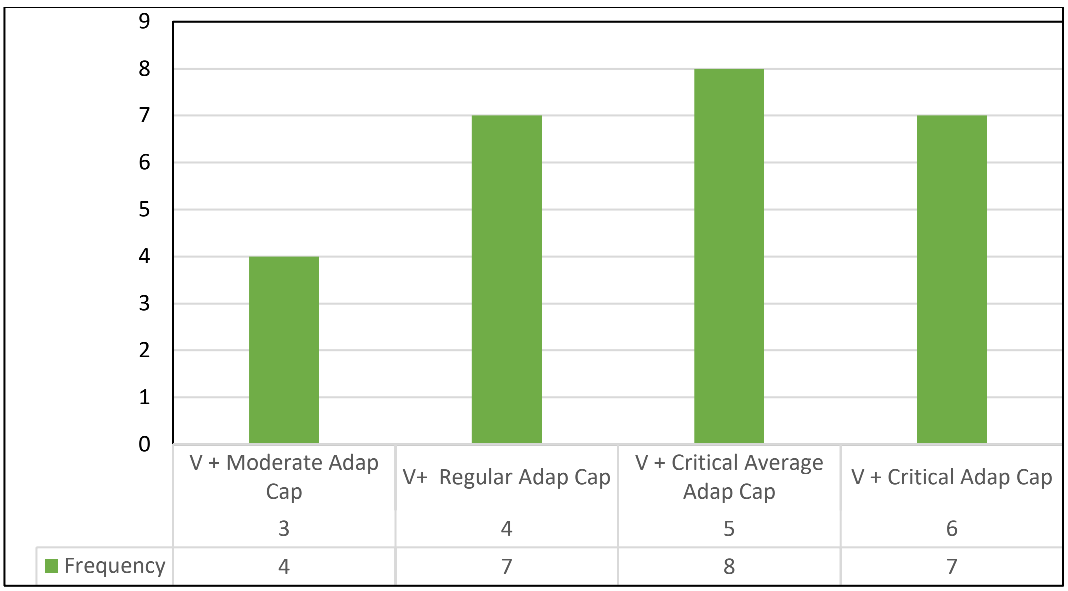


Figure 15. Evaluation results of categories of vulnerability and adaptive capacity of small producers from Apoya Naturalba, Turrialba, Costa Rica (2018).

Table 21 shows that 8 of the farms were categorized as vulnerable with average adaptive capacity (category 5). Distinctively, 7 farms resulted with vulnerability and critical adaptive capacity (category 4 and 6); of those, 5 farms directly corresponded with conventional coffee systems. This can be attributed to the fact that even though these farms implement the most practices (10 or 11), this did not necessarily reduce the vulnerability of the farms. Agrosustainable and organic farms, on the other hand, presented lesser vulnerability cases even though lesser practices were implemented. TVAAC is considered not only to categorize the farms based on the number and type of practices, but it places a numeric value to the perception and views of the producer so as to provide a clearer notion of how the farm is expected to respond in the face of climate change.

Table 21. Distribution of Vulnerability and Adaptive Capacity of farms by system evaluated in 2018.

Coffee System	**Vulnerability and Adaptive Capacity Category**				**Total**
	3	**4**	**5**	**6**	
Conventional	3	4	3	5	15
Agrosustainable	1	2	3	1	7
Organic	0	1	2	1	4
Total	**4**	**7**	**8**	**7**	**26**

6.12 Identification of Principal Limitations by System (Conventional, Organic Agrosustainable) 2018.

As seen in Table 22, for the variable of **Exposure**, temperature increase and irregular rainfall was perceived as a limitation for 100% of the producers from all three production systems. Producers who implemented Organic systems also reported strong winds and increased precipitation (75%) as limiting factors. Considering the natural climatic conditions of the zone and that many of the organic farms were located on high slopes, this explains the effect of stronger winds and increased precipitation (high intensity, shorter periods) when compared to the other systems. In Agrosustainable systems 57% of the producers reported strong winds, drought and water scarcity respectively.

About **Impact** variables, Organic producers perceived limitations within the system as a result of irregular coffee blooming (75%), a typical condition for coffee production in the zone. Producers also perceived an increase in pest and disease (75%) due to the fact that they used biological pest control with short term effects as a result of high precipitation. The producers also reported a decrease in production (50%) which is associated to the fact that they eliminated older trees and replanted new ones. Many of the young trees were nearing 3 years at the time of the study. Producers from agrosustainable systems reported irregular coffee blooming (86%), an increase in pests and diseases (57%) and decreased production (71%). The factors previously mentioned equally affected this system. In conventional systems loss of soil fertility was perceived by more than half of the producers (53%). This condition is perceived as the effect of intense conventional practices.

The variables perceived by producers concerning **adaptive capacity** included much greater limitations than two years earlier. In organic production systems, 100% of the producers considered that there was insufficient ground cover. Since many of the parcels were recently established (3 years), the shade trees which were either present from natural regeneration or planted were equally young; therefore there was not much leaf litter on the ground. However, in areas with older trees, leaf litter was present to protect and provide nutrients to the soil. 100%

of the producers perceived a limitation to acquire drought and disease resistant varieties. The reason was not only the high cost, but the fact that even if they were able to purchase the trees, it would be hard to manage them considering the age of the producer, limited land space and the fact that family participation was extremely low to absent. Again the lack of tree presence was a limitation for 75% of the organic producers since the parcel size were small and many plots were recently established. Nonetheless, producers had other trees on the farm which were outside the coffee parcel.

Finally, 75% of the producers perceived a limitation due to the lack of organic amendments to incorporate into the system. The main reason for this is that the elderly producers did not have the time to elaborate the inputs such as bokashi, bioles, repellents, foliar applications o compost. The also did not have the necessary resources to employ help, nor did they have enough time to prepare it themselves. As a response to this situation, it is evident that the administrator at the coffee mill makes available finished organic amendments to assist producers, but they still find it challenging to transport it to the farms due to a lack of transport.

In Agrosustainable systems, 71% of the producers perceived the lack of soil cover as a limitation. This is so because some of the farms are in a transitional process from conventional which did not have a strong tree presence in previous years. Soil cover existed, but the producers did not consider it was sufficient, especially in new plantations. Shade management was a limitation for 71% of the producers who indicated that it was difficult for them to implement. 57% still perceive that the lack of access to drought and disease resistant varieties is also a limitation. 71% of the producers also perceived that the lack of use of organic amendment was a limitation for reasons similar to the other systems. In the absence of what the producers considered “sufficient trees”, due to the parcel size, there was a lack of sufficient tree presence (86%) and effectively, this disallowed a proper cover in the event they had a water source on the farm.

In conventional systems, 67% of the producers perceived a limitation due to lack of soil conservation practices on the farm. With regards to soil cover, 71% perceived this as a limitation and indicated that they intend to plant more trees when they become available. The shade from trees, which were present either outside the coffee parcel or along the perimeter of the property, did not receive any shade management (67%). Similarly to the other systems, 67% of the producers responded that they did not use drought and disease resistant varieties, and 53% were old trees of the Caturra variety. 53% of the producers in this system perceived that the use of synthetic fertilizer was a problem; they expressed that excessive use can destroy the soil quality; meanwhile, insufficient use causes reduced production. The lack of use of organic amendments was perceived as a limitation for 53% of the producers for reasons related to time, accessibility of materials to elaborate bio inputs and, when made available by the Coffee mill, transportation of the products to the farm was still a problem. 30% perceived a limitation for the absence of sufficient trees on the farms, which as a result posed a problem for them to protect the water source (67%). A detailed list with percentage response can be observed in Annex 10.

Table 22. Principal Limitations by System (Conventional, Organic Agrosustainable) (2018).

Variable	System	Limitation	Response (-1) >50%
Exposure			
	Organic	Temperature Increase	100%
		Irregular rainfall pattern	100%
		Strong winds	75%
		Increased Precipitation	75%
	Agrosustainable	Temperature Increase	100%
		Irregular rainfall pattern	100%
		Strong winds	57%
		Droughts and water scarcity	57%
	Conventional	Temperature Increase	100%
		Irregular rainfall pattern	100%
Impacts (Sensitivity + Exposure)			
	Organic	Irregular coffee blooming	75%
		Increase in pest and disease	75%
		Decreased production	50%
	Agrosustainable	Irregular coffee blooming	86%
		Increase in pest and disease	57%
		Decreased production	71%
	Conventional	Loss of soil fertility	53%
Adaptive Capacity			
	Organic	Lack of soil cover	100%
		Lack of drought and disease resistant varieties	100%
		Lack of tree presence	75%
		Use of Organic amendments	75%
	Agrosustainable	Lack of soil cover	71%
		Shade management	71%
		Lack of drought and disease resistant varieties	57%
		Use of Organic amendments	71%
		Lack of cover on water source	86%
		Lack of tree presence	86%
	Conventional	Lack of soil conservation	67%
		Lack of soil cover	71%
		Shade Management	67%
		Old Coffee trees	53%
		Lack of drought and disease resistant varieties	67%
		Use of synthetic fertilizer	53%
		Use of organic amendments	53%
		Lack of cover on water source	67%
		Lack of tree presence	30%

6.13 Identification of practices which were adopted by small producers of Apoya-Naturalba

Table 23 demonstrates that the number of practices mentioned and implemented by small producers within the coffee plots is: 10 or 11 Conventional practices, 7 – 9 Organic practices and 5 or 6 Agrosustainable practices. When comparing the use of the practices mentioned, Conventional producers who were the majority (15) only differed from Organic (4) and Agrosustainable (7) in the use of herbicides and synthetic fertilizers in the coffee management. All other practices were similarly implemented across the three systems.

Table 23. Description of practices implemented by coffee producers in 3 types of production systems evaluated in 2018.

Coffee System	No. Producers	No. Practices implemented on-farm	Types of Practices implemented by small producers Apoya-Naturalba
Conventional	15	10 or 11 (High)	Farm diversification, Shade Management, Soil management, Use of Synthetic Fertilizer, Use Organic Fertilizer, Crop renovation, use of improved varieties, De-suckering, Pruning, manual weeding, Herbicide use.
Organic	4	7 – 9 (Intermediate)	Farm diversification, Shade Management, Soil management, Use Organic Fertilizer, Crop renovation, use of improved varieties, De-suckering, Pruning, Manual weeding.
Agrosustainable	7	5 or 6 (Low)	Farm diversification, Shade Management, Soil management, Use of Synthetic Fertilizer, Use Organic Fertilizer, Crop renovation, Use of improved varieties, De-suckering, Pruning, Manual weeding, Herbicide use.

The frequency of practices among the producers in Table 24 demonstrates that 100% of the farms are diversified[11]. 100% of the producers also implemented manual weed control in both Organic and Agrosustainable systems, meanwhile 87% of conventional coffee producers implemented a combination of both manual weeding and herbicides. The practice of De-suckering, Pruning and the use of improved varieties was used by all the producers. Notably, only a few farmers (10) across all three systems used organic fertilizer. This is so because organic fertilizer can be extremely costly for producers if they do not generate it themselves (Alves et al., 2015). In this study, only one organic farm showed evidence of the manufacture and use of organic inputs.

[11] Diversified farms had one (1) or more crop or animal species other than coffee.

Table 24. Frequency of practices implemented by producers from Apoya Naturalba, Turrialba, Costa Rica, in coffee production by systems in 2018.

System	Total practices implemented by producers											
	No. Producers	**MW**	**SF**	**HB**	**SC**	**SD**	**PR**	**DS**	**RP**	**IV**	**OF**	**DV**
Conventional	**15**	13	8	8	7	11	11	12	9	11	5	15
Agrosustainable	**7**	7	3	3	3	6	6	6	6	6	4	7
Organic	**4**	4	3	3	2	2	4	4	3	4	1	4
Total	**26**	**24**	**14**	**14**	**12**	**19**	**21**	**22**	**18**	**21**	**10**	**26**

MW-Manual Weeding, SF= Synthetic Fertilizer. HB-Herbicide. SC-Soil Conservation. SD – Shade trees. PR-Pruning. DS-De-suckering. RP-Replanting. IV-Improved Varities. OF- Organic Fertilizer. DV-Diversified.

Figure 16. Production of liquid fertilizers and vermiculture at the coffee mills of Naturalba S.A. in Boveda, Turrialba, Costa Rica.

More than half (53%) of the conventional producers used synthetic fertilizers in their production systems. 5 producers reported that they used organic residues from the farms to incorporate into their fertilizer program. However, in some instances, the mill provided producers with organic liquid fertilizers and compost as an incentive and to promote the use of organic inputs and demonstrate its effectiveness (Figure 15). However, many farmers expressed that the raw materials were not easily accessible and they lacked transportation to procure the necessary inputs.

6.14 Effects of practices in coffee production systems (Organic, Sustainable and Conventional Coffee stsyems)

Statistical analysis demonstrated there was no association between the Systems and the number of practices implemented on the farm (Table 25). The total number of farms (n=26) were encountered in diverse categories (Figure 17). There was also no association between production systems and the category of Vulnerability and adaptive capacity (Table 26). However, the contingency table (Table 28) shows that there is a positive relationship between the type of system and the coffee produced per hectare. Notably, the sample size in this study did not have an even distribution.

Table 25. Contingency table for variables of practices and coffee production systems evaluated in 2018.

No. Practices	Agrosustainable	Conventional	Organic	Total
High	4	7	2	13
Low	0	3	0	3
Medium	3	5	2	10
Total	7	15	4	26

Statistic	Value	df	p
Chi-square (Pearson)	2.58	4	0.6302
Chi-square (ML-G2)	3.67	4	0.4525
Contingency Coef. (Cramer)..	0.18		
Kappy (Cohen)	0.12		
Contingency Coef. (Pearson..	0.30		

Table 26. Contingency table for variables of category and coffee production systems evaluated in 2018.

CatClass	Agrosustainable	Conventional	Organic	Total
VCAPCrit	1	4	1	6
VCAPMedCrit	5	4	2	11
VCAPMod	0	2	0	2
VCapReg	1	5	1	7
Total	7	15	4	26

Statistic	Value	df	p
Chi-square (Pearson)	4.77	6	0.5740
Chi-square (ML-G2)	5.49	6	0.4826
Contingency Coef. (Cramer)..	0.25		
Contingency Coef. (Pearson..	0.39		

Table 277. Contingency table for variables of production and coffee production systems evaluated in 2018.

Total Prod (Fan/ha)	Agrosustainable	Conventional	Organic	Total
High Production	0	4	0	4
Low Production	7	11	4	22
Total	7	15	4	26

Statistic	Value	df	p
Chi-square (Pearson)	3.47	2	0.18
Chi-square (ML-G2)	4.93	2	0.09
Contingency Coef. (Cramer)..	0.26		
Contingency Coef. (Pearson..	0.34		

Table 26 shows practices that showed a positive relationship with the three systems(replanting, shade-use and diversity). A correspondence analysis was conducted to visually observe the degree of association between each variable, as seen in Figure 17. Agrosustainable and Organic systems were associated with intermediate diversity, young trees (replanted), shade presence and low production. Meanwhile, Conventional systems were associated with high coffee production. High production occurred in 4 farms and the remaining 11 showed intermediate production. Conventional farms also had low to high diversity, with older trees (no replant) and little shade.

Table 288. Variables affecting coffee production systems in coffee farms from Apoya Naturalba (2018).

Variables	P value (< 0.1)
Systems x Replanting	0.0600
Systems x Shade	0.0084
Systems x diveristy	0.0851

Figure 17. Correspondence analysis demonstrating the relationship between practices and productive systems (2018).

In a further attempt to describe the association between significant variables, Figure 18 demonstrates that high coffee production was also associated with mature, older (no replant) coffee plots that were in full sun (so shade trees), meanwhile low production demonstrated a strong association with young and young bearing shade-grown coffee, replanted within the last five years.

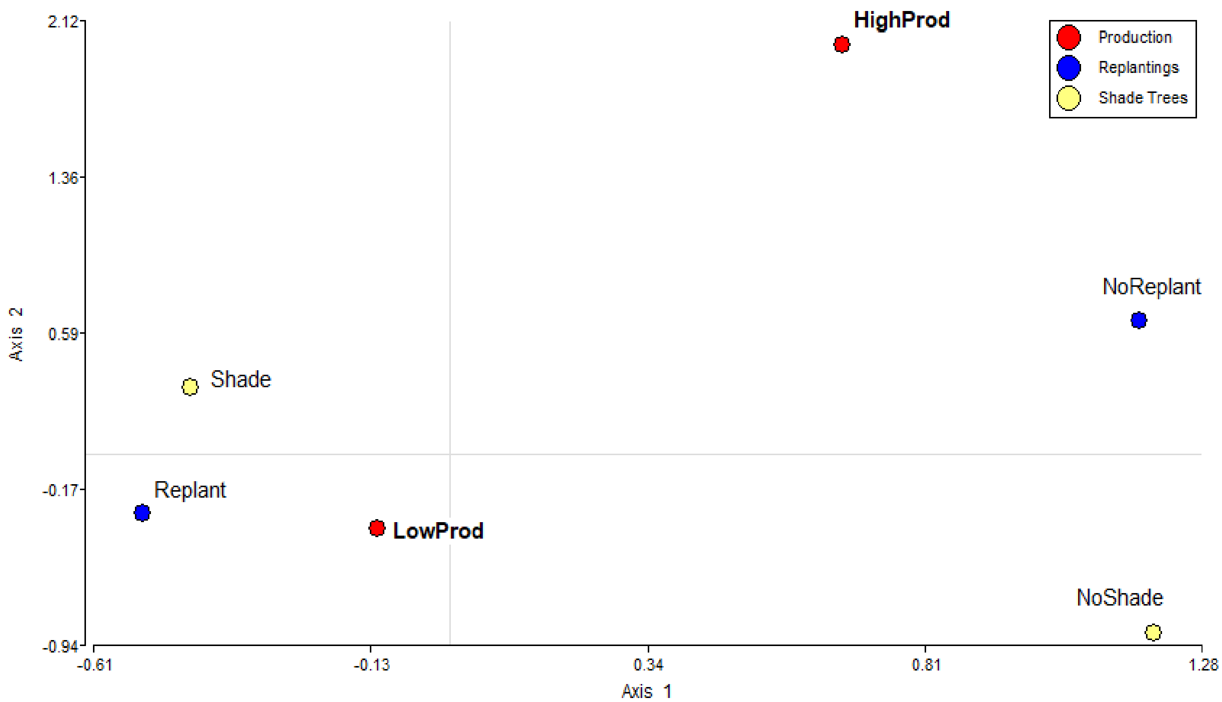


Figure 18. Correspondence analysis demonstrating the relationship between replanting and shade trees and productive systems (2018).

6.15 Limitations faced by small producers to confront climate change

As mentioned before, a description of the farming systems, its components and implemented practices was essential in this analysis to determine vulnerability and adaptive capacity. In an effort to obtain information on the perception of producers as to what it will take for them to become more resilient, a participatory workshop was undertaken as recommended by Virginio Filho et al. (2015). The data gathered during the field phase was presented as preliminary data to the producers and during the workshop, and it was discussed. The producers effectively identified a list of 10 limitations they face, and also indicated who they considered would support them to become more resilient. Table 27 demonstrates a summary of responses gathered from the session that was conducted. Annex provides a list of participants in the workshop.

Table 299. Results for identification of limitations (problems) and possible solutions by small producers from Turrialba, Costa Rica.

Q	Key Limitations (Problems)	% Response	Summary of Possible Actions (by producers)	Proposed measures/practices (Virginio Filho, et al., 2015)	Possible support Entity/organization (by Producers)
1	Changes in temperature	100	* Proper shade management and pruning to protect coffee trees and soil * Make use of available climate data and alert systems	* Incorporation of resistant varieties * Use of grafted Arabic coffee on Robusta varieties * Adapted and diversified production systems * Agroforestry systems and reforestation	National Meteorological Office, ICE, MAG, INDER, CATIE, UCR
2	Irregular rainfall patterns	100	* Build dams, provide training, * provide financing (irrigation, tools) * Technical assistance and information * Access to drought varieties * Increased accessibility to practical information	* Use water harvesting techniques * Use foliar fertilizers during dry periods * Irrigation Use	MAG, INDER, CATIE, UCR
11	Irregular coffee bloom (flowering)	73	* Spray nutrients * Apply cultural practices * Access to new varieties * More available information	* Establish an adequate fertilizer program * Apply adequate and opportune irrigation * Design and Shade Management	MAG, INDER, CATIE, UCR
9	Lack of soil conservation practices	69	* Implement site-specific recommendations & practices * Best management practices (soil) * Reduced herbicide use * Pruning (increase soil organic matter) * Construct drains on slopes	* Apply soil conservation practices (contours, live barriers, ditches, ground cover)	MAG, INDER, CATIE, UCR

			* Maintain ground cover		
18	Absence of Pruning and de-suckering	69	* Prune at the Canton level for <u>all</u> coffee farms * Periodical management off tree tissue * Control light intrusion at precise moments in coffee plots * Economical motivation (credit) to conduct practice * Make available records and data on production differences	* Initiate pruning and de-suckering programs after harvest * Two de-suckering per year is ideal	MAG, INDER, CATIE, UCR
23	Streams and water sources are not covered	69	* Reforestation * Respect boundary protection * Natural regeneration	* Recuperate forest cover near natural springs. * Use agroforestry systems to protect water sources, ground cover and not apply agrochemicals.	MINAE, ICE
25	Lack of trees on the property	69	* Plant Trees * Prepare nurseries (association)	* Use different agroforestry arrangements, reforestation and natural regeneration to guarantee a diversified agricultural production and environmental services.	MAG, INDER, CATIE, UCR
22	Lack of organic fertilizer use in coffee plantation	62	* Apply inputs * Provide Technical Recommendations * Management based on available materials and resources * Motivation so that the crop is profitable	* Incorporate quality organic fertilizer in the fertilizer program * Prepare organic fertilizer on-farm	PRODUCERS, MAG, INDER, CATIE, UCR

13	Increase of pest and disease incidence	42	* Apply cultural practices, Conduct Training, Provide Financing, Access to high resistant varieties, supply inputs * Access to new varieties * Fertilizer management * Define environmental causes * Improve ecosystem * New genetics against coffee rust	* Make opportune diagnosis to determine levels of disease and pest incidence * Apply adequate control measures in accordance to the weather and fruit load * Remain informed with early warning systems to take measures preventative and control * Integrated management of coffee plots * Conduct Integrated pest management practices * Design and Manage Shade * Combine lots with different varieties that are resistant to distinct varieties.	UCR, UNA, CATIE,
20	Decrease in production	38	* Apply fertilizer * Fertilizer management * Access to New varieties	Conduct an integral diagnostic of the coffee plots (productive, pest & disease, shade, ground cover) Conduct soil analysis, if possible, foliar analysis as well.	
	Other				
	Lack of Organizational processes on mitigation and Climate Change Adaptation	12	* Technicians need to provide trainings * Producers need to be incentivized * Create awareness, provide technical guidance and resources	* Establish and/or strengthen organizational actions (trainings, technical assistance, communication processes), follow up of programs for adaptation and mitigation. * Create committees to follow up and support the improvement of productive units.	MAG, INDER, CATIE, UCR, LOS MEDIOS DE COMUNICACIÓN

Figure 19 shows elements of the focal group session to discuss practices and limitations faced by producers. Three women participated, one was the daughter of a producer; the discussion was balanced in sharing ideas, constructive arguments and it also encouraged producers to remain a part of the association. Figure 20 shows the results of "¿Cómo me siento?" (How do I feel?), regarding the satisfaction and usefulness of the workshop.

Figure 19. Presentation and Discussion of farm limitations (problems) that affect coffee production by small producers from Apoya Naturalba in Turrialba Costa Rica.2018.

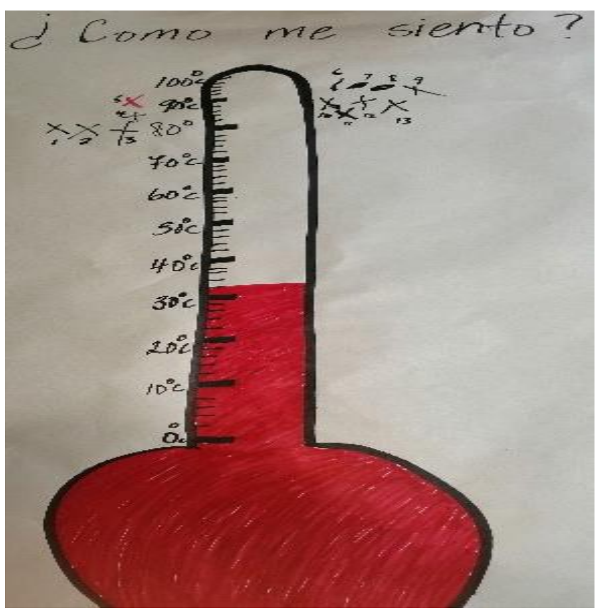


Figure 20. Representation of the satisfaction (100% – 80%) and (usefulness) of producers with the discussions during the workshop in, Turrialba, Costa Rica.

With the use of Pro Word Cloud, a software included in Microsoft Word Add ins, some of the key words that were mentioned by producers in the discussions were highlighted (Figure 21). Access to new varieties and information on climate change adaptation practices were highly important. The topic of provision of inputs was also mentioned since producers claim to have very few resources and support to invest in their coffee plots. Reforestation was mentioned several times because producers appear to have a high value for trees and its role in protecting water sources, habitats for biodiversity and the crop itself.

Figure 20. Key words that resulted from the discussions and presentations of small coffee producers.

7. Conclusions

- The average age of the producers in the present study is 58 years old, which coincides with the global demographic challenges facing sustainable agriculture. Small producers have more than 20 years' experience in coffee production, however, youth participation is absent to non-existent. The small producers used more than eight varieties of coffee in three principal types of production systems: Organic, Agrosustainable and Conventional. The average production of coffee in all three systems was significantly low when compared to the average attainable yields in the entire zone.

- Coffee trees were mostly grown in association with bananas, cocoa, natural forests, service trees and diverse fruit trees. Besides coffee, the association produced other products to diversify their markets and earn additional income: banana vinegar, organic chocolate powder, chocolate sweets, banana vinegar and organic sugar in few cases. Furthermore, the small producers generally expressed interest in gradually exploring new farming opportunities which would add value to coffee, the establishment of new crops, particularly cocoa as well as animal rearing and coffee tours.

- When comparing the results of the Tool for vulnerability analysis and adaptive capacity of coffee farms (TVAAC) conducted in 2016 with new results from 2018 for 8 small producers, two scenarios were presented; either the vulnerability and adaptive capacity of the farms remained in the same category as in 2016, or the producers became more vulnerable in 2018. The producers indicated that they lacked available credit to further invest in the farms during the last two years.

- New plantings and old, low-producing varieties were also contributing factors to the generally low production among small and medium sized farms. Temperature increase and irregular rainfall patterns were the two most common limitations across all production systems for both periods. Technical support by institutions who should assist coffee producers was absent for the majority of the producers. Considering the natural climatic conditions of Turrialba, coffee production was both directly and indirectly affected by climate variability.

- The management practices implemented were generally low technology and consistent with traditional coffee management practices. Due to the inability of many of the producers to conduct coffee management practices on their own, 69% of the producers employed part time workers to assist. At least 11 practices were implemented all together. The majority of the practices were implemented in conventional systems, followed by organic and agrosustainable. The study demonstrated that agrosustainable and organic farms particularly increased the presence of young coffee trees (replanted) under shade conditions.

- In the participatory workshop conducted to provide feedback and discuss the limitations faced by producers, they echoed the need for technical support from both local and international agencies. Reforestation was specifically mentioned several times during the workshop because producers have high value for trees and recognize their role in improving the coffee systems and building climate change resilience on the farms.

8. Recommendations

- The integral involvement of women and youths is essential to ensure sustainability of the coffee industry, particularly in Apoya Naturalba. This approach must be one that is inclusive, technological, innovative and accessible. If this extends to the community level, it can be an opportunity to promote entrepreneurial leadership among youths who would otherwise migrate to the cities in search for more opportunities and employment.

- Undoubtedly members of Apoya Naturalba are vulnerable to the effects of climate variability and change. Even though the TVAAC measures only the agronomic and environmental limitations faced by the producers, there is a need to incorporate an assessment of the socioeconomic impacts caused by climate change. This will complement the tool and facilitate the decision making process for the producers. It is not enough to categorize the farms and suggest possible actions, the producers need access to information involving the costs associated with implementing each adaptation practice and how it will benefit them throughout the development of the crop.

- The traditional practices currently being implemented are not enough to face the impacts of climate change. Whether the coffee systems are conventional, agrosustainable or organic, ecosystem-based adaptation practices must also be incorporated since they cover both the adaptation process and the involvement of the entire farm family.

- Farmers must continue to diversify their farms, include sustainable agroforestry practices and move away from traditional pure stand coffee. If the farms are more diverse, vulnerability will reduce. However, considering the size of these are small farms, careful planning must be done to ensure that the diversification efforts do not have a negative effect on coffee production.

- The process towards building resilience in each system should include a clear focus on what producers are currently doing well, which practices are working and which ones are not. A careful evaluation of these questions and answers may allow the development of viable solutions in collaboration with farm families.

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10. Annexes

Annex 1. Data Sheet for Farmer Profile

Farmer Profile							
Personal Information				**Family Information**			
Date of visit				Spouse Name			
Time of visit				How many family members assist on the farm			
Name of Producer				No. Children	Malse	Females	
Contact Number				Age of Children	Males	Females	
Age				Age of Children (Female)	Males	Females	
Gender	Male	Female		How many assists on the farm?	Male	Females	
Location				Level of Education (Male)			
Education level	Primary	College	University	Level of Education (Female)			
Check the box that represents the best answer							
How many additional persons work on the farm?	1	2	3	4	5+		
In which activities do they assist?	Planting	Weed	Pest Control	Pruning	Fert.	Harvest.	Sales
What is the rate paid per day for each activity?							
Do you participate in Trainings and Workshops? How often?	1x/yr.	2x/yr.	3x/yr.	None			
What type of trainings and workshops do you receive?	Coffee Management	Fruit Tree Management	Pest Management	Other			
What are your primary sources of income?	Sales from Coffee	Sales from Other Fruits and Veg	Animal Production	Value Added Products	Other		
Support Networks/Institutions (State, University Research, NGO, Association, Cooperative, Other							
Other observations:							

Annex 2. Data Record sheet for Farm Profile and Characterization

Crop Production Survey (Outside the Coffee Plantation)															
	Name of Farmer:														
Type of production system	Organic				Transition		Conventional								
Land tenure			Property			Rent									
Types of crop (Coffee, Fruit Trees, Forest Species) – *list by order of priority/importance*	Variety		Area (ha)		Spacing (m)	Age of crops (yrs.)	Number of plots		Yields/ha		Market Destination (Sales)		Association/ Intercropping	Home use (amt.)	Price/Unit/kg
1.															
2.															
3.															
4.															
5.															
What type of agronomic practices do you do for each crop? How much time per week do you spend on each activity?	**WC**	Hours	**PC**	Hours	**Fert**.	Hours	**Irri.**	Hours	**Harv.**	Hours	**Prun.**	Hours	**Other**		
1.															
2.															
3.															
4.															
5.															

Note: WC = Weed Control, PC = Pest Control, Fert. = Fertilization, Irri. = Irrigation, Harv. = Harvesting, Prun. = Pruning

Annex 3. Data Record Sheet for Coffee Production

		Crop Production Survey (Within the Coffee Plantation)								
Name of Farmer:										
Type of production system	Organic		Transition		Conventional					
Land tenure			Property	Rent						
Coffee Varieties and other crops	Area (ha)	Spacing (m)	Age of crops (yrs.)	Number of plots	Yields/ha	Market Destination (Sales)	Association/ Intercropping	Home use (amt.)	Price/Cajuela	
1.										
2.										
3.										
4.										
5.										

What type of agronomic practices do you do for your coffee plots? How much time per week do you spend on each activity per cycle?	**WC**	Hours	**PC**	Hours	**Fert.**	Hours	**Herb**	Hours	**Harv.**	Hours	**Prun.**	Hours	**Rep.**	Hours	Other
1.															
2.															
3.															
4.															
5.															

Do you engage in any type of value adding initiatives? Which?		Where do you sell the value-added product?		What is your selling price for each product?	

Please indicate the **calendarization of activities** in your coffee plantation each year		Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
As a member of APOYA - Naturalba What do you consider to be your **Role/function** in the association?		
What do you recognize as some of the **challenges** in being in the association?		
What are some of the **benefits** you receive for being a member of APOYA - -- Naturalba?		

WC = Weed Control, PC = Pest Control, Fert. = Fertilization, Herb. = Herbicides, Harv. = Harvesting, Prun. = Pruning, Rep. = Replanting

Annex 4. Data Record Sheet for Coffee Production

N°	Guiding Questions	Yes (%)	+/- (%)	No (%)
	Variables (Exposure)	**-1**	**0.5**	**1**
1	Have there been changes in temperature in the last 10 years? (Exposure)			
2	In recent years (5 or 10 years) have the rains been irregular? (Exposure)			
3	Is there an increase in rainfall with floods and landslides (5 or 10 years)? (Exposure)			
4	Is there a risk of hurricanes and tropical storms? (Exposure)			
5	Have there been (last 5 or 10 years) droughts, decrease or absence of water on the property? (Exposure)			
6	Are there strong winds and / or increases of these in recent years (5 or 10 years)? (Exposure)			
	Variable Impacts (Sensitivity + Exposure)			
7	Do most of the soils in coffee plantations and other land uses on the farm show signs of erosion? (Impacts)			
8	Has the fertility of the soil decreased in the last years? (Impacts)			
9	Is there irregular coffee bloom? (Impacts)			
10	Is there an increase in the fall of flowers and coffee fruits? and / or Is there an increase in defoliation of coffee plants? (Impacts)			
11	In the last 5 or 10 years has there been an increase in pests and diseases damage in coffee plantations? (Impacts)			
12	Has production been decreasing in recent years (5 or 10 years)? (Impacts)			
	Variables (Adaptive Capacity)			
13	Are soil conservation practices lacking in most of the area? (Adaptive capacity)			
14	Is grass cover and leaf litter absent in coffee plantations (between rows of plants)? (Adaptive capacity)			
15	The diversification (timber, fruit trees and other crops of food security), the diversity of birds in the coffee or farm is low or does not exist (adaptive capacity)			
16	Are there coffee plantations areas in full sun or with less than 20% shade coverage or with excess> 70%? (Adaptive capacity)			
17	Are the coffee plantations old (more than 15 years old)? (Adaptive capacity)			
18	Are coffee varieties resistant to drought, high temperatures absent? and / or Are varieties resistant to important diseases such as rust, crow's eye? (Adaptive capacity)			
19	Is the annual practice of pruning and de-suckering of coffee trees absent? (Adaptive capacity)			
20	Is the replanting of coffee trees absent every year? (Adaptive capacity)			
21	Is more than 140 kg of Nitrogen / mz / year (200 kg of N / ha / year) of synthetic origin (chemical) fertilizer applied? (Adaptive capacity)			
22	Is the practice of applying organic fertilizers and / or managing pulp and honey water in coffee plantations absent? (Adaptive capacity)			
23	Are most streams and water sources without forest cover? (Adaptive capacity)			
24	Are most areas of other uses of the farm without association with trees? (Adaptive capacity)			
25	Are organizational processes missing regarding mitigation and adaptation to climate change? (Adaptive capacity)			

Annex 5. Agenda for Participatory Workshop on Identifying and prioritizing limitations in Coffee production

Taller de Productores de Café e otros cultivos
Identificación y Priorización de opciones de adaptación y mitigación para los Sistemas de Producción de Café por Apoya-Naturalba en Turrialba, Costa Rica

Fecha: 25 de abril del 2019
Lugar: Finca Botánica, CATIE, Turrialba

8:00 a.m. – 8:30 a.m.	Registración de participantes
8:30 a.m. – 8:35 a.m.	Invocación
8:35 a.m. – 8:45 a.m.	Bienvenida
8:45 a.m. – 8:55 a.m.	Presentación de la dinámica y actividades del día – **Fay Garnett Estudiante de Maestría, CATIE**
8:55 a.m. – 9:20 a.m.	Presentación de los avances del estudio *(Análisis de la Vulnerabilidad y Capacidad Adaptiva de los pequeños Productores de café de Naturalba, Turrialba, Costa Rica)* - Fay **Garnett – Estudiante de Maestría, CATIE**
9:20 a.m. – 10:00 a.m.	**Actividad 1.** Identificación de limitaciones en la producción de café y otros cultivos y las opciones de adaptación y mitigación del cambio climático – **Todos los participantes**
10:00 a.m. – 10:20 a.m.	**Receso**
10:20 a.m. – 11:00a.m.	**Actividad 2.** Priorización de opciones para hacer frente a limitaciones de vulnerabilidad y adaptabilidad al cambio climático en la producción de café y otros cultivos - **Todos los participantes**
11:00 a.m. – 11:50 a.m.	Presentación Grupal **(15 minutos cada grupo)**
11:50 a.m. – 12:20 p.m.	**Almuerzo**
12:20 p.m. – 12:45 p.m.	**¡Dinámica del día!**
12:45 p.m. – 1:15 p.m. -	Tipos de erosión y plantas nativas para su manejo. **Lic. Christopher Mora – Apoya-Naturalba**
1:15 p.m. – 1:45 p.m.	Proyecto de árboles ICAFE. – **Ing. Lenin Poveda Vega – Representante ICAFE**
1:45 p.m. – 2:15 p.m.	Discusión con la Asamblea – **Marie Beautchet – Miembro Administrativa – Apoya-Naturalba**
2:15 p.m. – 2:30 p.m.	¡Cierre y Rifa para productores!

Annex 5. Workshop Guide for Workshop on Identifying and prioritizing limitations in Coffee production

Thesis Title: Analysis of climate change vulnerability and adaptive capacity of small coffee producers of APOYA- Naturalba in Turrialba, Costa Rica.

Workshop/Socialization Summary

Proposed Date: **Thursday, April 25th, 2018**
Location: **CATIE**
No. of session: **2**
Total No. Participants: **30**

Time	Session	Objectives	Workshop Development	Materials	Duration	Responsible Person
8:00-8:30 a.m.	Registration	Register participants and provide identification card (name tag) to each one.	A registration form will be used to record; Date, Full name, Age, Contact, Location, Production, System, Signature A name tag will be provided to each person to facilitate the discussions and group discussions.	Registration Form, pens, folder, name tag	30 minutes	Christopher
8:45 - 9:05 a.m.	Welcome and presentation of objectives	Present the objectives of the day and record expectations from the producers	The facilitating team will be presented to the participants. In PowerPoint, the objectives of the day will be explained, and the agenda will be reviewed. Each participant will present him/herself and they will state their expectations of the workshop. The expectations will be recorded on a flipchart to review at the end of the session.	Timer (Phone timer), Flip Chart and paper to record group expectation	20 minutes	Fay Garnett
9:10-9:55 am	Identification of limitations to reduce farm vulnerability to CC	Identify what are the current limitations which producers are experiencing	**Part 1.** A general overview will be explained of how the Vulnerability and Adaptability tool is conducted (25 questions) for analysis in coffee production.	Extension cord, projector, computer, speakers, Paper, pencils, Flipchart, markers, power point presentation.	10 minutes	Fay Garnett, Itzayana Garth, Katia Plazaola
			Part 2. Producers will be divided into three groups (conventional coffee, organic coffee, other crops/activities) and they will be asked; 1. What are your current limitations in coffee production/other activities as it relates to climate change? 2. Who/Which entity do you consider a possible support system to address your limitation 3. How can it be addressed, ideas?			Fay Garnett, Itzayana Garth, Katia Plazaola
9:55 – 10:15 a.m.	**Break**					

Annex 6. Results values (points) from the TVAAC (2016)

N°	Guiding Questions	Convencional			Convencional			Convencional			Convencional			Organic			Organic			Organic			Organic		
		CF2016			FR2016			VR2016			HA2016			VM2016			LO2016			AS2016			JS2016		
	Variables (Exposure)	**SI**	**-**	**NO**	**SI**	**-**	**NO**	**SI**	**-**	**NO**	**SI**	**-**	**NO**	**SI**	**-**	**NO**	**SI**		**NO**	**SI**	**-**	**NO**	**SI**	**-**	**NO**
1	Temperature		0.5		-1.0			-1.0			-1.0			-1.0				0.5		-1.0			-1.0		
2	Irregular Rains	-1.0					1.0	-1.0			-1.0			-1.0				0.5		-1.0			-1.0		
3	Increase Precipitation			1.0			1.0		0.5			0.5		-1.0					1.0			1.0	-1.0		
4	Hurricanes and Tropical Storms			1.0			1.0			1.0			1.0			1.0		0.5				1.0			1.0
5	Droughts and Water Scarcity		0.5				1.0			1.0			1.0		0.5			0.5		-1.0			-1.0		
6	Strong or increased winds	-1.0					1.0			1.0			1.0		0.5				1.0			1.0			1.0
	Variables Impacts (Sensitivity + Exposure)																								
7	Signs of Erosion			1.0			1.0			1.0	-1.0				0.5				1.0			1.0			1.0
8	Loss of Fertility		0.5		-1.0					1.0	-1.0				0.5				1.0	-1.0			-1.0		
9	Irregular coffee blooms	-1.0			-1.0				0.5		-1.0				0.5			0.5		-1.0			-1.0		
10	Increase in flower, leaf and fruit Fall		0.5		-1.0				0.5		-1.0			-1.0					1.0			1.0			1.0
11	Increase in Pest and Disease		0.5		-1.0			-1.0			-1.0				0.5			0.5		-1.0			-1.0		
12	Decrease in Production	-1.0			-1.0			-1.0			-1.0				0.5			0.5		-1.0			-1.0		
	Variables (Adaptive Capacity)																								
13	Lack of Soil Conservation			1.0			1.0			1.0	-1.0				0.5				1.0	-1.0			-1.0		
14	Lack of Soil Cover			1.0			1.0			1.0	-1.0				0.5				1.0			1.0			1.0
15	Lack of Diversity			1.0			1.0		0.5		-1.0					1.0			1.0	-1.0					1.0
16	Shade Management		0.5				1.0		0.5		-1.0					1.0			1.0	-1.0			-1.0		
17	Old Coffee Trees		0.5		-1.0				0.5		-1.0			-1.0					1.0	-1.0			-1.0		
18	Lack of Drought and Disease resistant trees			1.0	-1.0				0.5		-1.0				0.5			0.5		-1.0			-1.0		
19	Lack of Pruning and Tree formation			1.0		0.5				1.0			1.0			1.0			1.0			1.0			1.0
20	Lack of Replanting	-1.0			-1.0				0.5			0.5			0.5				1.0	-1.0			-1.0		

21	Use of Synthetic Fertilizer			1.0			1.0		0.5				1.0			1.0			1.0			1.0			1.0
22	Use of Organic amendments			1.0	-1.0			-1.0			-1.0				0.5				1.0			1.0			1.0
23	Lack of water source cover			1.0			1.0		0.5				1.0			1.0			1.0			1.0			1.0
24	Lack of Tree presence			1.0			1.0		0.5		-1.0					1.0			1.0			1.0			1.0
25	Lack or organizational processes for CC	-1.0					1.0	-1.0				0.5			0.5				1.0			1.0			1.0
		-6.0	3.5	12.0	-10.0	0.5	14.0	-6.0	5.5	8.0	-16.0	1.5	6.0	-5.0	6.5	7.0	0.0	4.0	17.0	-13.0	0.0	12.0	-13.0	0.0	12.0
		9.5			4.5			7.5			-8.5			8.5			21			-1			-1		
	Category of Vulnerability and Adaptive Capacity	3			4			4			6			3			1			5			5		

*Extracted from Escarraga et al. (2016)

Annex 7. Workshop for Small Coffee Producers Identification and Prioritization of adaptation and mitigation options for Coffee Production Systems Apoya-Naturalba in Turrialba, Costa Rica. 2018.

Please prioritize each limitation using a scale of (1 - 10)	Identified limitation *	Who can contribute to implement the suggested measures? The producing family with the help of: (Please mark with an x)						
		Producer Family	**Association of Producers**	**Cooperative**	**NGO (local, National, Intl.)**	**National Coffee Institute**	**Ministry of Agriculture**	**Other (Which?)**
	Change in Temperature							
	Irregular rains							
	Irregular flowering							
	Increase in Pest and Disease							
	Reduced Production							
	No Ground Cover							
	Absence of Pruning and Shoot Removal							
	Lack of Organic Material							
	Streams and Water sources with lack of tree cover (Absence of trees on property)							
	Lack of Organizational processes for Climate Change Mitigation and Adaptation.							
¿Any other limitation? Write here please. **								

* Limitations identified as Top-10 of the study using the tool to determine the vulnerability and adaptive capacity of coffee producers. ** Relevant for crops that are not coffee. Modified format of the original: Technical manual to reduce the vulnerability of coffee plantations in the face of climate change. Villareyna Acuña R. et. Al.2017

Annex 8. Attendance list of producers who participated in the Workshop for Identification of limitations and prioritization of options for mitigation

CATIE

Naturalba

APOYA

Taller de Productores de Café

Identificación y Priorización de opciones de adaptación y mitigación para los Sistemas de Producción de Café por Apoya-Naturalba en Turrialba, Costa Rica

Fecha: 25 de abril del 2019
Lugar: Finca Botánica, CATIE, Turrialba

Registración de participantes

	Nombre	Edad	Contacto	Ubicación	Producción	Sistema	Firma
1	Macario Fuentes	59	89462157	Savillos	café-cacao	sostenible	[illegible]
2	Vitalia M Ramírez	67	85697692	Eumán	Convencional	Café	Vitalia M Ramírez
3	Marta Porras	59	85707165	Joma	Café	convencional	Marta Porras
4	Ramon Sang	70	85876308	Jama.	cafe	convencional	Ramon SS
5	ALFonso [illegible]	53	8376-0311	Sitio de mata	cafe	sostenible	[illegible]
6	Fabio Obando T.	58	8666 6969.	San Juan Sur	café	orgánico	[illegible]
7	Emilce Fuentes Hidalgo	74	83806561	Pavones.	Café	orgánico	Emilce [illegible]
8	Nazareth Obando	24	84834425	San Juan Sur	café	orgánico	[illegible]
9	Josef Mendoza	54	88595096	Pavones Florencio	Cafe	Sostenible	[illegible]
10	Federico Rivera	63	86652637	Savillos	cafe	sostenible	Federico Rivera

Annex 9. Comparison of Results from Tool for vulnerability analysis and adaptive capacity of coffee farms (TVACC). 2016 vs. 2018

N°	**Guiding Questions**	**Producer**															
		CF		FR		VR		HA		VM		LO		AS		JS	
	Variables (Exposure)	**2016CF**	**2018CF**	**2016FR**	**2018FR**	**VR2016**	**VR2018**	**HA2016**	**HA2018**	**VM2016**	**VM2018**	**LO2016**	**LO2018**	**AS2016**	**AS2018**	**JS2016**	**JS2018**
1	Temperature	0.5	-1	-1	-1	-1	-1	-1	-1	-1	-1	0.5	-1	-1	-1	-1	-1
2	Irregular Rains	-1	-1	1	-1	-1	-1	-1	-1	-1	-1	0.5	-1	-1	-1	-1	-1
3	Increase Precipitation	1	1	1	0.5	0.5	1	0.5	-1	-1	1	1	1	1	0.5	-1	-1
4	Hurricanes and Tropical Storms	1	1	1	1	1	1	-1	-1	1	1	0.5	1	1	1	1	1
5	Droughts and Water Scarcity	0.5	1	1	-1	1	1	-1	-1	0.5	-1	0.5	-1	-1	1	-1	0.5
6	Strong or increased winds	-1	1	1	-1	1	1	0.5	-1	0.5	-1	1	0.5	1	-1	1	1
	Variables Impacts (Sensitivity + Exposure)																
7	Signs of Erosion	1	-1	1	-1	1	1	-1	0.5	0.5	1	1	1	1	-1	1	0.5
8	Loss of Fertility	0.5	-1	-1	-1	1	-1	-1	-1	0.5	1	1	1	-1	-1	-1	-1
9	Irregular coffee blooms?	-1	-1	-1	-1	0.5	-1	-1	-1	0.5	1	0.5	-1	-1	-1	-1	-1
10	Increase in flower, leaf and fruit Fall	0.5	1	-1	-1	0.5	1	-1	-1	-1	1	1	-1	1	-1	1	-1

11	Increase in Pest and Disease	0.5	0.5	-1	-1	-1	-1	-1	-1	0.5	1	0.5	1	-1	-1	-1	-1
12	Decrease in Production	-1	-1	-1	-1	-1	-1	-1	-1	0.5	1	0.5	-1	-1	-1	-1	-1
	Variables (Adaptive Capacity)																
13	Lack of Soil Conservation	1	-1	1	-1	1	1	-1	-1	0.5	-1	1	1	-1	-1	-1	0.5
14	Lack of Soil Cover	1	-1	1	1	1	1	-1	-1	0.5	-1	1	-1	1	-1	1	-1
15	Lack of Diversity	1	1	1	1	0.5	0.5	-1	1	1	1	1	1	-1	1	1	1
16	Shade Management	0.5	0.5	1	1	0.5	-1	-1	-1	1	1	1	-1	-1	-1	-1	-1
17	Old Coffee Trees	0.5	0.5	-1	-1	0.5	-1	-1	1	-1	1	1	-1	-1	1	-1	0.5
18	Lack of Drought and Disease resistant trees	1	-1	-1	1	0.5	1	-1	-1	0.5	-1	0.5	-1	-1	-1	-1	-1
19	Lack of Pruning and Tree formation	1	-1	0.5	1	1	1	0.5	1	1	1	1	0.5	1	1	1	1
20	Lack of Replanting	-1	-1	-1	1	0.5	1	1	1	0.5	-1	1	0.5	-1	-1	-1	-1
21	Use of Synthetic Fertilizer	1	-1	1	1	0.5	-1	-1	1	1	1	1	1	1	1	1	-1
22	Use of Organic amendments	1	1	-1	-1	-1	1	1	1	0.5	-1	1	-1	1	-1	1	1

23	Lack of water source cover	1	-1	1	-1	0.5	1	-1	1	1	-1	1	-1	1	-1	1	-1
24	Lack of Tree presence	1	-1	1	1	0.5	1	1	-1	1	-1	1	-1	1	-1	1	-1
25	Lack of organizational processes for CC	-1	1	1	1	-1	1	0.5	1	0.5	1	1	1	1	1	1	1
		9.5	-4.5	4.5	-3.5	7.5	6.5	-13	-7.5	8.5	3	21	-2.5	-1	-9.5	-1	-7
Category (Vulnerabilidad & Adaptive Capacity)		**3**	**5**	**4**	**5**	**4**	**4**	**6**	**6**	**3**	**4**	**1**	**5**	**5**	**6**	**5**	**6**

Annex 10. Results of Analysis of limitations by Systems for variables of Adaptive Capacity 2016vs2018

N°	Guiding Questions	%Responses by System																										
		Org2016			Org2018			**Average**			AgroS2016			AgroS2018			**Average**			Conv2016			Conv2018			Average		
	Variables (Exposure)	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**
1	Temperature	0.75	0.25	0.00	1.00	0.00	0.00	**0.88**	0.13	0.00	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00	0.50	0.50	0.00	1.00	0.00	0.00	**0.75**	0.25	0.00
2	Irregular Rains	0.75	0.25	0.00	1.00	0.00	0.00	**0.88**	0.13	0.00	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00	0.50	0.50	0.50	1.00	0.00	0.00	**0.75**	0.25	0.25
3	Increase Precipitation	0.50	0.00	0.50	0.25	0.25	0.50	0.38	0.13	0.50	0.00	1.00	0.00	0.50	0.00	0.50	0.25	0.50	0.25	0.00	0.00	1.00	0.00	0.50	0.50	0.00	0.25	**0.75**
4	Hurricanes and Tropical Storms	0.75	0.25	0.00	0.00	0.00	1.00	0.38	0.13	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**
5	Droughts and Water Scarcity	0.50	0.50	0.00	0.50	0.25	0.25	0.50	0.38	0.13	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.00	0.00	0.50	0.50	0.00	0.50	0.25	0.00	0.50
6	Strong or increased winds	0.75	0.25	0.00	0.50	0.25	0.25	**0.63**	0.25	0.13	0.00	0.50	0.50	0.50	0.00	0.50	0.25	0.25	0.50	0.50	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50
Variables Impacts (Sensitivity + Exposure)																												
7	Signs of Erosion	0.75	0.25	0.00	0.25	0.25	0.50	0.50	0.25	0.25	0.50	0.00	0.00	0.00	0.50	0.50	0.25	0.25	0.25	0.00	0.00	1.00	1.00	0.00	0.00	0.50	0.00	0.50
8	Loss of Fertility	0.50	0.25	0.25	0.50	0.00	0.50	0.50	0.13	0.38	0.50	0.00	0.00	1.00	0.00	0.00	**0.75**	0.00	0.00	0.50	0.50	0.00	1.00	0.00	0.00	**0.75**	0.25	0.00
9	Irregular coffee blooms?	0.50	0.50	0.00	0.50	0.00	0.50	0.50	0.25	0.25	0.50	0.50	0.50	1.00	0.00	0.00	**0.75**	0.25	0.25	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00
10	Increase in flower, leaf and fruit Fall	0.25	0.00	0.75	0.75	0.00	0.25	0.50	0.00	0.50	0.50	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50	0.50	0.50	0.00	0.50	0.00	0.50	0.50	0.25	0.25
11	Increase in Pest and Disease	0.50	0.50	0.00	0.50	0.00	0.50	0.50	0.25	0.25	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00	0.50	0.50	0.00	0.50	0.00	0.50	0.50	0.25	0.25
12	Decrease in Production	0.50	0.50	0.00	0.75	0.00	0.25	**0.63**	0.25	0.13	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**	0.00	0.00
Variables (Adaptive Capacity)																												
13	Lack of Soil Conservation	0.50	0.25	0.25	0.50	0.25	0.25	0.50	0.25	0.25	0.50	0.00	0.00	0.50	0.00	0.50	0.50	0.00	0.25	0.00	0.00	1.00	1.00	0.00	0.00	0.50	0.00	0.50
14	Lack of Soil Cover	0.00	0.25	0.75	1.00	0.00	0.00	0.50	0.13	0.38	0.50	0.00	0.00	0.50	0.00	0.50	0.50	0.00	0.25	0.00	0.00	1.00	0.50	0.00	0.50	0.25	0.00	**0.75**
15	Lack of Diversity	0.25	0.00	0.75	0.00	0.00	1.00	0.13	0.00	**0.88**	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50	0.50	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	**1.00**

16	Shade Management	0.50	0.00	0.50	0.75	0.00	0.25	**0.63**	0.00	0.38	0.50	0.50	0.50	1.00	0.00	0.00	**0.75**	0.25	0.25	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.50
17	Old Coffee Trees	0.75	0.00	0.25	0.25	0.25	0.50	0.50	0.13	0.38	0.50	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00
18	Lack of Drought and Disease resistant trees	0.50	0.50	0.00	1.00	0.00	0.00	**0.75**	0.25	0.00	0.50	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50
19	Lack of Pruning and Tree formation	0.00	0.00	1.00	0.00	0.25	0.75	0.00	0.13	**0.88**	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.50	0.00	0.50	0.50	0.50	0.00	0.50	0.25	0.25	0.50
20	Lack of Replanting	0.50	0.25	0.25	0.75	0.25	0.00	**0.63**	0.25	0.13	0.00	0.50	0.50	0.00	0.00	1.00	0.00	0.25	**0.75**	1.00	0.00	0.00	0.50	0.00	0.50	**0.75**	0.00	0.25
21	Use of Synthetic Fertilizer	0.00	0.00	1.00	0.25	0.00	0.75	0.13	0.00	**0.88**	0.00	0.50	0.50	0.50	0.00	0.50	0.25	0.25	0.50	0.00	0.00	1.00	0.50	0.00	0.50	0.25	0.00	**0.75**
22	Use of Organic amendments	0.00	0.25	0.75	0.75	0.00	0.25	0.38	0.13	0.50	1.00	0.00	0.00	0.00	0.00	1.00	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50	0.50	0.00	0.50
23	Lack of cover on water source	0.00	0.00	1.00	1.00	0.00	0.00	0.50	0.00	0.50	0.00	0.50	0.50	0.00	0.00	1.00	0.00	0.25	**0.75**	0.50	0.00	0.50	1.00	0.00	0.00	**0.75**	0.00	0.25
24	Lack of Tree presence	0.00	0.00	1.00	1.00	0.00	0.00	0.50	0.00	0.50	0.50	0.50	0.50	0.50	0.00	0.50	0.50	0.25	0.50	1.00	0.00	0.00	0.50	0.00	0.50	**0.75**	0.00	0.25
25	Lack or organizational processes for CC	0.00	0.25	0.75	0.00	0.00	1.00	0.00	0.13	**0.88**	0.00	0.50	0.50	0.00	0.00	1.00	0.00	0.25	**0.75**	0.50	0.00	0.50	0.00	0.00	1.00	0.25	0.00	**0.75**

Annex 11. Reponses to TVAAC by producers (2018)

N°	Guiding Questions									
		Org2018			AgroS2018			Conv2018		
	Variables (Exposure)	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**	**-1**	**0.5**	**1**
1	Temperature	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
2	Irregular Rains	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
3	Increase Precipitation	0.75	0.25	0.00	0.29	0.14	0.57	0.40	0.27	0.33
4	Hurricanes and Tropical Storms	0.00	0.25	0.75	0.14	0.00	0.86	0.33	0.07	0.60
5	Droughts and Water Scarcity	0.00	0.25	0.75	0.57	0.00	0.43	0.40	0.13	0.27
6	Strong or increased winds	0.75	0.25	0.00	0.57	0.14	0.29	0.27	0.07	0.67
Variables Impacts (Sensitivity + Exposure)										
7	Signs of Erosion	0.00	0.75	0.25	0.29	0.00	0.71	0.27	0.13	0.60
8	Loss of Fertility	0.50	0.00	0.50	0.30	0.00	0.57	0.53	0.07	0.40
9	Irregular coffee blooms?	0.75	0.00	0.25	0.86	0.00	0.14	0.60	0.13	0.27
10	Increase in flower, leaf and fruit Fall	0.00	0.00	1.00	0.43	0.14	0.43	0.27	0.07	0.67
11	Increase in Pest and Disease	0.75	0.25	0.00	0.57	0.00	0.43	0.80	0.07	0.13
12	Decrease in Production	0.50	0.00	0.50	0.71	0.00	0.29	0.67	0.07	0.27
Variables (Adaptive Capacity)										
13	Lack of Soil Conservation	0.00	0.00	1.00	0.43	0.00	0.57	0.53	0.07	0.40
14	Lack of Soil Cover	1.00	0.00	0.00	0.71	0.00	0.29	0.67	0.00	0.33
15	Lack of Diversity	0.25	0.00	0.75	0.00	0.14	0.86	0.13	0.00	0.87
16	Shade Management	0.00	0.25	0.75	0.71	0.00	0.29	0.53	0.07	0.40
17	Old Coffee Trees	0.00	0.00	1.00	0.43	0.14	0.43	0.53	0.13	0.33
18	Lack of Drought and Disease resistant trees	1.00	0.00	0.00	0.57	0.00	0.43	0.67	0.00	0.33
19	Lack of Pruning and Tree formation	0.25	0.00	0.75	0.14	0.14	0.71	0.33	0.07	0.60
20	Lack of Replanting	0.25	0.25	0.50	0.43	0.14	0.43	0.40	0.00	0.60
21	Use of Synthetic Fertilizer	0.25	0.00	0.75	0.14	0.00	0.86	0.53	0.00	47.00
22	Use of Organic amendments	0.75	0.00	0.25	0.71	0.00	0.29	0.53	0.07	0.40
23	Lack of Cover on water source	0.50	0.00	0.50	0.86	0.00	0.14	0.67	0.00	0.33
24	Lack of Tree presence	0.75	0.00	0.25	0.86	0.00	0.14	0.60	0.00	0.40
25	Lack or organizational processes for CC	0.25	0.00	0.75	0.00	0.00	1.00	0.13	0.00	0.87