Food and Agriculture Organization of the United Nations

FUNDING PROPOSAL TO THE GREEN CLIMATE FUND

– RELIVE –

REsilient LIVElihoods of vulnerable smallholder farmers in the Mayan landscapes and the Dry Corridor of Guatemala

ANNEX 2

FEASIBILITY STUDY

JULY 2020

Republic of Guatemala

FPV15SEP22

Table of Contents

List of tables

List of figures

A.1. EXECUTIVE SUMMARY

Guatemala is considered one of the most vulnerable countries to the impacts of climate change in the region and the world, due to a combination of factors: its location, the biophysical characteristics of its territory, and the vulnerable socioeconomic conditions of its population. Guatemala is the second most vulnerable country to climate change in Latin America and 11th worldwide in terms of exposure and vulnerability. High population growth rates, high percentage of poverty and extreme poverty (59.3% and 23.4%, respectively), as well as limited access to land for food production, basic social services, social safety nets, financing and information are conditions that, when combined, restrict vulnerable populations to adapt to the new climatic conditions prevailing in their territories. Guatemala is one of the countries with the highest score in the Global Hunger Index (GHI), despite a decrease from 22.2 points in 2008 to 20.7 in 2017 which reflects a slight improvement of the different aspects that trigger hunger, it still ranks first in Latin America and the Caribbean, and occupies the sixth place at the global level for the prevalence of chronic malnutrition in children under five years (boys 46.5% and girls 41.7%). In rural areas, around 76% of the rural population and 79% of the indigenous people live in poverty. Chronic malnutrition affects 53% of children in rural areas and 61% of children from indigenous origin.

Multiple scenarios show that the country will be seriously affected by the impacts of climate change, being the poor the most affected, which is why the project focuses especially on this historically vulnerable population. The most exposed territories and its population will be prioritized.

It exists a clear link between climate change and rural livelihoods, since the expected climate impacts would result in lower yields of staple crops (maize and beans), on which the vast majority of the prioritized population depend for their subsistence. Moreover, the evidence shows that in certain areas, small farmers may lose their harvests as a result of extended dry spells. As for cash crops that account for a significant part of the local economy, such as coffee and cacao, climate change will result in lower yields and the presence of pests and the appearance of diseases will not only affect yields, but also the quality of the production. As such, scenarios are set to have a severe impact on the livelihoods of these already vulnerable small farmers.

In the project´s prioritized municipalities, most of the population (66 to 76%) live in rural areas. These are small farmers who live in poverty and extreme poverty, which is why the impacts of climate change make these populations all the more vulnerable to high chronic hunger and acute malnutrition. The above-mentioned scenarios will in turn push rural people to migrate in an irregular and precarious manner to urban centers and abroad. In turn, as the impacts of climate change become more acute, people's income and food sources will be further compromised – much than they were to begin with – poverty and migration rates will be set to increase, creating a cycle of poverty that will cause migration, which will be in part responsible for a decreased capacity for communities to cope and adapt to climate change.

The prioritized municipalities are located in five Departments: Petén, Alta Verapaz, Baja Verapaz, Zacapa and Chiquimula, accounting for 29 municipalities. The production of farmers is mainly maize, beans, coffee, cacao and green vegetable; as well as backyard family plots for the production of additional food products.

Rural population in the project's area of action is extremely vulnerable due to the territories´ biophysical and socioeconomic conditions. Therefore, the project plans to work on measures for the adaptation of maize and bean agricultural systems, together with family vegetable gardens to improve the resilience of family agriculture, ensuring sufficient production and diversification of foods in the families' diet. Additionally, specific measures will be promoted to adapt coffee and cacao agroforestry systems and make them more resilient to pests and diseases, so to improve the quantity and quality of the production, the processing modalities of both products, and the community organization as a way to increase farmers' possibilities of accessing markets and obtaining better prices for their products.

A complementary action proposed by the RELIVE project is the strengthening of local organizations (at the micro-watershed level) in project intervention areas in order to improve water quality and availability for irrigation to improve the resilience of farming and food systems.

In terms of agro-meteorological information and early warning/decision support system, the project will take advantage of existing tools and platforms, such the use of the FAO-Country-level ASIS Tool [1], which will be launch in Guatemala in April 2020, with the aim to support the country to monitor agricultural drought and manage its risks, using satellite data to detect cropped land that could be affected by drought, and the Central America's Seasonal Climate Outlook Forum lead by the Regional Committee of Hydraulic Resources (CRRH) of the Central American Integration System (SICA), in which FAO, MAGA, INSIVUMEH are part of it.

The project also aims to improve the capacities of farmers and technical personnel to make better decisions based on climate-related information and data. Therefore, the availability of climate information in the country, as well as the institutional and structural weaknesses for the generation and access of information are taken into account. The RELIVE project will work to strengthen the generation and access to climate information in the project's areas of intervention, so to support decision-making mechanisms on adaptation measures and to improve the resilience of farmers.

In order to boost the previously described actions for crop adaptation, the project will improve the knowledge of farmers using MAGA's SNER (National Agricultural Extension System), including extension technicians and CADERs (Learning Centers for Rural Development), providing trainings through the farmer to farmer methodology and direct field practice. MAGA technicians will also be supported by the project´s and local organization technicians to expand the coverage. This rural extension services system will be strengthened on topics such as, climate change adaptation, vulnerability assessment and the application of key measures for resilience in agriculture, agroforestry systems, as well as in the conservation and management of water resources. These actions will ensure that the knowledge reaches farmers in the prioritized areas, improving their capacities to implement the measures proposed by the project.

To boost the project's outcomes the project will be linked with similar initiatives that were or are being implemented. Synergies can be created through the joint work and lessons can be learned from these initiatives. The most important projects related thematically or territorially with the RELIVE project are hereafter described, explaining how these initiatives may be used to establish cooperation and learn from their experience. A list of projects that FAO has implemented in Guatemala alongside key partners is provided to show FAO´s technical expertise and experience that ensure that feasibility of the RELIVE project and also prove how FAO institutional relations from many years supports its execution.

[1] http://www.fao.org/giews/earthobservation/asistool.jsp?lang=en

The sustainability of the project is ensured by involving the relevant actors since the beginning of its planning and throughout its implementation. These stakeholders include government institutions involved in the project, particularly MARN, MAGA and INAB. Additionally, consultations were carried out at different levels of government in prioritized territories to define the most important issues (that were incorporated into the project) and working directly with them, promotes ownership of the actions by local actors. As such, these stakeholders will also participate financially on the execution of the project through their in-kind contributions (work days and working spaces in the communities)

RELIVE is a sound project, in technical, scientific and financial terms. The economic and financial analyses prove that it is a strong project that has the capacity to create economic value chains for the society, taking careful consideration of the productive, environmental and climatic impacts.

A.2. INTRODUCTION

1. The Feasibility Study was conducted to add substance and strengthened the rationale for the Financial Proposal entitled "Ensuring the Resilience to Climate Change of Small Vulnerable Farmers in the Mayan Landscapes and the Dry Corridor of Guatemala" that the Food and Agriculture Organization of the United Nations (FAO) will submit for the consideration of the Green Climate Fund. It contains detailed information on the geographical, cultural and historical context in which the project will be implemented, as well as provides evidence-backed analyses on how the threats of climate change might impact the most vulnerable populations and how the proposed project seeks to address these impacts on household food and nutrition security and create resilient food and agricultural systems.
2. Guatemala is highly vulnerable to the effects of climate change; this situation is further accentuated by the combination of biophysical and socioeconomic factors. Most of the country's population lives in rural areas, in poverty and extreme poverty, with high levels of chronic malnutrition. Thus, this reality threatens people's ability to cope and survive as they are ill-prepared and equipped to face the crop damages, especially as a result of rainfall and temperature changes which might create a state of prolonged drought or excess humidity. Crops meant for subsistence or small surplus sales do not find the necessary conditions to develop, as an indirect effect of climate change on food and agricultural systems is the spread of pest and diseases that further stress crops.
3. In this context, the RELIVE project proposes actions in the project's proposed areas of intervention to improve the production of staple grains, as well as coffee and cacao-based agroforestry systems, through adaptive measures for resilient crops to new climate conditions.
4. Details on the structure of the Feasibility Study and the project´s actions are described in the next paragraphs. The study is organized in four sections, as follows.
5. Section A outlines the starting point of the project, taking as the baseline the current socioeconomic context, especially in rural areas and prioritized areas to carry out the project. It also includes a description of agricultural production and farmers, the biophysical characteristics at the national level and in the municipalities of interest, the current status of farming extension and training systems, the legal/political and institutional frameworks in place, especially those related to the objectives and activities of the project, and initiatives and/or projects related to climate change in Guatemala. The current status of the available climate information is also described.
6. Section B reviews historic climate change trends and climate variability in the country and the available climate projections, describing the vulnerability and impacts resulting from those changes, especially in the agricultural sector of the project´s interest (production of

basic grains such as maize and beans, coffee and cacao), and the potential impact on water availability.

7. Section C describes the project vision and the scope, starting with the effects of climate change on agricultural production, food security, water availability and forests, with emphasis on small producers of basic grains, coffee and cacao. Areas prioritized to carry out the project were selected by incorporating multiple indicators to determine farmers' vulnerability to the impacts associated with climate change or variability. These variables are: climate hazards (change in aridity); exposure; vulnerability; climate threat (percentage of change in aridity); percentage of the municipal territory devoted to annual crops and/or coffee; and percentage of the territory suitable for forest restoration. In addition, a qualitative and quantitative description of the project beneficiaries, as well as their relationship with the project activities, using selection criteria that include poverty, land availability, production scale and family size, and the existing barriers for the implementation of the project actions.

8. Based on the above, the REsilient LIVElihoods of vulnerable smallholder farmers in the Mayan landscapes and the Dry Corridor of Guatemala (RELIVE) project aims to build the resilience of Guatemala's most vulnerable farmers and their livelihoods against the impacts of climate change. The project objectives will be achieved through three interlinked components. The first component will target agricultural climate resilience actions at local level, the second component will ensure access to water resources and management at watershed scale, and the third component will facilitate the necessary enabling conditions:

   Component 1. Implementing climate resilient agricultural practices and enhancing farmers' livelihoods;

   Component 2. Supporting efficient water management for agriculture to reduce the impact of increased water scarcity;

   Component 3. Improved enabling conditions for climate resilient livelihoods.

9. The different practices to be implemented under these three components aim at:

   i) Resilience of the agro-ecological landscape and farmers' livelihoods through access to climate information, means of adaptation, diversification of livelihoods and climate-sensitive farming extension and promotion;

   ii) Efficient water management through comprehensive management plans; restoration projects for water regulation; and implementation of appropriate technologies for water collection and supply at the farm level;

   iii) Strengthening of interagency coordination and local governance for water management; and supporting training and information sharing platforms on climate change adaptation.

10. Through the implemented practices, the project will contribute to the following GCF's adaptation result areas: Increasing the resilience of i) most vulnerable people, communities and regions; ii) health and well-being, and food and water security and; iii) ecosystem and ecosystem services.

11. Finally, Section D contains a series of indicators that show the project's feasibility in economic and financial terms, allowing to conclude that RELIVE is a robust project that creates economic value for the society and generates a multiplier effect for local resilient development.

12. In summary, Sections A and B introduce the context in which the problems to be addressed by the project, and Section C discusses the problems in greater detail, specifying geographic areas and the context of agricultural systems prioritized by the project, which are the basis of the solutions proposal that constitute the project. Finally, Section D provides an economic and financial analysis of the proposed actions.

SECTION B. Context

B.1. Baseline

B.1.1. National Socioeconomic Context

13. Guatemala is classified as one of the most vulnerable countries to the effects of climate variability and extreme weather events and ranks eleventh at the global level (Eckstein, Künzel & Schäfer, 2018) and second in Latin America (Mapplecroft, 2014). This situation is reflected in the high human and economic costs that extreme weather events have had in the country (INSIVUMEH 2002, ECLAC, 2005, Guha-Sapir et al., 2017) and the low resilience of the affected communities facing these challenges. Recently, drought conditions associated with the “El Niño” phenomenon in Central America have been linked with the reduction of the production of basic grains (especially maize and beans) in farming communities that depend on rainfall for crop irrigation (UNOCHA 2016, FEWS NET 2015).

14. The above is especially important considering the living conditions of the Guatemalan population. The country has a surface of 108,889 square kilometers. It is divided into 22 departments and 340 municipalities. It is estimated that 70 per cent of the land is used for agriculture, livestock and forestry (MAGA, 2012). According to National Statistical Institute (INE) population projections for 2018, the country has 17,302,084 inhabitants. Table 1 shows detailed population data related which was taken from the 2014 National Living Standards Measurement Survey (known by its Spanish acronym as ENCOVI).

B.1.2. Food and nutritional security

15. The prevalence of (moderate and severe) food insecurity in households in 2014 was 36.9%; the prevalence of sub-optimal food in 2014 was 15.6%. Both values are considered high. The Global Hunger Index (GHI) went down from 22.2 in 2008 to 20.7 in 2017. However, Guatemala is among the countries with a high GHI scale. Guatemala ranks first in Latin America and the Caribbean in the prevalence of chronic malnutrition among children under 5, and has the sixth place at global level. The prevalence of chronic malnutrition among boys under 5 was 46.5% and 41.7% among girls of the same age group (SIINSAN. 2019).

B.1.3. Rural context and agricultural production in Guatemala

16. The degree of rurality varies widely by department. The national average masks the rural reality of some departments, including those prioritized for this project: Alta Verapaz (76%), Chiquimula (73%), El Petén (69%), Baja Verapaz (67%) and Zacapa (66%), in contrast with others, such as Guatemala (13%) and Sacatepéquez (14%).

17. It was estimated that in 2014 there were 1,126,712 rural farmers, of which 72% lived in poverty; and among these, 31% (348,740 producers) lived in extreme poverty, with high vulnerability to hunger and the lack of incentives for producing food, which is why they tend to migrate towards regional urban centers or outside the country, in the search for better economic conditions that help satisfy family needs (MAGA, 2012).

Table 1: Main characteristics of population and employment in Guatemala, 2019

<table>
<tr><th>INDICATOR</th><th colspan="4">DATA</th></tr>
<tr><td>GENDER:</td><td colspan="2">51.5% are female</td><td colspan="2">48.5% are male</td></tr>
<tr><td>AGE:</td><td>33.4% under 15</td><td>61.0 % in to 15-64</td><td colspan="2">5.62% under 65</td></tr>
<tr><td>ETHNICITY:</td><td colspan="4">43.4.8% identify themselves as indigenous</td></tr>
<tr><td>PLACE OF RESIDENCE:</td><td colspan="2">46.15 % live in rural areas</td><td colspan="2">53.85 % live in urban areas</td></tr>
<tr><td>POVERTY:</td><td colspan="4">59.3 % live in poverty; 79.2 % are indigenous and 76.1 % live in rural areas</td></tr>
<tr><td>EXTREME POVERTY:</td><td colspan="4">23.4 % live in extreme poverty, of which 39.8 % are indigenous</td></tr>
<tr><td>HEALTH:</td><td colspan="4">89.2 % have no insurance coverage</td></tr>
<tr><td rowspan="2">ILLITERACY:</td><td colspan="4">79.1 % of those over 15 can read and write.
Of the total number of men in the country, 84.8% can read and write, and of the total number of women in the country, 74% can read and write.</td></tr>
<tr><td colspan="4">The highest illiteracy rates are found among the indigenous population and the lowest literacy rate is found among indigenous women with 57.6 %.</td></tr>
<tr><td rowspan="2">EDUCATION:
(Average number of years of schooling)</td><td colspan="4">Total: 5.6 years</td></tr>
<tr><td colspan="2">Males: 6 years
Females: 5.3 years</td><td colspan="2">Indigenous population: 4 years
Non-indigenous population: 6.6 years</td></tr>
<tr><td rowspan="2">Main reason for not attending school</td><td colspan="4">Lack of funds</td></tr>
<tr><td colspan="2">Primary 52.7 %</td><td colspan="2">Secondary 49.6 %</td></tr>
<tr><td rowspan="5">EMPLOYMENT:</td><td colspan="4">Working age population (WAP): 12,005,359</td></tr>
<tr><td colspan="4">Economically active population (EAP): 7,114,935</td></tr>
<tr><td colspan="2">Females: 32%
Males: 68%</td><td colspan="2">Indigenous: 35%
Non indigenous: 65%</td></tr>
<tr><td colspan="4">Employed population (EP): 6,935,863</td></tr>
<tr><td>Females: 35%
Males: 65%</td><td colspan="2">Indigenous: 59.3% are employed
Non-indigenous: 58.7% are employed</td><td>Main economic activity
Agriculture: 32%
Commerce: 27%
Other: 41%</td></tr>
</table>

Source: Developed in-house with XII National Population Census and VII Housing, ENCOVI 2014, ENEI 1-2019 data.

18. In 2014, among farming households, 98.0% reported having made profits from crops, 29.8% from livestock by-products, 16.1% from animal husbandry and 12.5% from forest products. The annual average income was Q.7,156, assuming that they earned an average of Q.4,963 from agriculture; Q.1,471 from the sale of livestock by-products; Q595 from the sale of livestock; and Q.127 from the sale of forest products. Households living in extreme poverty had average earnings of Q.4,185, those living in non-extreme poverty Q.5,767, and the non-poor earned Q.12,397 (MAGA, 2012).

B.1.3.1. Production of basic grains

B.1.3.1.1. Beans

19. During the period 2007-2017, the land area for bean production and yields experienced sustained growth. During this period, production ranged between 200,000 tons and 250,000 tons, whereas yields ranged between 0.85 ton/ha and 0.99 ton/ha (Figure 1). In terms of

production per department, the departments of Petén and Chiquimula are responsible for close to 40% of the bean production at the national level (Figure 2).

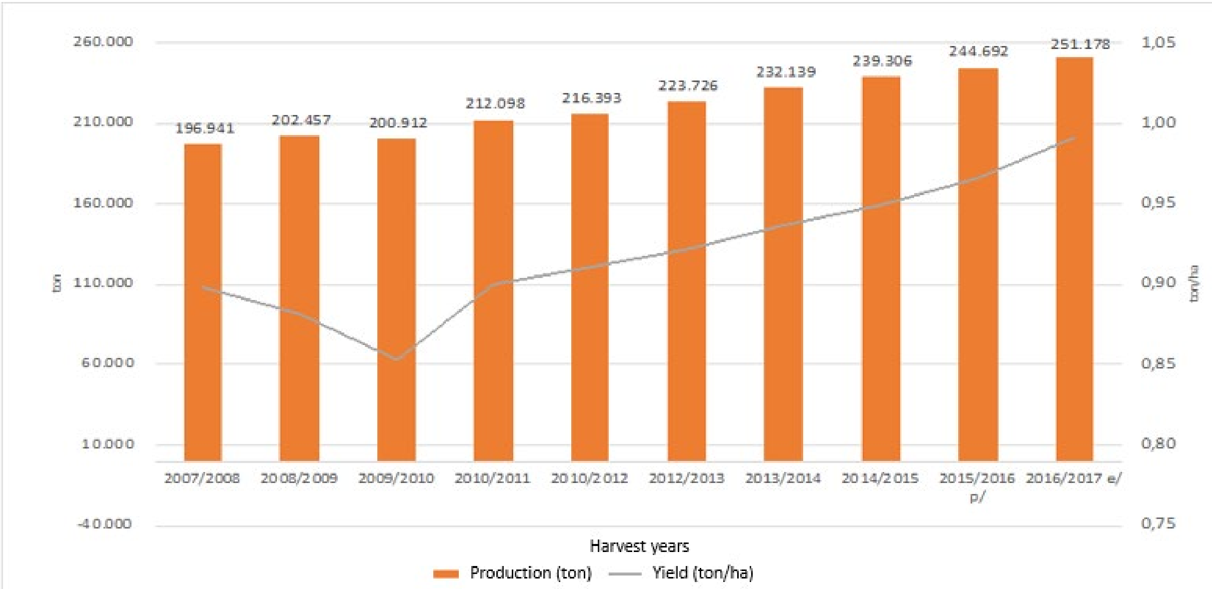


Figure 1. National bean production and yield in Guatemala, 2007-2008 to 2016/2017
Source: Bank of Guatemala, cited by MAGA (2018).
Note: (/) Preliminary figures; (e/) Estimated figures.

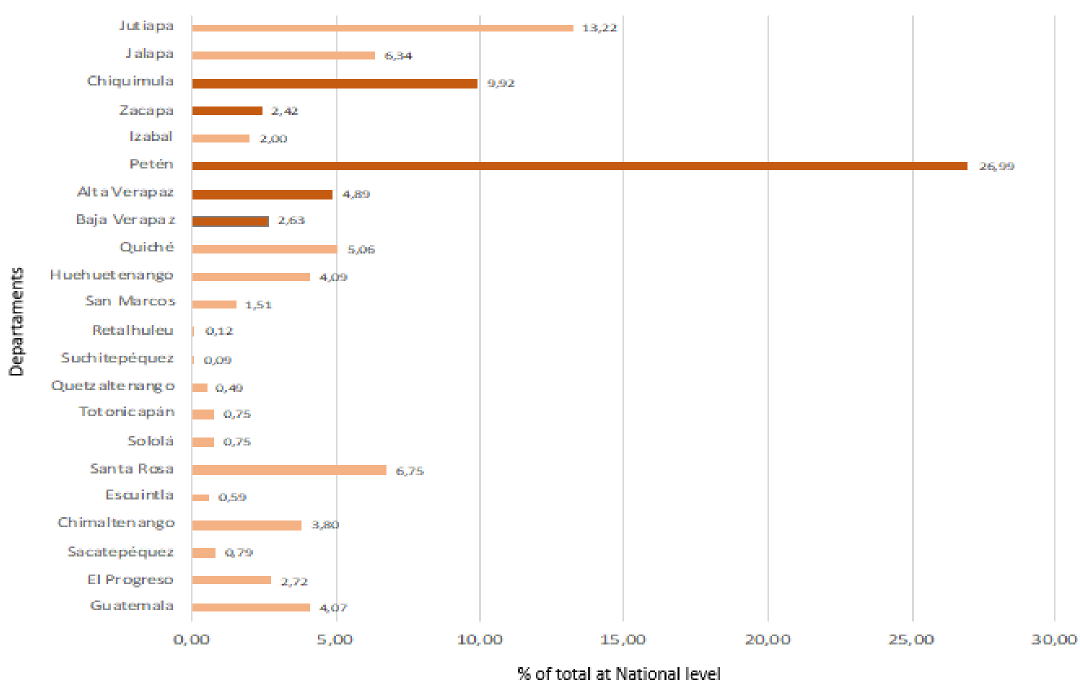


Figure 2. Bean production estimates by department, 2015/2016 – 2016/2017
Source: MAGA/Diplan estimates, based on figures from the 4th National Agricultural Census and Bank of Guatemala (Banguat) estimates.

20. Bean harvests reduce seasonally from May to August, and drops during June and July, when the market is supplied with stored reserves or imports. Households are most vulnerable to food insecurity during these periods because they have limited resources to buy beans.

B.1.3.1.2. Maize

21. In Guatemala, according to data provided by MAGA (2018), domestic production of white maize ranged between 1.7 and 1.8 million tons for the periods 2012/2013 to 2015/2016. Production of this commodity was estimated preliminarily at 1.9 million tons for the periods 2016-2017 and 2017-2018. Finally, for the 2018-2019 cycle, production has been projected at 2 million tons (Figure 3). MAGA indicates that the volume of losses is related to Guatemala's high vulnerability to climate change and natural disasters. INE (2016) indicates that in recent years, maize production in Guatemala has been affected by climate change, which has taken the form of prolonged droughts and intense rainfall over short periods, which in turn has resulted in increased production costs. This, together with stagnant maize prices, has led to unfavorable conditions for the production of this crop.

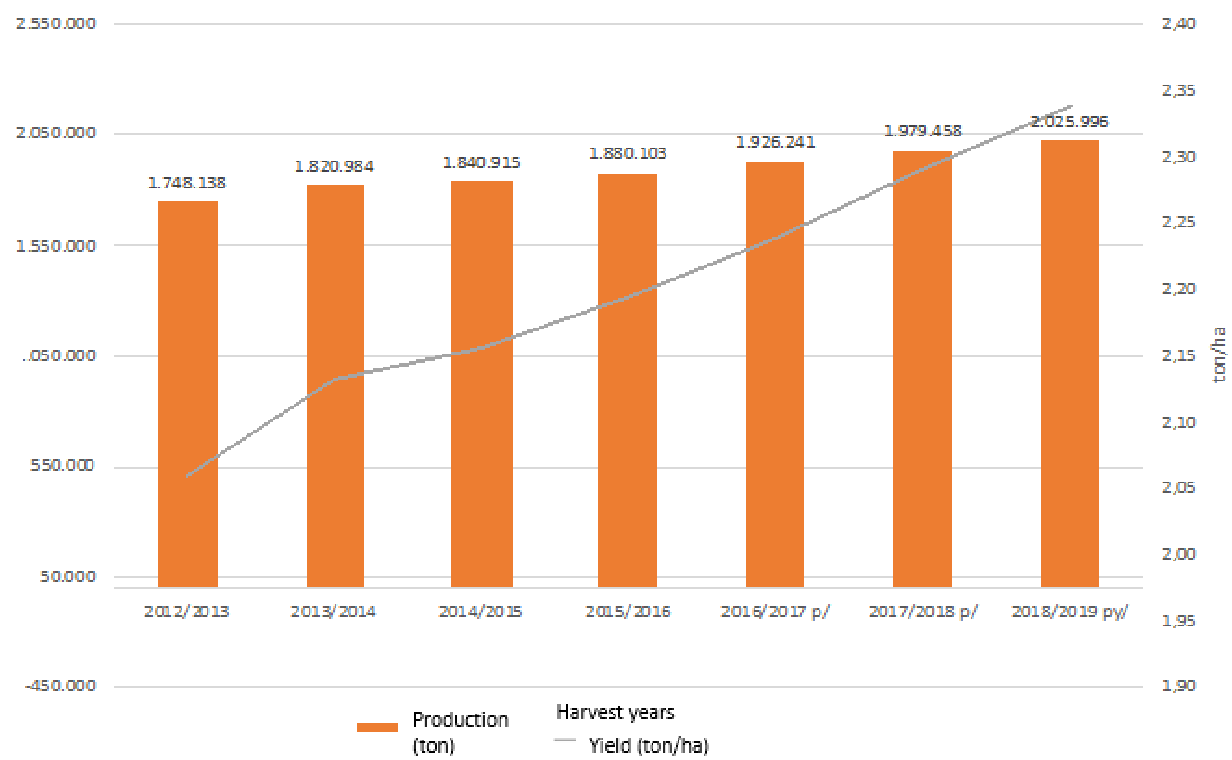


Figure 3. National maize production and yield in Guatemala, 2012-2013 to 2018-2019
Source: El agro en cifras, with Bank of Guatemala figures, cited by MAGA (2018).

22. As for production by departments, the departments of Petén and Alta Verapaz account for 31% of production (Figure 4).

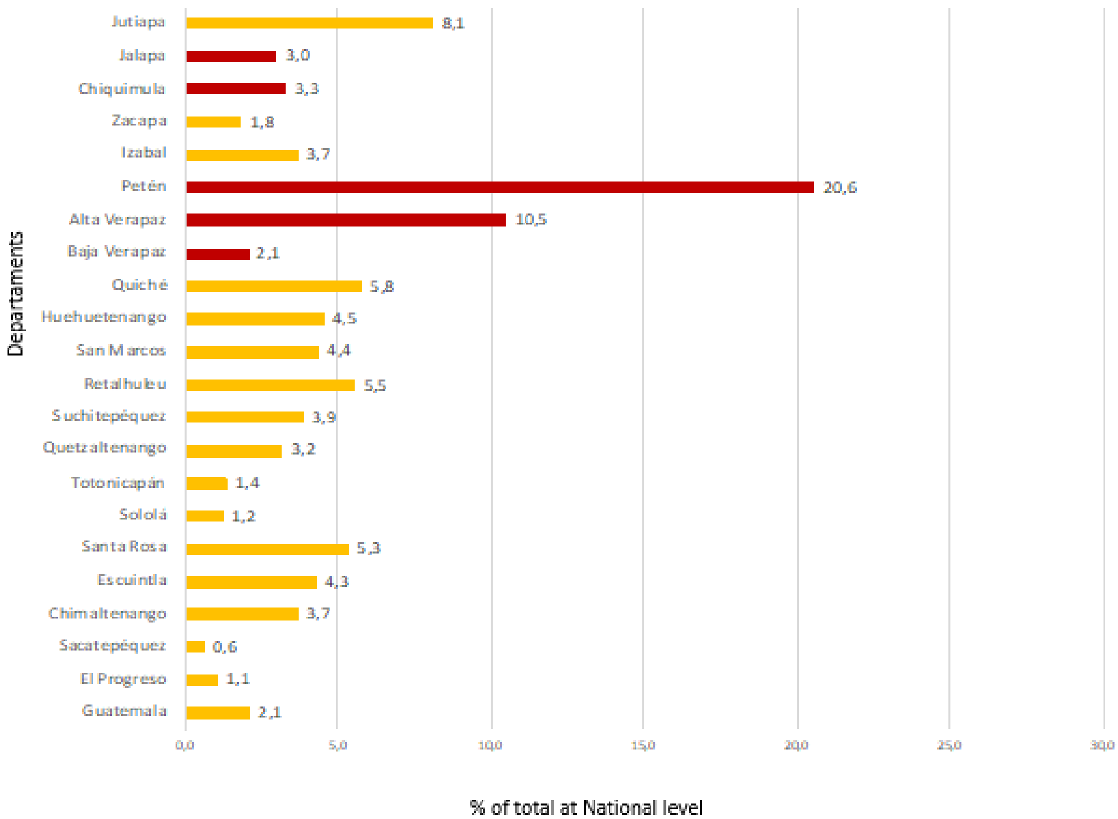


Figure 4. White maize production estimates in Guatemala by department, 2017-2018 – 2016/2017

Source: MAGA 2018 based on the 4th National Agricultural Census and Bank of Guatemala (Banguat) data.

23. Although maize production shows constant growth, imports are always needed to cover total and seasonal demand. Due to seasonal scarcity from May to July, homes are more vulnerable because of their low capacity to buy the product and the constant increases to price.

B.1.3.2. Cacao production

24. In 2014 the cacao producing area was estimated in 6,300 manzanas (4,410 Ha), distributed among Alta Verapaz (31%), Suchitepéquez (31%), San Marcos (25%) and other departments (13%), particularly Petén, Izabal, Quiché and Retalhuleu. This crop is mainly produced by small and medium-sized farmers as a natural crop and to a small extent using organic technologies. According to the Strategic Plan for the Cacao Agricultural Chain in Guatemala (2016-2025), only 2.76% of the area suitable for growing cacao is currently used for that purpose, which shows the high potential for expansion. It is worth noting that there has been a 3.8% average annual growth in the production and a 1.8% increase in the planted area. Yields range between 0.26 and 0.30 metric tons per hectare.

B.1.3.3. Coffee production

25. Coffee is grown in the 22 departments of Guatemala. Around 62% is concentrated in six departments as follows: Santa Rosa (18.9%), San Marcos (11.8%), Chimaltenango (9.3%), Huehuetenango (9.1%), Alta Verapaz (7%) and Suchitepéquez (5.3%). Productivity (gold quintals/hectare) ranged from 19.58 to 14.7 between 2004 and 2014 and dropped considerably during the last reported year (2014) with respect to the two previous years (2012: 19.28 and 2013: 19.14). According to ANACAFÉ data (cited by ADEC, 2016), the cultivated area for the period 2013-2014 was 305,000 Ha. The coffee sector in Guatemala is of great economic and social importance due to the characteristics of the crop and the areas where it is produced. It is the crop that concentrates the largest number of people who migrate seasonally to work on the harvest.

B.1.3.4. Characterization of basic grain producers in Guatemala

26. Basic grain production in Guatemala is generally conducted by four types of producers whose productivity depends on factors such as area, location and quality of the land they cultivate. According to FAO and WFP (2010), the four types of growers are:

   * **Below-subsistence growers.** These farmers cover the basic family food requirements (especially maize and beans) by working their small parcels. They complement their production with food bought in the market with the income generated by their labor.

   * **Subsistence growers.** They are able to meet family food requirements (maize, beans and sorghum) by growing them on their small parcels.

   * **Surplus growers.** They produce sufficient amounts to meet family needs and sell the surplus on the market.

   * **Commercial growers.** They sell their parcels' production.

27. The number of households that produced basic grains in Guatemala was estimated at 941,800 for 2006. The average size of these households is six people. For the same year, the rural population linked to a household that directly produced basic grains was estimated at 4.7 million, or 67% of the rural population for that year (Table 2).

Table 2: Main characteristics of households producing basic grains (BG) in Guatemala

Country/Region	# of BG producer households (1000s)	Average family size	% Rural	Rural BG population, 1000s	Total rural population (1000s)	% BG/total rural population	% Total BG/total population
Guatemala	941.8	6.0	82.7	4.673	6,935	67	42.5
Total Central America	2,064.5	5.4	-	10.337	18,415	56	29.0

Source: 2006 Guatemalan standard of living surveys cited by Baumeister, 2010.

28. Guatemala is the country in Central America with the largest total population that engages in basic grain production, 42.5%, followed by Honduras with 30%. In Guatemala, most

households producing basic grains are headed by men (85%). As for the division of labor, men are responsible for the preparation of the land and the sowing, while women are engaged on harvest, post-harvest and food processing activities. For 2006, the total area planted with basic grains exceeded a million hectares. Of these, 72% are planted with maize and 23% with beans. It was estimated that a farmer has an average surface of 0.84 Ha for the production of maize and a 0.47 Ha for beans. This average area per producer is the smallest in Central America (Baumeister, 2010).

29. According to INE (2003), in the 29 municipalities prioritized by FAO, there is a total 125,386 maize plantations with an average size of 1.17 Ha, and a total of 49,768 bean plantations with an average size of 0.77 Ha (Supplementary Material 1).

30. Basic grain producers in Guatemala are mainly located in the northwest (22%), departments of Quiché and Huehuetenango, and in the southwest (30%), departments of San Marcos, Retalhuleu, Quetzaltenango and Suchitepéquez. There is a considerable presence of indigenous groups in these departments (Baumeister, 2010).

31. The average age of the families is 46 years, with 13.7% of members under 30 and 13% over 65. The average years of schooling is 2.1.

32. For 50% of producers of basic grains, this occupation represents the main economic activity. Of these, 98% are small, self-employed growers and only 1% are farmers with permanent paid employees. As for other sources of income, close to 58% of the households that produce basic grains in Guatemala have some family members working as permanent salaried employees in the agricultural sector (25%) and in non-agricultural sectors (33%). These percentages may be higher, since they do not record seasonal paid work. 18% of the households receive remittances from abroad (Baumeister, 2010).

33. 68% of basic grain producers in Guatemala live in poverty (48% of these in extreme poverty). And 96% of the rural population living in poverty in Guatemala produces basic grains (Baumeister, 2010).

34. As for land tenure, according to ENCOVI 2006 data quoted by Baumeister (2010), 62% of basic grain producers own the land. Using data from the 2003 census, Romero (2014) analyzed the type of tenure according to the average plot size among producers who engage in family agriculture and found that 73% of the producers with plots of up to 0.7 Ha own the land, whereas 23% rent the land. In the case of producers who have between 0.7 and 3.49 Ha, close to 78% are landowners and 18% rent the land (Table 3).

Table 3: Type of land tenure among producers who engage in family agriculture in Guatemala according to plot size.

Type of land tenure	Percentage of owners according to plot size			
	Under 0.7 Ha	0.7 – 3.49 Ha	More than 3.49 Ha	TOTAL
Own	72.8	77.5	90.8	76.2
Rented	22.8	17.8	5.4	19.4
Others*	4.4	4.7	3.8	4.4

Source: adapted from Romero, 2014.
**Others include: usufruct, beneficiary, occupied and others.*
NOTE: more detailed information is shown in Appendix 4.

B.1.3.5. Characterization of households with family vegetable gardens in Guatemala

35. In the specific case of the project, households that have family gardens are the same ones that grow basic grains, i.e. small below-subsistence, subsistence and small surplus growers who grow produce in gardens along with basic grains. Because they have limited access to credit and technological markets, their productive infrastructure is deficient; they also have limited access to basic services. A detailed description of these is provided in the previous section, Characterization of basic grain producers in Guatemala.

B.1.3.6. Characterization of coffee producers in Guatemala

36. It is estimated that there are currently more than 125,000 coffee growers. Growers are classified according to the size of their production: small (≤200 quintals of parchment coffee), medium (201 to 2,000 quintals of parchment coffee), large (2,001 to 4,000), and agribusiness from 4,001 upwards. Each group's participation in exportable production for 2013-2014 was estimated as follows: small 43%, medium 31%, large 14% and agribusiness 11%. This is shown in the following figure:

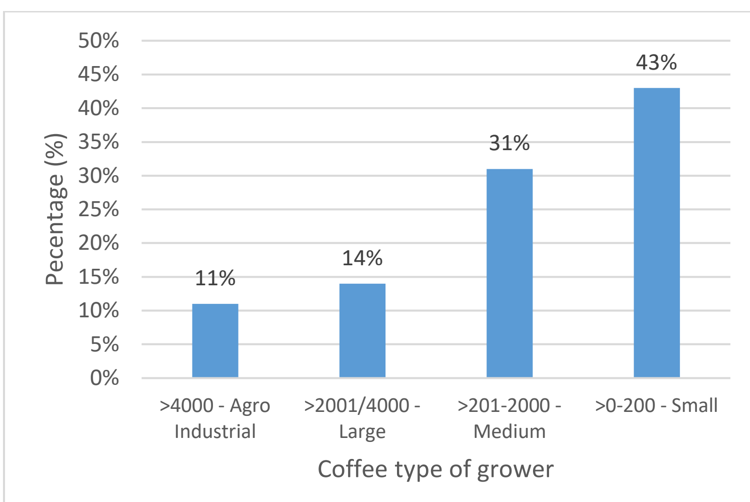


Figure 5. Participation in coffee production, 2013-2014, by type of grower.
Source: ADEC (2016).

37. Coffee processing varies among regions. In some places, such as the department of Huehuetenango, most small producers have small wet processing facilities; in others, such as Cobán, very little wet processing is done and a large part of the coffee is taken outside the region for processing; in other regions processors buy directly from growers and in other places intermediary retailers provide processing facilities with ripe or parchment coffee. This influences fermentation and coffee quality, since a considerable amount of time elapses during transportation (24 to 48 hours in Alta Verapaz; 12 to 18 hours on the south coast) between harvesting and processing. Medium and large producers generally do not sell cherry coffee, but have wet processing facilities, infrastructure and vehicles to transport the coffee, which allows them to move the coffee in a relatively short time and avoid long waits that lead to fermentation (ADEC, 2016).

38. Coffee harvested on small plantations seems to have more quality problems due to the unevenness of the beans. Some medium and large producers uphold the tradition of producing good quality coffee.

B.1.3.7. Characterization of cacao producers in Guatemala

39. Cacao producers may be classified in three types: individuals, informal groups of producers and MSMES represented by associations and cooperatives. Regardless of whether they are legally incorporated or not, all producer organizations are linked in productive, organizational or commercial terms to organizations known as "anchors".

40. There are two possible scenarios for cacao producers. The first one includes producers that grow, harvest, ferment and dry the cacao themselves using traditional artisanal methods; they may sell their product for Q8.00 to Q8.50 a pound. The other scenario includes producers that grow, harvest and sell the unprocessed cacao at a collection center. These producers might sell for approximately Q3.00 a pound. These price estimates are for July-August 2014 (MAGA, 2016).

B.1.3.8. Commercialization of maize, beans, coffee and cocoa [2]

Maize

41. Most of the maize produced is for the domestic market, either for human consumption or for the production of animal concentrate. According to the MAGA (2018), the country needed by 2017 a volume of 63, 987,360 quintals (equivalent to 2, 943,418.6 Tons) to meet its needs. Of the total need (demand), domestic production only reaches to cover 65.4%, the rest must be imported, with yellow maize representing the highest volume of income (MAGA 2018).

---

[2] 1. FAO 2018. Medios de vida resilientes para pequeños agricultores vulnerables al clima (RELIVE-Guatemala. Documento complementario. PRODUCTO 2.1. Estudios de la cadena de valor y mercado para los productos propuestos en las medidas de adaptación a implementar. Guatemala 2018.
2. MAGA 2016. Plan Estrategico de la Agrocadena de cacao en Guatemala 2016-2025 PEDAC. Guatermala.

42. The maize produced is marketed by different channels at the national level:

Producers can sell it in smaller places (communities), or they can sell it to intermediaries, as well as hand it over to cooperatives, if they become partners.

Intermediaries and cooperatives can sell it to private companies or take it to departmental squares or to the Terminal where wholesalers are.

Once maize is marketed, it follows a transformational step, either for human consumption (mainly for tortillas) and for the industry in general.

43. Internationally, demand was forecast to be higher in 2018. There is expected to be increased demand for cereals such as maize, barley and sorghum, as well as rice (FAO 2018). In 2017, Guatemala exported grains and cornmeal to 13 countries, being the main destination market El Salvador (TradeMap 2018).

Beans

44. Wholesalers have the most bargaining power (they move more volume), they buy from individual producers, intermediaries or producer organizations, which are located in the production zones. After purchase, they take the bean to other wholesalers at 21 Calle in Zone 1, the market of the terminal of zone 4 and the Central de Mayoreo (CENMA) of zone 12, the three points located in Guatemala City.

45. Wholesalers supply cantonal markets, retail stores, institutional buyers, retail packing companies, international buyers (Salvador, Honduras and Mexico) supermarkets, South Coast sugar mills and other buyers that reach directly to the final consumer.

46. Guatemala City concentrates 70% of the bean trade: the remaining 30% takes place in the Zone 4 market and in small peripheral markets. The cost of transporting Guatemala to departments is in a range of 8 or 10 quetzals per quintal (Guatemalan Ministry of Economy 2015).

47. Distributors are located in the cities of the interior of the country, whose businesses are known as deposits. They buy the bean at the 21st Street markets in Guatemala City and supply vendors in local markets, grocery stores and small department stores. They sell the bean both for quintal and per pound; and in quantity ranging from 50 to 100 quintals per week (Guatemalan Ministry of Economy, 2015).

48. Over the past 5 years, bean imports have maintained their growth with a 31.9% rate comparing what was imported in 2013 and 2017. This phenomenon responds to the need to supply the market, mainly of red bean (which is produced little in the country), as well as to a lesser extent the black bean.

49. Recently, some producer organizations have started exporting their production to El Salvador. ATESCATEL has made several exports to DILOSA of El Salvador, which has started

to demand red beans both for direct grain consumption and for use in the production of products as ground beans (Guatemalan Ministry of Economy, 2015).

Coffee

50. The coffee produced in the country is mainly intended for export in gold (there is a small percentage that is exported as a final product) and only a small part of stays in the country.

51. In order to export, it is necessary to be registered as an exporter with the National Coffee Association (ANACAFE), which is the only institution that can provide them, according to the Coffee Act since 1963 (ANACAFE s.f.). There are currently 65 companies or organizations licensed as a coffee exporter, of which 25 belong to ADEC. It is estimated that the export of coffee generates 600,000 direct jobs and US$748 million in foreign exchange, representing 2.5% of national GDP (ADEC 2016; ANACAFE s.f).

52. According to TradeMap (2018), Guatemala exported coffee (as well as processed products, and coffee shells) in the amount of US$748,582,000 in 2017. The main destination was the United States (37.8%), followed by Japan (15.1%) Canada (11.4%). It is important to mention that many of the big coffee buyers (in the United States and Europe), look for coffee like Guatemala to improve the quality of robust coffee, making mixtures (improving the price). Therefore, a good part of what is sold does not end up being consumed pure but mixed (according to the interviews conducted).

53. There are several national programs such as AGEXPORT Special Cafes, that are constantly looking for new market opportunities for its partners. In addition, they intervene in political spaces and promote actions for improvements to the export system.

54. There are companies of both national and international capital, which are engaged in roasting and packaging coffee for the domestic market. Commonly the coffee that can be found is of second or third quality, since the first is specific for export, although there are some cases where you can find quality coffee (in specialized cafes).

55. Coffee for daily consumption is found in supermarkets, as well as coffee shops prepared in fast food chains as well as coffee shops. Of the latter the most frequented, according to the interviews are: Café Barista, Starbucks, Café Saúl, &Café, El Injerto, McCafé, Café Gitano and Café León.

Cocoa

56. The destination of Guatemala's cocoa production according to BANGUAT records is 4% towards the external market and 96% benefit and transform nationally. However, the cocoa bean processed in Guatemala in both large industries and local artisanal industries is not enough to meet the growing domestic demand, so since 2009, cocoa bean imports increased to meet demand.

57. According to the International Cocoa Organization (ICCO), global production in the 2012-2013 cocoa year was 3,942 TM, and for the 2013-2014 season was 4,345 TM, indicating an

annual increase in global production equivalent to 10.22% compared to the previous period. According to the presidency of the ICCO World Cocoa Organization, at the World Cocoa Congress held in Amsterdam in June 2014, it was indicated that action is needed to promote cocoa production, as the annual deficit of 150 thousand tm per year is projected to be exponential by 2020.

58. Under this scenario, the project will provide under activity 1.3.2. trainings to introduce these products into the national and local market and adding value to retain it at the origin, thus improving their income as a way of increasing their resilience. Market access based on the differentiated characteristics of the national product will be promoted, by developing links to local and national markets through the association with coffee and cocoa guilds identified in a participatory manner by the farmers. Thus, the project will unlock potential private sector engagement with companies that will purchases RELIVE's production.

B.1.4. Biophysical considerations

59. Guatemala is located in Central America and borders on Mexico to the north and west, with the Pacific Ocean to the southwest, with Belize to the northeast, with Honduras to the southeast and with El Salvador to the southeast. It has an area of 108,889 square kilometers and is the most populous country in Central America with a population of 15.6 million (estimate for 2014).

60. The country has bimodal seasonal rainfall, with a humid northern hemisphere summer and a dry northern hemisphere winter season. The country is influenced by the extension to the north of the Intertropical Convergence Zone (ITCZ) during the northern hemisphere summer. The rainy season, dominated by convective storms, usually starts in April or early May with two peaks around June and September and a dry period or midsummer drought that can last for 5 to 15 days; its mechanisms are not yet fully understood. The rainy season continues until October in most of the country, but persists until the beginning and middle of December in the north and east of the country. The dry season goes from November to April. The topographic complexity of Guatemala's mountains and volcanoes results in considerable spatial heterogeneity of average weather conditions. Annual rainfall exceeds 4,000 mm in parts of the lowlands in the northwest and the south coast, but in the so-called "dry corridor" annual rainfall is under 800 mm (Pons, Brincker & Castellanos, 2018). These complex hydro-climatic conditions have to do with various climatic mechanisms and their interaction with the country's topography (Karmalkar et al., 2011).

61. Generally speaking, projections of climate models suggest an increase in average temperatures and a reduction of rainfall, which might lead to reduced availability of water in the country. Because Guatemala depends on rain-fed agriculture, assessing future temperature, rainfall and aridity scenarios might contribute to a better understanding of the challenges that lie ahead and may be useful in defining appropriate adaptation strategies to increase the resilience of rural communities exposed to these hydrological changes.

62. Data analyses show that temperatures in the country are increasing, in absolute and relative terms, at a rate of 1.8% to 7.7%. MARN data (2015) suggest that the most pronounced temperature increase trends are seen in the lowlands in northern Alta Verapaz, at the Flores station in Petén, the Puerto Barrios station in Izabal and the Cobán station in Alta Verapaz.

63. The average annual precipitation has increased significantly in all the regions according to the MARN analysis (2015), which compares the baseline (1971-2000) with the current period (2001-2014). But the work done by Kalmarkar et al. (2011), Hidalgo & Alfaro (2015), Knutti & Sedlácek (2013), IPCC (2013), Pons, Brincker & Castellanos (2018) shows that precipitation is going to drop.

64. With regard to biophysical conditions in the municipalities where the work areas are located, it can be stated that the department of Alta Verapaz has altitudes ranging from 80 to 1,600 meters over sea level; there are five life zones: temperate humid subtropical forest, wet warm subtropical forest, wet cold subtropical forest, low mountain subtropical rain forest and subtropical rainforest. The northern wet warm subtropical forest is most prevalent in most of the territory (72%). In terms of physiography, 91% of the department consists of sedimentary highlands (Departmental Development Council of Alta Verapaz, 2011).

65. Baja Verapaz has altitudes ranging from 940 to 1,570 meters above sea level. 51% of the department is located in the vast Chuacús mountain range landscape, 21% in the hills and deep valleys of the northern Chuacús mountain range, 8% in the Sierra de las Minas mountain range, 6% in the interior Chuacús plains, 4% on degraded serpentinite slopes and the rest on ancient Motagua River terraces, recent Motagua River terraces, degraded slopes of the Cuchumatanes mountain range, Tactic Tucurú Senahú mountains, degraded sedimentary slopes and the Polochic River alluvial and colluvial fan. The predominating life zones are low subtropical humid mountain forest, temperate subtropical humid forest, warm wet subtropical forest, cold wet subtropical forest, low subtropical mountain rainforest and dry subtropical forest (Departmental Development Council of Baja Verapaz, 2010).

66. The department of Chiquimula has altitudes ranging from 300 to 1,500 meters over sea level. Crystalline highlands and volcanic highlands are located here. There are three life zones: dry subtropical forest, humid temperate subtropical forest, wet temperate subtropical forest (Departmental Development Council of Chiquimula, 2011).

67. Since Petén has an average altitude of 127 meters over sea level and is crossed by several mountain ranges that reach altitudes that only exceed 500 meters over sea level in in very few areas, geologically these formations are part of the limestone plateaus of the Yucatán Peninsula. Based on climate factors (bio temperature, precipitation and humidity), plant formations and animals as well as the soils and altitude, it can be said that there are two life zones: warm subtropical humid forest and warm subtropical dry forest (SEGEPLAN, 2013).

68. The department of Zacapa has an average altitude of 185 meters over sea level, with values ranging from 130 to 880 meters over sea level. Its physiography is characterized by three well-defined zones: the northern part, made up of the Sierra de las Minas mountain range, the central part that crosses the department from West to East, where a series of valleys serve as the banks of the Motagua River, and the southern part, where the Sierra del Merendón mountain range and mountains separated by relatively deep gullies are found. It comprises three life zones: dry subtropical mountain scrubland, dry subtropical forest and temperate humid subtropical forest (Departmental Development Council of Zacapa, 2011).

69. Specific data on land use and forest cover in the work area are shown below in Table 4.

B.1.5. Status of forest resources in Guatemala

70. Guatemala has approximately 3,674,728 ha of forest cover, equivalent to 34% of the national territory; however, in recent years, the ecosystems have undergone substantial changes, which reflect in the loss of forest cover and threats to biodiversity, where the loss of forest cover and its ecosystemic services are not replaced at the same rate as the annual destruction. This means that not only there are fewer forests each year, but there is a reduction of biodiversity which increases GHG emissions increasing the country's vulnerability. "A historical analysis of forest cover in Guatemala estimated that forest cover in 1950 was 6,973,924 hectares, which had been reduced to 3,722,595 by 2010. This equals a deforestation rate of 0.77% during the period in question (GCI, 2017)

    The gross deforestation rate estimated for the period 2006-2010 was 132,137 ha/year. In relative terms, the forest inventory has diminished at the rate of 1.00% per annum. The most affected types of forests were natural broadleaf forests, mixed forests, conifers and mangroves. Of all types of forests, mangroves have suffered the greatest losses (MARN. 2017).

71. There is a vicious circle between climate vulnerability, land degradation and deforestation. The key drivers of deforestation and degradation are summarized as follow:

    a. **Agricultural expansion due to poverty and drought:** poverty and lack of employment result in strong dependence on agriculture, in particular on production of basic grain for subsistence. Land degradation due to unsustainable practices and water scarcity result in low yields and thus the need for more arable land often located in forest areas. As a response, the project is aiming at promoting adaptation practices to address land degradation and improve the productivity of the soil in order to keep farmers producing in their lands an avoid the agricultural expansion.

Table 4: Land use intensity in the prioritized municipalities.

Municipality	Adequate use (Ha)	Overutilization (Ha)	Under-utilization (Ha)
Cobán	63.75%	10.25%	24.43%
Chahal	62.78%	12.08%	23.58%
San Pedro Carchá	64.98%	28.04%	6.48%
Cahabón	56.78%	33.85%	8.53%
Lanquín	51.72%	42.60%	4.99%
San Cristóbal Verapaz	64.39%	26.16%	7.72%
Senahú	48.45%	45.53%	5.56%
Panzós	57.77%	15.39%	18.26%
San Juan Chamelco	63.16%	26.56%	9.20%
Santa Cruz Verapaz	53.14%	11.52%	33.62%
Tucurú	53.16%	33.36%	12.94%
Tamahú	71.60%	21.56%	6.66%
Tactic	60.44%	25.95%	11.87%
Purulhá	70.37%	23.66%	5.22%
San Miguel Chicaj	55.04%	40.61%	1.88%
Rabinal	70.67%	21.53%	5.91%
La Unión	53.84%	10.69%	34.94%
Camotán	44.90%	39.08%	14.50%
Jocotán	44.19%	53.11%	1.46%
Chiquimula	59.69%	28.92%	6.98%
San Juan la Ermita	50.89%	45.01%	2.86%
Olopa	81.98%	15.52%	2.09%
Santa Catalina la Tinta	60.10%	29.80%	7.65%
Chisec	52.79%	10.38%	34.88%
Fray Bartolomé de las Casas	47.03%	8.57%	41.09%
Raxruhá	45.02%	7.77%	46.00%
Dolores	57.19%	27.54%	10.65%
Poptún	60.27%	21.22%	16.07%
San Luis	71.88%	13.09%	11.76%

Source: Pons, Brincker & Castellanos (2018)

b. **Lack of knowledge of sustainable agricultural practices**: even when the agricultural practices used by producers are based on traditional practices, these have not been improved or adapted to climate change threats and impacts. For example, within the traditional milpa system, slash and burn is a typical practice. This practice causes the loss of organic matter from the soil, impairs the nutrient cycle and increases the evaporation of water contained in the soil. The project aims to have a paradigm shift by the introduction of adaptation practices for soil and water management to enhance the soil fertility and water retention in the soil while avoiding land degradation.

c. **Harvesting for firewood:** The project proposes that agroforestry systems will include timber species to provide wood for firewood via sustainably managed model.

Table 5: Forest cover by municipality as of 2012, in hectares and percentages with respect to the area of the municipality

Municipality	Area of the municipality in Ha	Area in Ha	%
Cahabón	76,026	23,484.51	30.89
Chahal	46,045	18,276.48	39.69
Chisec	109,863	45,686.70	41.59
Cobán	226,595	105,790.77	46.69
Fray Bartolomé de las Casas	121,298	45,297.99	37.34
Lanquín	23,609	5,163.66	21.87
Panzós	72,890	20,345.85	27.91
Raxruhá	60,266	19,506.06	32.37
San Cristóbal Verapaz	38,418	15,537.15	40.44
San Juan Chamelco	18,686	4,744.08	25.39
San Pedro Carchá	131,397	31,844.16	24.24
Santa Catalina la Tinta	19,724	7,363.71	37.33
Santa Cruz Verapaz	7,800	3,030.39	38.85
Senahú	70,526	16,468.92	23.35
Tactic	11,636	2,848.56	24.48
Tamahú	6,988	2,286.36	32.72
Tucurú	21,901	5,754.51	26.28
Purulhá	51,681	20,913.93	40.47
Rabinal	31,171	10,391.49	33.34
San Miguel Chicaj	32,694	5,033.52	15.40
Camotán	23,039	2,769.03	12.02
Chiquimula	35,155	1,945.80	5.53
Jocotán	25,099	1,189.80	4.74
Olopa	11,210	3,006.18	26.82
San Juan la Ermita	8,048	473.31	5.88
Dolores	139,656	67,029.48	48.00
Poptún	168,734	69,177.33	41.00
San Luis	238,379	96,601.59	40.52
La Unión	21,450	7,360.65	34.31

Source: Pons, Brincker & Castellanos (2018)

B.1.6. Extension and training in the agricultural sector

B.1.6.1. The National Rural Extension System (SNER by its Spanish acronym)

72. The SNER is formed by public, private and international cooperation institutions that directly or indirectly bring efforts and resources to promote the national agricultural development (MAGA, 2013) (see Figure 6). The central component is the "Rural Extension Service", a public agency that is the body and spearhead of the system that channels all the support, processes and services required by the population that depends on agriculture in rural areas (MAGA, 2013). The system provides technical support through the

research/training components and specialized offices of the Ministry of Agriculture, Livestock and Food (MAGA by its Spanish acronym).

73. Development, adaptation and transfer of appropriate technologies are provided to the technical staff of the rural extension service by the Agricultural Science and Technology Institute (known as ICTA by its Spanish acronym) and research institutes of the country's universities. In addition to the above mention, training is provided by the National Central Agricultural School (known as ENCA by its Spanish acronym), Agricultural Training Schools (EFA by their Spanish acronym) and the agronomy schools of the country's universities (MAGA, 2013). In the area of development, productive infrastructure, organization, marketing, information, health and safety, specialized MAGA agencies support, advise and implement processes, and works jointly and in coordination with the rural extension service (MAGA, 2013).

74. Another important component of the system is international cooperation. Through this component, rural extension receives essential technical, strategic and financial support for its programs. Although currently the relationship is limited, the component of local governments has great potential for participation, since these governments are directly responsible for their communities' development and receive financial resources provided by the central Government for the purpose. It is worth noting that this component also includes non-governmental organizations (NGOs) that work in rural development, since their expertise and technologies should be scaled up (MAGA, 2013).

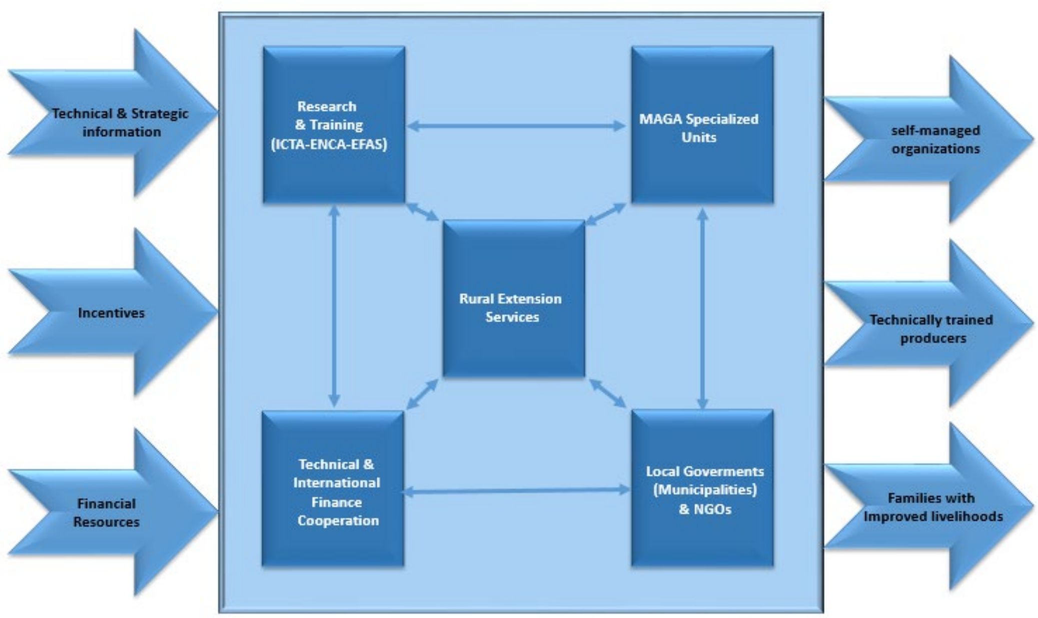


Figure 6. Structure of the National Rural Extension System.
Source: (MAGA, 2013).

75. All these components interact with rural extension services and among themselves, transferring knowledge and resources to underpin agricultural development efforts throughout all the communities in the country. These interactions provide stability, harmony and limits to the system, which in practice operates as a unit or as a whole (MAGA, 2013).

76. In addition to the components, interactions and limits, the system comprises two more elements (for more details, see Figure 6), which are:

77. System outputs or products are essentially three: (1) farmers trained to produce their own foods sustainably and efficiently market the surpluses they produce; (2) formal farmers´ associations that provide self-managed technical, financial and commercial services to their members; and (3) rural families that consume safe and nutritive foods that generate more income and live in sanitary homes with the essential services for decent life; this also includes strengthened human capital at the local level as a sub-product (MAGA, 2013).

B.1.6.2. The Rural Extension Service

78. With its presence throughout the national territory, MAGA is responsible for implementing training and technical assistance programs seeking to solve the problems of agricultural production systems in rural areas. The subjects of the efforts of the Rural Extension Service and hence of the SNER are agricultural producers and their families, classified as below-subsistence, subsistence and surplus producers. Each of these groups receives differentiated assistance (MAGA, 2013).

79. Organic structure of the Rural Extension Service: The Rural Extension Service is an official agency that is part of the MAGA’s organic scheme. The service works under the leadership of the National Rural Extension Direction. The service is structured as follows: rural extension department, departmental coordinating offices, municipal extension agency (AME by its Spanish acronym), coordination of municipal extension agencies, team of extension agents that make up the National Rural Extension System, Learning Center for Rural Development (CADER by its Spanish acronym) and volunteer promoters.

80. The first two have strategic and coordination functions at the national, departmental and local level, respectively. The operational part of the Rural Extension Service begins with Municipal Extension Agencies (AMEs), which constitute the operational unit of the rural extension service and report hierarchically to the MAGA Departmental Coordination Office (MAGA, 2013).

81. To perform the inherent functions, each AME is made up of at least three persons appointed by MAGA: a rural development extension agent, a family agriculture extension agent and an extension agent for healthy homes and households.

82. Family agriculture extension agents and volunteer promoters work to form and train community groups that revolve around the CADERs. When these community groups reach an appropriate level of development in their productive units, they may join an established

formal organization or create a new organization. For an organization to graduate it must meet member service self-management indicators and parameters on matters regarding technical assistance, procurement of inputs, credit intermediation, production collection and marketing (MAGA, 2013).

83. The operational actors of the Rural Extension Service are described as follows:

84. **The Learning Center for Rural Development (CADER**): It is staffed by (a) a volunteer promoter who acts as coordinator/facilitator; (b) a group of rural families; and (c) a menu of technological innovations promoted by the SNER. Technological training for the families is provided using the "Farmer to Farmer" or "learning by doing" methodology (MAGA, 2013).

85. **Volunteer promoters:** They are the key link of the rural extension service, since they make it possible to broaden the coverage of MAGA extension agents' services. They are leading farmers, selected and appointed by community groups; they receive special training from MAGA extension agents and their main responsibility is to act as the link between the extension agent and the group for identification and management of all the activities that are planned with community participation. Their function is to generate a multiplying effect in the rest of the group. Promoters are not compensated for their work; MAGA determines the incentives they may access (MAGA, 2013).

    To become a volunteer promoter, the producers must meet the following criteria: 1) be a well-known and respected member of the community, 2) be an agriculture, forestry and/or agroforestry farmer, 3) have ownership rights over the land used for agricultural, forestry or agroforestry activities, 4) know how to read and write, 5) speak the local language.

86. **Community groups**: These are groups of farmers interested in carrying out actions to develop agricultural and rural development activities. Depending on the extent of their evolution, these groups may be linked to existing formal organizations or form new formal organizations. MAGA will provide the necessary support for this purpose. These groups will make the extension service more efficient by assisting a group, thus meeting the demands of a larger number of farmers with a single action (MAGA, 2013).

87. **Formal Organizations of Agricultural Producers** (OFPAs by their Spanish acronym): These are legally established organizations formed by rural farmers with common interests, such as cooperatives, farmers' associations, associative farmer enterprises, agricultural microbusinesses, etc. They are considered strategic for the efficient development human and social capital through the extension process.

88. **Limitations of coverage:** There has always been a wide gap between the need and demand for agricultural extension services and MAGA's capacity to provide these services (MAGA, 2013). In response, PAFFEC undertook to reactivate the National Rural Extension Service (SNER), consolidating local extension services as discussed in the previous section. This function requires substantial support on the part of MAGA's departmental and national agencies. Consolidation includes the design and the establishment of agreements for the

planning and the local operation of the service, using participative methodologies that encourage the ownership and decision-making process of the extension service of and for farmers' families (MAGA, 2016).

89. Consolidation includes the conception and agreements of planning and local operation of the service, applying participatory methodologies that stimulate the appropriation and decision-making for an extension service for and for farmer families (MAGA, 2016).

B.1.6.3. The SNER and climate change: Climate Change Special Executing Unit

90. MAGA created the Climate Change Special Executing Unit through the Ministerial Resolution 157-2011, for the overall purpose of promoting the adaptation of the Guatemalan agricultural sector to climate variability, taking into account the different climate change scenarios and their effects on different agricultural activities. For this purpose, it has planned the following activities: (i) providing technical training and updating information on agricultural climate change adaptation and mitigation; (ii) developing studies, research and feasibility projects; (iii) monitoring and assessment applied to agricultural adaptation to climate change, to support the departmental offices of the Ministry and the National Agricultural Extension System (MAGA, 2015).

91. Advisory services to incorporate the climate change approach into the MAGA's budget structure are part of "Program 01: Central activities", which includes the direction and support activities for productive management, since they contribute to its operation. The actions of the advisory services seek to promote the climate change approach in the country's agricultural processes by providing technical assistance and counseling to institutional actors involved in supporting rural families, to ensure livelihoods with equity and plan the impacts of climate change in an appropriate, coordinated and sustained manner (MAGA, 2015).

92. Some of the main goals of this specialized unit are to:

    a. Train and update MAGA staff on techniques for agricultural adaptation to and mitigation of climate change.
    b. Conduct studies and research for agricultural adaptation to and mitigation of climate change.
    c. Develop teaching materials for understanding techniques and/or practices for agricultural adaptation to and mitigation of climate change.
    d. Manage and establish cooperation agreements for joint work on implementing actions for agricultural adaptation to climate change and GHG mitigation.

93. The operational structure of the Rural Extension Service at the municipal level is shown in Figure 7.

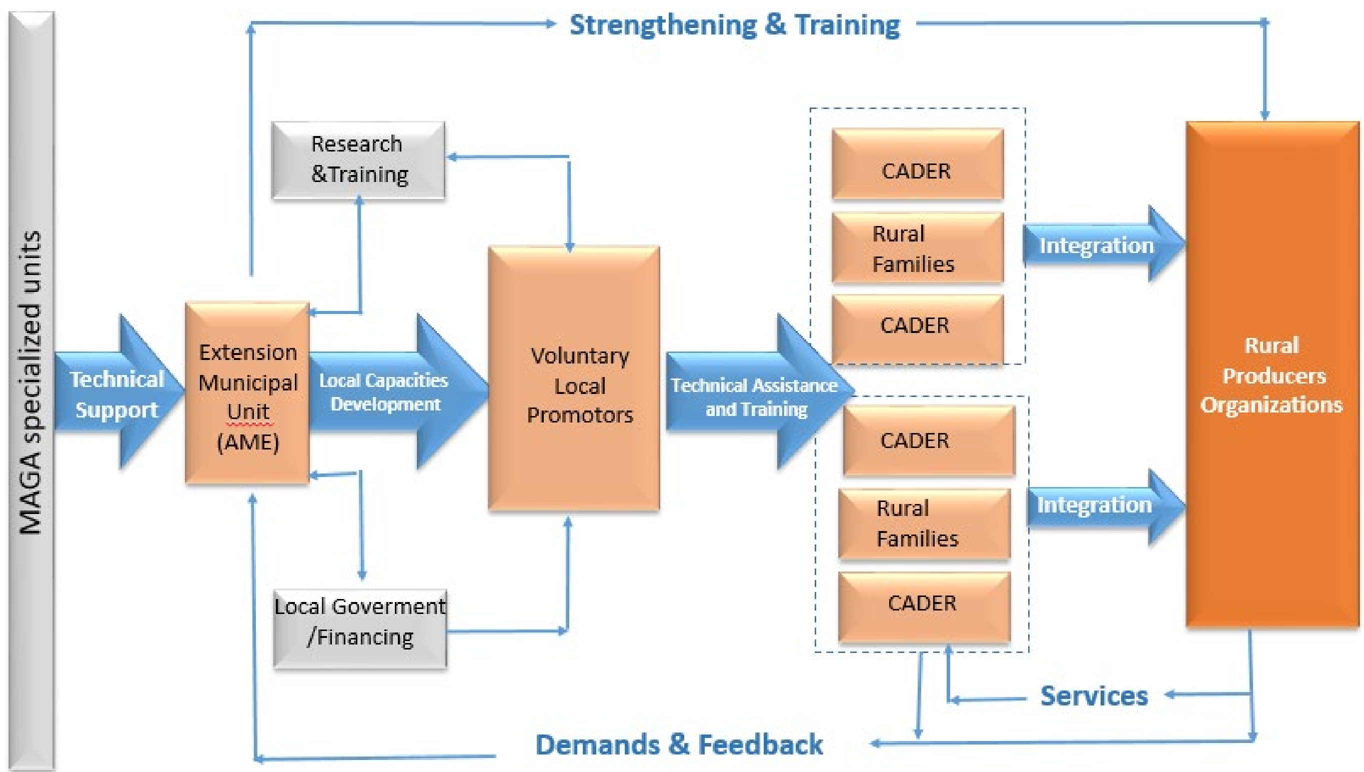


Figure 7. Operational structure of the Rural Extension Service at the municipal level. Source: MAGA, 2013.

94. As a specialized unit and as stated earlier, the Climate Change Unit must support the Rural Extension System on the matters in which it specializes, and also receives support from the system to communicate to the target population issues related with climate change and agriculture, thus contributing to achieving the goals of both agencies.

B.1.7. Socioeconomic context in project municipalities

95. This section contains a brief description of the socioeconomic conditions in the municipalities selected for program implementation. To describe them, the municipalities were grouped under the department they belong to.

B.1.7.1. Alta Verapaz

96. This department is divided into 17 municipalities with an approximate population of 814,300 (INE, 2002), of which 90% are indigenous. Most speak Q'eqchi' and Poqomchi' is spoken in southern municipalities bordering Baja Verapaz.

97. The municipalities that will probably be involved in the project are the departmental capital and largest city, Cobán, as well as the prioritized municipalities in this region: Chisec, Panzós, Santa Catalina la Tinta, Tucurú, Cahabón, Cobán, Fray Bartolomé de las Casas, Lanquín, San Cristóbal Verapaz, San Pedro Carchá, Santa Cruz Verapaz, Senahú, Tamahú, Chahal, Raxruhá, San Juan Chamelco and Tactic.

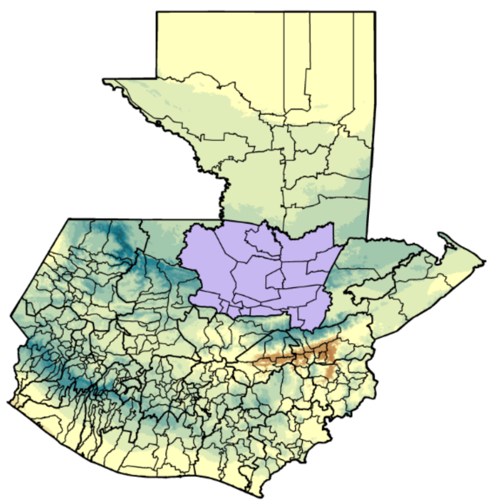


Figure 8. Municipalities selected in the Department of Alta Verapaz.

B.1.7.2. Baja Verapaz

98. There are eight municipalities in this department. It has approximately 80,207 inhabitants (INE, 2002). 56% of the population is indigenous. The Achí language is spoken in the municipalities of San Miguel Chicaj and Rabinal; and Poqomchi' in a strip to the north of these municipalities close to Alta Verapaz. Poqomchi' and Q'eqchi' are spoken in Purulhá, and Spanish in certain regions in the south of the municipality.

99. The largest city in this region is Salamá, municipal capital of the department of Baja Verapaz. The prioritized municipalities in this region are Purulhá, Rabinal and San Miguel Chicaj.

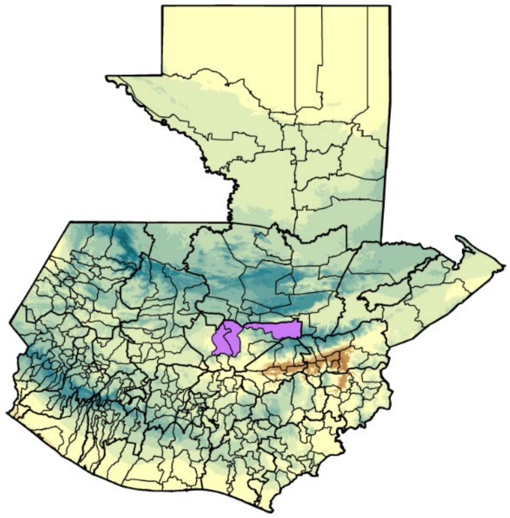


Figure 9. Municipalities selected in Baja Verapaz.

B.1.7.3. Petén

100. The department of Petén has 14 municipalities, and around 101,558 inhabitants (INE, 2002), of which 33% are indigenous. Q'eqchi' is spoken in the three selected municipalities, but Mopán is also spoken in the center-east of the municipality of San Luis and Spanish is spoken in the northern half of the municipality of Dolores. The largest city in this region is Poptún. The selected municipalities are Poptún, San Luis and Dolores.

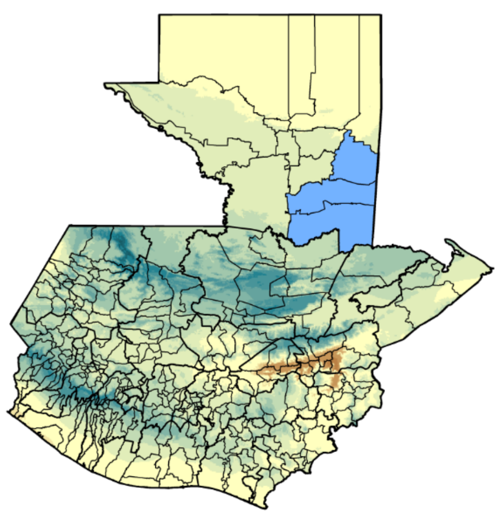


Figure 10. Selected municipalities in the department of Petén.

B.1.7.4. Zacapa

101. Zacapa has 10 municipalities and a population of 199,583 (INE, 2002), of which only 1% is indigenous. The project will be carried out in the municipalities with the highest rates of indigenous population. Ch'orti' and Spanish are spoken. The largest city is Zacapa, and the project will only work in one municipality, La Unión.

B.1.7.5. Chiquimula

102. Chiquimula has 11 municipalities and 300,323 inhabitants (INE, 2002), of which 7% are indigenous. Like in Zacapa, the project will focus on the municipalities with the highest rates of indigenous population. The languages spoken in this department are Ch'orti' and Spanish. The largest city is the departmental capital, Chiquimula. The selected municipalities are Chiquimula, Olopa, Camotán, Jocotán and San Juan La Ermita.

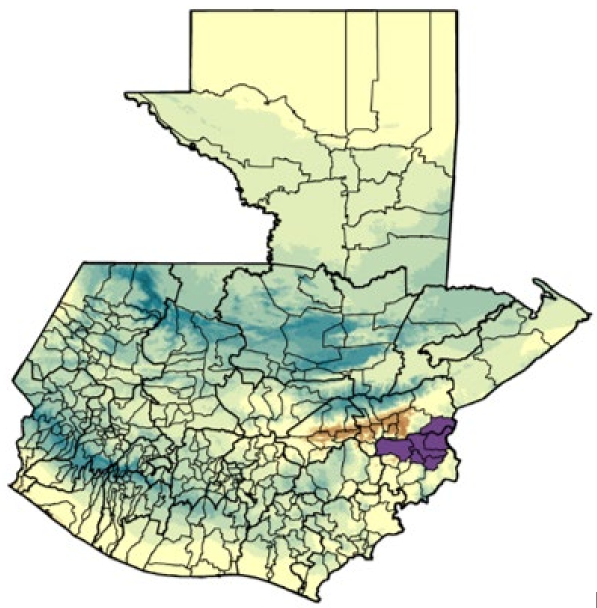


Figure 11. Selected municipalities in the department of Chiquimula.

Table 6: Main Socio-economic characteristics of the project target areas and projected climate change impacts on crop yields by 2030 (for scenarios A2 and B2) with baseline mean annual yield between 2001 – 2009.[3]

Departments ***Population*** [4]	**Livelihoods**	**Socio-economic context**[5]
Alta Verapaz ***Population:* 814,300** ***Indigenous population:* 90%**	Cultivation of coffee, cardamom, vegetables, forestry and basic grains such as beans and maize for subsistence. - 28.82% of the land is dedicated to annual basic grains agriculture, 1.61% to coffee, 6.96% to pastures, and 38.7% to forests.	Poverty in this department affects up to 94% of the rural population (of which up to 76%. are within the range of extreme poverty). [6]
Baja Verapaz ***Population :* 80,207** ***Indigenous population :* 56%**	Cultivation of basic grains such as beans and maize, coffee, cardamom, vegetables and forest plantations. - 42.33% of the land is dedicated to basic grains annual agriculture, 0.24% to coffee, 9.06% to pastures, and 39.95% to forests.	Poverty in this department reaches up to 96% of rural population (of which up to 71% people live in extreme poverty).
Petén ***Population :* 101,558** ***Indigenous population :* 33%**	Majority of livelihoods in the south are based on agriculture and cultivate mainly basic grains such as beans and maize and in the north, forestry and ecotourism.[7] - 15.93% of the land is dedicated to annual basic grains agriculture, 10.04% to pastures, and % to 45.31 forests.	The department is characterized by high poverty levels, which reach up to 86% of the population (of which up to 45% in extreme poverty conditions).
Zacapa y Chiquimula ***Population : 209,944*** ***Indigenous population Zacapa:* 1% and *Chiquimula:* 7%**	The region's livelihoods are mostly based on subsistence crops such as maize and beans and cash crops such as coffee, and vegetables and fruits. - 37.18% of the land is dedicated to basic grains annual agriculture, 6.22% to coffee, 5.91% to pastures, and 19.37% to forests	Poverty in the prioritized municipalities reaches up to 93% of the population and extreme poverty up to 66%of the population.

[3] ECLAC, 2018. La economía del Cambio Climático en Guatemala. Documento técnico 2018. ECLAC: https://repositorio.cepal.org/handle/11362/43725

[4] INE, 2002. INE. *Censos Nacionales XI de Población y VI de habitación 2002.* Guatemala: Instituto Nacional de Estadística (INE). Obtenido de https://www.ine.gob.gt/sistema/uploads/2014/02/20/jZqeGe1H9WdUDngYXkWt3GIhUUQCukcg.pdf

[5] INE (2014). Caracterización Departamental Alta Verapaz 2013. Recuperado: https://www.ine.gob.gt/sistema/uploads/2015/07/20/1fSmvhzbhVOQ5jcalarWvnNo3yoeBPu0.pdf

[6] Poverty condition is considered when a family/individual cannot meet the minimum cost necessary to cover a basket that allows to meet food and non-food needs. Source: Instituto Nacional de Estadística (INE). (2015). República de Guatemala: Encuesta Nacional de Condiciones de Vida 2014. Principales resultados. Guatemala: INE..

[7] FEWS NET. (8 de Octubre de 2015). *FEWS NET FAMINE EARLY WARNING SYSTEMS NETWORK*. Obtenido de Continuing El Niño drives increased food insecurity across many regions: http://www.fews.net/ global/alert/october-8-2015

Table 7: Main socioeconomic indicators of the municipalities prioritized for the project.

No.	Department / Municipality	Population					% Poverty (Rural population)		Socioeconomic context				Malnutrition (2016)		
		Total	% women	% men	% indigenous population	Indigenous group (majority)	General	Extreme poverty	PEA TOTAL (%)	PEA women (%)	PEA men (%)	Main economic activity	Chronic (Cases)	Acute (Cases)	Mortality (Cases)
1	**Alta Verapaz**														
1.1	Chahal	32,138	51	49	94	Q'eqchi	48	12	31	10	90	Agriculture	73	28	1
1.2	Chisec	96,287	52	48	91	Q'eqchi	97	65	34	15	85	Subsistence agriculture Unskilled labor	619	72	3
1.3	Cobán	289,421	50	50	93	Q'eqchi	79	26	31	ND*	ND*	ND*	939	93	2
1.4	Fray Bartolomé de las Casas	75,850	50	50	95	Q'eqchi	85	40	38	10	90	Agriculture	47	134	2
1.5	Lanquín	29,419	50	49	99	Q'eqchi	85	29	35	6	94	ND*	390	18	0
1.6	Panzós	67,340	50	50	98	Q'eqchi	97	76	33	12	88	Agriculture	390	72	2
1.7	Raxuhá	39,796	51	49	85	Q'eqchi	87	37	24				73	26	2
1.8	San Cristóbal Verapaz	70,528	51	49	99	Poqomchi	87	53	35	20	80	Agriculture	524	151	1
1.9	San Juan Chamelco	69,175	51	49	98	Q'eqchi	41	3	44	39	61	Subsistence agriculture Textile manufacturing	784	15	1
1.10	San Pedro Carchá	264,679	50	50	99	Q'eqchi	89	46	40	12	82	Agriculture Unskilled labor	273	56	2
1.11	Santa Catalina la Tinta	45,222	50	50	97	Q'eqchi	96	61	34	ND*	ND*	Agriculture (large plantations and subsistence)	138	42	0
1.12	Santa Cruz Verapaz	50,299	51	49	96	Poqomchi	81	37	25	ND*	ND*	Private initiative	601	18	1
1.13	Santa María Cahabón	69,349	50	50	98	Q'eqchi	80	26	ND*	ND*	ND*	ND*	52	26	2
1.14	Senahú	73,237	ND*	ND*	99	Q'eqchi	86	28	31	38	62	Agriculture (migratory)	1	28	1
1.15	Tactic	41,281	52	48	87	Poqomchi	40	10	45	36	64	ND*	2	24	1
1.16	Tamahú	24,697	50	50	99	Poqomchi	80	50	28	17	83	Skilled labor Agriculture	58	61	1
1.17	Tucurú	49,011	50	50	97	Q'eqchi	95	65	29	14	86	Subsistence agriculture	1	28	1

Source: developed in-house with INE data.

* Undetermined information

Table 8 (continuation): Main socioeconomic indicators of the municipalities prioritized for the project.

No.	Department / Municipality	Population					% Poverty (Rural population)		Socioeconomic context				Malnutrition (2016)		
		Total	% women	% men	% indigenous population	Indigenous group (majority)	General	Extreme poverty	PEA TOTAL (%)	PEA women (%)	PEA men (%)	Main economic activity	Chronic (Cases)	Acute (Cases)	Mortality (Cases)
2	Baja Verapaz														
2.1	Purulhá	64,476	50	50	92	Q'eqchi Poqomchi	97	71	ND*	ND*	ND*	ND*	1	53	1
2.2	Rabinal	39,386	53	47	82	Achi	68	ND*	ND*	ND*	ND*	ND*	ND*	17	1
2.3	San Miguel Chicaj	31,190	52	48	93	Achi	77	25	13	ND*	ND*	Agriculture	1	28	1
3	**Petén**														
3.1	Dolores	56,676	50	50	15	Q'eqchi	54	13	39	ND*	ND*	Agriculture	94	20	ND*
3.2	Poptún	79,311	50	50	35	Q'eqchi	49	12	36	ND*	ND*	Agriculture services, livestock, commerce	188	77	1
3.3	San Luis	88,848	50	50	60	Q'eqchi	86	45	39	ND*	ND*	Agriculture Hunting Silviculture Fishing	59	73	1
4	**Zacapa**														
4.1	La Unión	35,284	50	50	1	Ch'orti	74	ND*	33	12	88	Agriculture (coffee labor)	389	58	1
5	**Chiquimula**														
5.1	Camotán	48,435	ND*	ND*	69	Ch'orti	86	41	ND*	ND*	ND*	Agriculture (basic grains, coffee and vegetable production)	ND*	143	1
5.2	Chiquimula	87,882	53	47	3	Varios	86	35	33	32	68		1	95	2
5.3	Jocotán	53,960	ND*	ND*	81	ND*	94	60	22	ND*	ND*	Survival agriculture	ND*	142	2
5.4	Olopa	29,113	51	49	65	Ch'orti	85	ND*	ND*	ND*	ND*	Subsistence agriculture Informal commerce Unskilled labor	ND*	16	2
5.5	San Juan La Ermita	20,000	ND*	ND*	9	Ch'orti	87	40	42	ND*	ND*	Agriculture Construction work Mineral mining and processing	ND*	39	ND*

Source: developed in-house with INE data. *Undetermined information

B.2. Legal / political framework

103. The political/strategic and legal/regulatory framework presented below is binding in environmental, forest and diversity terms, social development, food security and sovereignty and climate change. It has also been prioritized based on recognition of the persistence of conditions of social, environmental and economic vulnerability experienced by most of the population.

Table 9: Legal/political framework on the environment, forests and biodiversity related to the project

Linkage topic	Name of the policy	Description	Project articulation
Environment, forests and biodiversity	Law Promoting the Establishment, Recovery, Restoration, Management, Production and Protection of Forests in Guatemala (PROBOSQUE) (Decree 2-2015)	Aiming to recover the country's forest cover, to strengthen social organization, to restore degraded woodlands, to ensure livelihoods for food and energy security and to reduce the effects of climate change, the State will grant forest incentives in the form of cash payments to implement reforestation or natural forest management projects according to a management plan for projects such as natural forests for protecting against climate change; natural forests for forestry production; industrial and energy plantations; forest systems in agricultural and ranching landscapes; forest restoration; headwaters; coastal areas and water sources.	The project is aligned with the objectives of the law with regard to forest restoration for community development by: • Promoting forest diversification in lands suitable for agriculture and livestock and restoring degraded forest lands through agro-forestry systems, forest plantations and other modalities that help provide firewood and timber in rural areas and recover the productive and protective base in degraded forest lands. • Helping to ensure livelihoods, food security, energy security and mitigation and reduction of natural disaster risks associated with the effects of climate variability and change and protecting the rural infrastructure of the Guatemalan population by promoting activities for forest establishment, recovery, restoration, management, production and protection.
	Environmental Protection and Improvement Law (Decree 68-86)	This law stipulates that the State, municipalities and the inhabitants of the national territory will foster social, economic, scientific and technological development to prevent environmental pollution and preserve a balanced environment. Therefore, plants, animals, the soil, the subsoil and water should be used and utilized rationally.	The project is aligned with the specific objectives of the Law (Art. 12): (c) Gearing educational, environmental and cultural systems towards the training of human resources qualified in environmental sciences and education at all levels to create environmental awareness among the entire population; (e) Creating all kinds of incentives and stimuli to promote programs and initiatives for environmental protection, improvement and restoration; (f) Comprehensive use and rational management of water basins and systems; (h) Saving and restoring bodies of water that are threatened or in danger of extinction.
	Forestry Law (Decree 101-96)	The set of laws that declares reforestation and forest conservation as a matter of national urgency and social interest for the country, promoting forest development and sustainable management of forest resources.	The project contributes to the specific objectives of this Law: (d) Supporting, promoting and encouraging public and private investment in forestry activities to increase production, marketing, diversification, industrialization and conservation of forest resources. (f) Promoting a better standard of living for communities by increasing the supply of forest goods and services to meet the need for firewood, housing, rural infrastructure and food.
	Law on Forest Incentives for Holders of Small Parcels of Land suitable for Forestry or Agro-forestry (PINPEP by its Spanish acronym) (Decree 51-2010).	The purpose of this law is the creation of the forest incentive program for owners of small plots of land suitable for forestry or agro-forestry.	The project contributes to the objectives of this law: (c) Promoting gender equity, prioritizing the participation of groups of women in the management of natural forests, establishing and maintaining forest plantation and agro-forestry systems. (d) Generating employment in rural areas by establishing and maintaining natural forest management projects, forest plantations and agro-forestry systems.
	National Strategy to Address Deforestation and Forest Degradation (ENDDBG by its Spanish acronym) (REDD+ (in progress)	The main objective of this strategy is to coordinate forest governance to create or implement the main existing public policy instruments that make it possible to incorporate different actors and social and productive processes in reversing the causes of deforestation and forest degradation through actions to recover and protect the country's forest cover.	The project contributes to the options and actions/activities of this strategy in terms of regulatory harmonization; land management; institutional strengthening; strengthening incentive programs (especially PINPEP); goods and services; activities compatible with sustainable protection and management of forest systems (means of subsistence); and wood energy strategy.

Table 10: Legal / political framework on development linked to the project

Linkage topic	Name of the policy	Description	Project articulation
Social development	K'atun National Development Plan: Our Guatemala 2032 (2016)	The K'atun Plan is the national long-term development policy that articulates policies, plans, programs, projects and investments; in other words, the development management cycle. The Plan is the tool that guides interventions that the private sector, other civil society organizations and international donors may establish for the purpose of contributing to development.	The Plan defines priority topics, including natural resources, to which this project will contribute in support of partial achievement of some of the goals: • Priority: climate change ○ Goal 1: improved adaptation capacity and resilience of the population and ecosystems to climate change. • Priority: Conservation and sustainable use of forests and biodiversity for climate change adaptation and mitigation. ○ Goal 1: 32% of the land surface is covered with forests that generate economic and environmental assets for the population. ○ Goal 2: By 2032, at least 29% of the country's territory is covered with natural forests and forest cover has increased by 3% through environmental restoration on lands that are suitable for forest protection and conservation. • Priority: Sustainable management of water resources for achieving social, economic and environmental objectives. ○ Goal 2: 100% of the areas considered very suitable for water regulation and catchment are protected and sustainably managed using a water basin and/or land management approach with Maya, Xinka, Garifuna, age and gender relevance according to the social context. ○ Goal 3: At least 10 billion cubic meters of water are being stored in ponds and reservoirs. ○ Goal 4: At least 50% of lands having a very high and high potential for irrigation possess efficient irrigation systems to improve agricultural productivity. • Priority: Improved agricultural methods and family agriculture with Maya, Xinka, Garifuna, age and gender relevance. ○ Goal 1: 100% of farming households living in below-subsistence conditions and 50% of households living in subsistence conditions have seen improvements in their agricultural productivity levels through implementation of family agriculture and better agricultural methods. • Priority: Land management for sustainable use of natural resources, agricultural production and adaptation to climate change and mitigation of its effects. • Priority: agricultural production for food security.
	Comprehensive National Rural Development Policy (PNDRI by its Spanish acronym)	The overall purpose of the PNDRI is the progressive and permanent improvement of people's quality of life in general; of inhabitants of rural areas through equitable access to and sustainable use of productive resources, means of production, natural assets and environmental services, to achieve comprehensive and sustainable human development in rural areas.	The project, seeking to help reduce food insecurity and unforeseen impacts on agricultural production, especially on the main crops on which food security is based, addresses three of the sector policies proposed by the PNDRI: • Agricultural, livestock, forest and hydrobiological policy: implementing sustainable and culturally relevant production models to achieve the full human development of the subjects of the Comprehensive National Rural Development Policy and Law. • Socio-environmental policy: promoting environmental sustainability of integrated rural development and the public character of all natural assets and environmental services, as well as protecting and improving the environment, promoting a comprehensive environmental management and land management model that also preserves the rights of indigenous and farmer communities, as well as the required consultations and the studies on environmental impact and cultural relevance. • Policy to reduce vulnerability and manage risks: mitigate and reduce social, economic and environmental vulnerability in rural and suburban areas.

Table 11: Legal / political food and nutritional security framework linked to the project

Linkage topics	Name of the policy	Description	Articulation of the project
Food and nutritional security	National Food and Nutritional Security Policy (PNSAN) by its Spanish acronym)	The purpose of this policy is to offer a coordinated and articulated, efficient and permanent strategic framework among the public sector, civil society and international cooperation agencies that can ensure food and nutritional security, understood as people's right to physical and economic access at all times to sufficient safe and nutritive food to meet their nutritional needs in accordance with their cultural values and with gender equity, to enable them to lead active and healthy lives and thus contribute to sustainable human development and Guatemala's economic and social development.	The project will support the following strategies included in the PNSAN: (i) promotion of sustainable production systems, and (ii) prioritization of populations and geographic areas. It is also in line with the crosscutting issues included in the policy, such as: (i) the environment; (ii) prioritizing the vulnerable population, defined as the population that has limited response capacity to a natural event or cause that places it at risk; (iii) vulnerability to disasters; (iv) Safe water or water suitable for human consumption and use in food production.
	2016-2020 Strategic Food and Nutritional Security Plan (PESAN by its Spanish acronym)	The 2016-2020 PESAN follows three different approaches. One of them refers to risk management and adaptation to climate change. Its importance lies in the fact that the 2016-2020 PESAN considers three strategic objectives leading to consolidation of the necessary political frameworks that express food and nutrition security and institution building to address the structural and situational determinants of food and nutritional insecurity. The crosscutting issues of this plan include: the right to food and nutrition, transparency and accountability, cultural relevance, gender equity and the environment and natural resources. Their contents have been included in each of the three strategic objectives as crosscutting issues.	In this sense, the project is aligned with the following strategic lines of this plan: • Planning, developing and monitoring actions to build resilience to food and nutritional insecurity (INSAN by its Spanish acronym) in the territories. • Integration and linkage of community structures to improve their response to adverse events with regard to food and nutritional security (SAN by its Spanish acronym). • Activation of emergency funds to operationalize the plans.
	Family agriculture program to strengthen peasant economies (PAFFEC by its Spanish acronym) 2016-2020	The PAFFEC seeks to contribute to the national effort led by the Government of the Republic to eradicate hunger and malnutrition as essential conditions to overcome the country's lag in rural development (MAGA, 2017).	The project will contribute to the strategic pillar "Sustainable increase of farmers family production for SAN", which includes actions to consolidate productive systems and crop diversification.
	National Rural Extension System (SNER by its Spanish acronym)	The SNER is a set of public, private and international cooperation components that directly or indirectly contribute to improving national agricultural development. The system is formed by professional service providers and rural families who interact jointly to strengthen the productive, as well as the food, economic and socio-environmental capacities of the rural population using informal education processes (Urarte, 2011).	The project will propose actions directly linked to this system, specifically to strengthen capacities in prioritized areas.

Table 12: Legal / political climate change framework linked to the project

Linkage topic	Name of the policy	Description	Project articulation
Climate change	Framework law to regulate vulnerability reduction, mandatory adaptation to the effects of climate change and mitigation of greenhouse gases (Decree 7-2013)	The purpose of this law is to establish the necessary regulations to prevent, plan and respond in an urgent, appropriate, coordinated and sustained manner to the impacts of climate change on the country (Art. 1) so that the State may adopt practices that promote conditions to reduce vulnerability, improve the capacity for adaptation and make it possible to develop proposals for mitigating the effects of climate change due to greenhouse gas emissions (Art. 2).	The project will contribute with inputs, actions and instruments that support compliance with the following articles of the Framework Law: Article 15: Institutional strategic plans for reducing vulnerability, climate change adaptation and mitigation. Article 16: Appropriate productive practices for adaptation to climate change. Article 17: Soil protection; and Article 20: Reducing emissions by changing land uses.
	National Climate Change Policy (PNCC by its Spanish acronym)	The purpose of this policy is for the State of Guatemala, through the central Government, municipalities, organized civil society and citizens in general to adopt risk prevention, vulnerability reduction and improved climate change adaptation practices and contribute to reducing greenhouse gas emissions in the territory, to help improve its inhabitants' quality of life and strengthen their capacity for advocacy in international climate change negotiations.	The project will contribute to the following advocacy areas of the National Climate Change Policy: appropriate production practices, reduction of vulnerability and improved adaptation to climate change in key sectors of society: agriculture, livestock and food security; forest resources; comprehensive management of water resources; ecosystem conservation and management.
	National Climate Change Action Plan (PANCC by its Spanish acronym)	The overall purpose of the PANCC is to define in a clear and orderly manner the main actions and guidelines Government institutions and other sectors of the State should follow to contribute effectively to reducing the vulnerability present in most of the national territory; to improve the country's capacity for adaptation and reduce greenhouse gases in view of the threat posed by climate change and variability. It should be noted that the PANCC covers the main aspects of climate change: climate science, adaptation and mitigation. They define the goals and the responsible and jointly responsible actors by topic, including academia and civil society.	The project will support achieving some of the goals established in the plan, which include adaptation and mitigation actions together with the leading public institutions on agriculture, livestock and food security, forest resources, ecosystems, comprehensive management of water resources and land use. En los mecanismos planteados en el NDC del país, el proyecto contribuirá específicamente a la continuidad de la implementación y cumplimiento de instrumentos de política de gestión forestal en la que resaltan: Recuperación, Restauración, Manejo, Producción y Protección de Bosques de Guatemala -PROBOSQUE, Decreto 02-2015-, el Programa de Incentivos Forestales - PINFOR- y Programa de Incentivos Forestales para Poseedores de Pequeñas Extensiones de Tierra de Vocación Forestal o Agroforestal –PINPEP-, Estrategia Nacional de Restauración del Paisaje Forestal, la Estrategia de Vínculo entre Bosque Industria y Mercado y la Estrategia Nacional para el Combate de la Tala Ilegal.
	National Determined and Contemplated Contributions (NDCs)	Guatemala submitted to the UNFCCC its "Nationally Contemplated and Determined Contribution" (NDC). In accordance with the principle of common but differentiated responsibilities and its current capacities, it aims to achieve 11.2% reduction of its total GHEs in base year 2005 projected to 2030 in a trend scenario (BAU). It also plans a more ambitious reduction of up to 22.6% of its total GHGEs for base year 2005 projected to 2030, on the condition that technical and financial support is provided through new and additional public and private international resources to achieve this ambitious goal.	Within the contemplated mechanisms in the NDC, the project will contribute specifically to the continued implementation and compliance with forest management policy instruments, specifically: forest recovery, restoration, management, production and protection in Guatemala (PROBOSQUE, Decree 02-2015), the Forest Incentive Program (PINFOR) and the Forest Incentive Program for small holders of land suitable for forestry or agro-Forestry (PINPEP, the National Strategy for Restoration of the Forest Landscape, the Strategy to link Forests, Industry and Market and the National Strategy for the fight against Illegal Logging.

B.3. Institutional framework

B.3.1. General Institutional Framework related to the Project

104. The response of the institutional subsystem has been insufficient and, in certain cases, absent. This is evidenced by the scarce resources allocated for the protection and sustainability of the natural subsystem. In fact, an analysis of expenditures by purpose and function shows that the allocation for environmental protection and risk management are among those that receive fewer resources. For the period 2010-2013, the average investment in issues related to environmental protection only reached 1% of the country's total budget (560.5 million quetzals) (CONADUR, 2014). (All Spanish acronyms are expressed in Spanish).

105. It should be noted that education, health, agriculture and food security, disaster risk reduction and others are directly related to the adaptation to climate change. Institutional strengthening in these areas and its linkage with climate change should therefore be a priority for the State.

106. As for the State's institutional density, the 2009/2010 Human Development Report, states that there is a stronger presence in education and health at the municipal level (CONADUR, 2014). The Human Development report uses the State Density Index (SDI) as a quantitative tool to measure (with 2008-2010 data) how agencies, bureaucracy and resources are distributed in the municipal sphere. This index considers three components: education, health and others (which encompasses all the other State functions).

107. The Climate Change Framework Law stipulates that, based on the National Plan of Action for Climate Change Adaptation and Mitigation, the relevant public institutions should have in place institutional strategic plans, which should be reviewed and updated periodically (article 15). It adds that priority should be given to developing strategic and operational plans, at least within the following institutions, according to the issues specified on adaptation matters (Torselli, Morataya & Coyoy, 2016):

(a) **Human Health**. The Ministry of Public Health and Social Welfare (MSPAS) and the Guatemalan Social Security Institute (IGSS) should consider climate change in their plans to improve prevention and reduce vector-borne diseases that might increase due to climate variability, considering at least acute respiratory infections and diarrheal diseases.

(b) **Food Security.** MAGA and the Food and Nutritional Security Secretariat (SESAN) should develop plans to ensure that the Guatemalan agricultural sector adapts to climate variability and the impacts of climate change taking into account the scenarios and effects of increased global temperatures. They should prioritize actions that have a direct effect on food production, especially for self-consumption and subsistence in prioritized areas.

(c) **Forest Resources, Ecosystems and Protected Areas.** The National Forestry Institute (INAB), CONAP, the National Forest Fire Prevention and Control System (SIPECIF) and MARN, as required, shall develop local, regional and national plans to prevent and combat forest fires, for efficient management of the units that are part of the Guatemalan System of

Protected Areas (SIGAP), ecological corridors and forest ecosystems, to improve their resilience to climate variability and climate change and ensure preservation of ecological processes and natural goods and services.

(d) **Infrastructure.** The Ministry of Communications, Infrastructure and Housing (MICIVI), other relevant public institutions and municipalities should adopt infrastructure design and construction standards that take into account climate variability and change considering the characteristics of the country's different regions.

108. The current challenge is the approval of the regulations needed to operationalize the National Climate Change Fund (FONCC), which would ensure that resources and State budget allocations are available to finance risk management, vulnerability reduction, mandatory adaptation and required mitigation plans, programs and projects.

109. Generally speaking, the adaptation actions that the project will propose have well-founded legal and regulatory backing that will contribute to meet the goals established by the same institutions by linking their Climate Change Directions and Units, and strengthening interagency relations.

110. Tables 13, 14 and 15 include an analysis of strengths and weaknesses of the main instruments linked to the project´s actions.

B.3.2. The National Development Council System

111. Pursuant to the Law on Urban and Rural Development Councils (2002), the Development Council System is the main space for the Maya, Xinka, Garifuna and non-indigenous population to participate in public management to carry out the democratic development planning process, taking into account principles of national, multi-ethnic, multicultural and multilingual characteristics of the Guatemalan nation. Its purpose is to organize and coordinate public administration by formulating development policies, budgetary plans and programs and promoting interagency, public and private coordination.

112. The Development Council System is organized by several levels:

(a) The national level, with the national Urban and Rural Development Council (CONADUR);

(b) The regional level, with Regional Urban and Rural Development Councils (COREDURs)

(c) The departmental level, with Departmental Development Councils (CODEDEs)

(d) The municipal level, with Municipal Development Councils (COMUDEs)

(e) The community level, with Community Development Councils (COCODEs)

Table 13: Strengths and weaknesses analysis of National Forestry Institute legal instruments linked to the project

Instrument	Strengths	Weaknesses
Law on Forest Incentives for Small Holders of Lands Suitable for forestry or agro-forestry (PINPEP) (Dec. 51-2010)	It is part of State forestry policies (maintaining and increasing forest cover) Recognizes holders of small plots of land suitable for forestry and agro-forestry (includes different modalities)	Limited institutional capacity to respond to PINPEP users. The landholders must have financial resources to finance a forestry regent and a forest management plan. Scarce legal and technical State support.
Law for Promotion of Establishment, Recovery, Restoration, Management, Production and Protection of Forests in Guatemala (PROBOSQUE) (Dec. 2-2015)	Provides continuity to 18 years of PINFOR Experience and critical mass already established, with different modalities to be promoted. Identification of alternative financial sources Different spaces/fora for interagency dialogue. • Forest consultation working groups • Firewood working group • Working group on control and prevention of illegal logging. • Working group on food and nutritional security. • Working group on restoration of the forest landscape. During the time PROBOSQUE has been operating, most of the funds of this incentive program (as well as PINFOR funding) have not reached vulnerable small farmers. The reason is because this type of farmers cannot meet the requirements established by INAB, even though the National Forestry Service authorities have shown great interest in to include them as beneficiaries of the program (especially those working with agroforestry systems). Although this might seem a weakness, in this particular case this should be considered a strength, since project activities will ensure funds from this Government Program reach a group that otherwise would not be included as beneficiaries. Another aspect included in the project framework is that activities will ensure incentives to support climate change adaptation practices. Based on this information it can be said that PROBOSQUE (and PINPEP) funding meets the additionality criteria of GCF, because without the project, funds will not reach the vulnerable small farmers, and the funding will not be used for climate change adaptation purposes.	Lacks a structure for channeling financial resources. Exceeds institutional capacity for addressing growing demand for forest incentive projects. Scarce review and update of regulatory instruments for ongoing improvement of institutional services. Insufficient disclosure and promotion of access, operation, benefits and monitoring mechanisms. Poor access to information on weather conditions and early warning systems.
National Strategy for the Restoration of the Forest Landscape, 2015-2045	Inter-sector approach Working group on restoration of the forest landscape Provides discussion spaces, such as: Interagency coordination group Links with other national/international strategies: (a) Biodiversity; (b) Low-emission development; (c) REDD+ (under preparation) Coordination with MAGA: • VISAN (Vice Ministry for Food and Nutritional Security) • Productive reconversion bureau • Bureau for natural resources and agro-tourism • PAFFEC • SNER	Lack of official baseline information that responds to the goals established for each pillar. Scarce information to the general public on the strategy, in terms of how to participate according to specific interests or sector activity. Incipient knowledge among the population on the notion of restoration of the forest landscape. Absence of communication channels between the central government and municipal, departmental and regional GCI delegations.

Table 14: Analysis of the strengths and weaknesses of MARN legal instruments linked to the project

Instrument	Strengths	Weaknesses
(Decree 7-2013) Framework Law on Regulation of Vulnerability Reduction, Mandatory Adaptation to the Effects of Climate Change and Greenhouse Gas Mitigation (LMCC) (Decree 7-2013)	National reference for the United Nations Framework Convention on Climate Change (UNFCCC). Linkage with national policies and strategies. Inter-sector approach to address the impacts of climate change, reduction of vulnerability and improvement of adaptation capacities. Creation of the National Climate Change Council. Development of the PANCC.	Lacks structure for channeling national and international financial resources. Absence of official records for monitoring GHG emissions. Incipient knowledge of emission compensation mechanisms. Incipient development of tools for classifying spending on climate change (mitigation and adaptation actions). Little dissemination and promotion of social participation, monitoring, evaluation and auditing. Some of the regulations of the law have not been developed and approved.
National Plan of Action on Climate Change (PANCC)	Defines and organizes the main actions and guidelines resulting from the LMCC. Linkage with other national plans and policies. Guides the development of institutional strategic plans. Coordination with SEGEPLAN.	Absence of budgetary quantification with regard to losses, damages and sector investments. The link between MEM and MSPAS needs to be improved. Poor development of MARN's institutional capacities.

Table 15: Analysis of Strengths and Weaknesses of MAGA legal instruments related to the project

Instrument	Strengths	Weaknesses
PAFFEC (Family Agriculture Program for Strengthening Peasant Economy)	Linked to national policies: (a) Comprehensive rural development, assisting prioritized subjects*; (b) Food and nutritional security; (c) Climate change. Linked to INAB through PINPEP and PROBOSQUE.	Absence of a single register of beneficiary families. Social programs are still viewed from the standpoint of welfare and patronage.
2013-2030 Irrigation Policy	Recognizes the vital and strategic importance of access to irrigation for food and nutritional security and to boost small and medium farmers´ agriculture.	Little participation in developing the process. Discussion and validation processes are absent. Institutional void due to the lack of a general water law or specific laws governing water use for agriculture.
National Rural Extension System (SNER)	Facilitates implementation of MAGA's institutional mandate and helps to boost farmer economy, considered as a priority subject* for the PNDRI.	Insufficient staff and resources for Rural Learning and Development Centers (CADER) Unstable working conditions for extension agents/ rural promoters. Limited mobility in the territories; lack of inputs, materials and equipment. No articulation between extension agents and/or promoters from other government agencies. Deficient use of installed technical capacities.

Source: Author´s analysis

113. The composition and functions of each of the levels are regulated by the Law. There are also special levels or types of Development councils. These are:

- **Second-Tier Community Development Councils** (Article 15). These councils are set up by the coordinating bodies of the COCODEs in municipalities that have more than 20 Community Development Councils.
- **Indigenous Advisory Councils** (Article 23). These are set up at community level to advise the coordinating body of the Community Development Council and the Municipal Development Council where there is at least one indigenous community. They are created by authorities recognized by indigenous communities themselves according to their own principles, values, rules and procedures.

114. Development Councils may appoint any working committees they deem necessary, and the Regional, Departmental and Municipal levels have a technical unit that advises and follows up the implementation of policies, plans, programs and projects.

115. As for consultation with indigenous peoples, Article 26 of the Law stipulates that "Until a law governing consultation with indigenous peoples is enacted, the Maya, Xinka and Garifuna peoples should be consulted through their representatives on development councils on development measures promoted by the Executive Power that directly affect them".

B.4. Other Initiatives and Projects linked to Climate Change in Guatemala

116. This section contains a summary of national initiatives and projects linked to climate change adaptation and variability, stressing the links between these and the RELIVE project in order to establish synergies to complement, strengthen and/or scale up project outcomes, or implement actions based on the outcomes and lessons learned from finalized projects.

117. More than fifteen projects that are currently or recently implemented are listed, which have a direct relationship with adaptation to climate change, on which the RELIVE project can build or create synergies. The table below explains the most relevant details.

Table 16: Initiatives or Projects Related to the RELIVE Project

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
1	NAP-Agriculture (Integrating Agriculture into National Adaptation Plans)	• Strengthen matters related to irrigation, adaptation to climate change in the country's agricultural sector and strengthening institutional capacities by developing or updating policy and planning instruments at the national, sector and local levels, to assist the Ministry of Agriculture, Livestock and Food (MAGA). • Beneficiaries: SNER extension agents and local farmers' associations in the project area. • FAO coordinates, UNDP collaborates in the implementation, MAGA is a partner. • Funding source: BMU[8].	Globally launched in 2015. Launched in Guatemala in 2018.	260,000	Both projects work on adaptation measures related to agriculture and water management and since both projects coincide in part of the geographical area (Zacapa and Chiquimula), coordinated and complementary actions that enhance the outcomes of both projects will be undertaken.
2	Adaptation to Climate Change in the Dry Corridor of Guatemala	• Its objective is to improve productive systems and sustainable water, soil and forest management as a measure of adaptation to the negative effects of climate change in the communities of the dry corridor. • Actions are aimed to reduce deforestation, introduce climate change strategies, increase basic grain yields through irrigation and women's participation in agricultural and forest production. • Funding source: KFW.	Beginning: 2016 End: 2022.	10.1 million	Themes (adaptation to climate change) and part of the geographic area (Baja Verapaz and Zacapa) in common and complementary approaches may lead to synergies in common territorial areas. Depending on time periods, the RELIVE project might be able to implement them based on results and lessons learned, especially with regard to component 1 and outcomes 1.2 and 1.3.
3	Debt Swaps for Adaptation to Climate Change	• Its objective is to increase the resilience of communities and productive landscapes in the municipalities of Zacualpa, San Pedro Jocopilas, San Andrés Sajcabajá, Sacapulas, San Bartolomé Jocotenango and Canillá, in the department of Quiché. • The specific objectives seek to provide access to water for households and for farming, soil protection practices, forest conservation in water recharge areas, improving productivity, market access and productive linkages. • Funding source: KFW.	6 years (dates not specified)	11.2 million	The same topics in adaptation: Access to water and improved productivity; different geographic area. The temporality may be the same, facilitating exchanges among project implementers/ technicians and beneficiaries (producers) to share experiences and lessons learned.
5	Project on Productive Landscapes Resilient to Climate Change and Strengthened Socioeconomic Networks in Guatemala	• Objective: to increase the resilience to climate of productive landscapes and of socioeconomic systems in the target municipalities threatened by the impacts of climate change and variability, particularly increasingly frequent and intense hydrometeorological phenomena. • Strengthen institutional and political capacity for planning, management of ecosystems for resilience, increase the capacity of community associations to reduce risks of socioeconomic and ecosystem losses, establishment of an information system. • Geographic area: 12 municipalities, 7 in Sololá, 5 in Suchitepéquez. • Funding source: Adaptation Fund.	July 2015 – July 2019	5 million	The same topics are shared by the projects, although the geographic implementation areas are different. The RELIVE project may be implemented using the project's recommendations and lessons learned.
6	Rural Development and Climate Change Adaptation, Phase II, ADAPTATE II	• Its objective has been to help reduce the population's and ecosystems' vulnerability to climate change in the Dry Corridor through management of environmental goods and services. • It promoted the coordinated actions among authorities, community representatives and civil society in environmental management processes, municipal and community measures for managing natural resources, new technical solutions in value chains to improve resource use efficiency and increase resources.	2016-2018 (now closing)	2.5 million	This Project was developed in the departments of Baja Verapaz and El Progreso. Some municipalities in Baja Verapaz are being considered in the RELIVE project; therefore, the geographic area and vulnerability reduction topics are the same, although each project follows a different approach. This is one

[8]Banco Alemán de Ambiente, Conservación de la Naturaleza y Seguridad Nuclear. German Bank for the Environment, Conservation of Nature and Nuclear Safety.

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
		• Funding source: GIZ			of the projects that will serve as the basis for development the Koica project, which will be the counterpart of the RELIVE project, and thus offers recommendations and lessons learned for implementation.
7	Joint Comprehensive Cuilco River, San Marcos Rural Development Program	• The objective of this project is the strengthening of the integrated rural development in prioritized municipalities to reduce the inhabitants' health and community habitat vulnerabilities and enhance the population's and the territories´ productive opportunities. • Financial source: Swedish government • Executing entities PNUD (leader), FAO y OMS. • Funding source: Swedish International Development Cooperation Agency – Sida.	2015-2018	4.5 million	This project, located in a different territorial area, is being closed. However, it conducted actions geared toward improving adaptation capacities with particular emphasis on food security and water management for household use and its outcomes and experiences might be useful for implementing the RELIVE project.
8	Ixil Rural Development Program	• Its outcomes focus on below-subsistence and subsistence families that were victims of the internal armed conflict, as well as community organizations able to improve their habitat conditions, development management, governance of renewable natural resources and entrepreneurial abilities. • Local governments and sector institutions in the Ixil region have developed capacities to achieve peaceful and inclusive governance processes that focus on rights and a culture of resilience. • Financial source: Swedish government • Executing entities PNUD (leader), FAO y OMS. • Funding source: Swedish International Development Cooperation Agency - Sida–.	2015-2018	5.36 million	This project is also being closed. It is located in a different territorial area but it conducted actions geared toward improving adaptation capacities with particular emphasis on food security and water management for household use and its outcomes and experiences might be useful for implementing the RELIVE project.
9	Building Livelihood Resilience to Climate Change in the High Basins of the Guatemalan Highlands	• Its main objective is to reduce the impacts of climate change on the water cycle in selected water basins by scaling up ecosystem-based adaptation actions (EbAs). These actions will help improve water recharge and production and the population's and ecosystems' resilience to climate change. • The project will focus on three areas: (1) integrated and climatically intelligent basin management adapted to the local context of the Highlands; (2) financing for climate action in basins by the communities through the channeling of resources towards priority areas; and (3) climate information provided to farmers and other stakeholders. • Funding sources: Green Climate Fund and Koica. Implementing partner: IUCN.	7 years; about to begin.	37.7 million (22 GCF, 4.6 KOIKA, 11 Government of Guatemala)	It is related to the RELIVE project since it focuses on adaptation and basin management, although the approach and the area are different. The project in question focuses on restoration of the forest landscape as a means for ecosystem adaptation and improvement of vulnerable populations' means of subsistence in the action area. The RELIVE project focuses thematically on adaptation through resilient agriculture for food security for vulnerable populations and might be able to use some of the inputs generated by this project. Their implementation might coincide at some point, so the technical teams and producers who benefit from each project might be able to share experiences and lessons. Also, while, the project "Building livelihood resilience to climate change in the upper basins of Guatemala's highlands", includes interventions to install meteorological stations that will be used by INSIVUMERH, this equipment will be installed only in the area targeted by the project. While these interventions will strengthen INSIVUMEH capacity to provide better climate services, this will be rather

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
					targeted for the project areas with little relevance to other territories in the country and the climate data generated there, will not be useful to inform the smallholder farmers located in the area of RELIVE project. Therefore, RELIVE project objective is to install hydro-meteorological equipment in the area of the project, which will provide reliable information with very specific variables informing smallholder producers of coffee, cocoa, beans and maize. The project will as well provide capacity building to INSIVUMEH on collecting and processing the climate information. The two projects are therefore complementary and coordinated with the objective to improve the national network of meteorological stations managed by INSIVUMEH. INSIVUMEH will benefit from capacity building activities on generating agro-weather information and will continue, as part of their monitoring network, to use and manage the newly installed hydro-meteorological equipment acquired through both projects covering different regions.
10	Climate, Nature and Communities in Guatemala (CNCG)	• Its purpose is conservation of Guatemala's natural assets and support national efforts to reduce the negative effects of climate change and promote the sustainable development of communities that depend on forests. • The project worked through five components; one focuses on climate change adaptation in the western region of the country using three strategies: (1) Greater access to climate information; (2) Improved organization or governance to address the issue; and (3) better agricultural practices. • Funding sources: USAID; a Rainforest Alliance-led consortium.	2013-2018	25 million	Although this project's area of action is different, the RELIVE project can build on the CNCG project's experience and lessons learned, since they established a climate change information system in the western region and worked on agricultural practices adapted to the climate.
11	Buena Milpa (Good Maize)	• Its objective is to reduce poverty, food insecurity and malnutrition while improving the sustainability and resilience of systems based on maize cultivation, reducing environmental degradation and improving means of subsistence. • It focuses on improving crops and provides soil management, seed selection and grain storage training. • Financial sources: USAID, CIMMYT[9] partner. Partners: MAGA and ICTA.	2011-2019	3.63 million	This project has developed information, learning and best practices for improving maize growing capacity for adaptation through food security. This information and experiences may be used to implement the RELIVE project with regard to maize-related practices.
12	Más Frijol (More Beans)	• Its objective has been to improve the nutrition of families in the Western Highlands of Guatemala by improving bean productivity using different practices and nutrition information. • Financial source: USAID. Implemented by the University of Michigan with ICTA and the Health Ministry.	2014-2019	3.55 million	As in the previous case, the experience and information from this project might be useful in implementing the RELIVE project with regard to bean growing.

[9] International Research Center for the Improvement of Maize and Wheat.

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
13	Más Riego (More Irrigation)	• Its overall objective is to improve nutrition and household income, as it expands the number of small owners' commercial enterprises that serve small farmers' families. • It promotes drip irrigation and agricultural conservation practices, linking vegetable production and resilience to climate change by protecting water sources, harvesting rainwater and conserving soils. • Financial source: USAID.	2015-2019	3 million	As in the previous case, the experience and information from this project might be useful in implementing the RELIVE project with regard to water management.
14	Sustainable Economic Observatory	• It will establish a sustainable economy observatory (research center/think tank) to strengthen the participation and contributions of civil society, the public and private sectors and other stakeholders in discussion, analysis, design and implementation of effective policies and programs and the national and local level. • It focuses on rural development and food security, growth of the agricultural sector, the environment, including resilience to climate change, biodiversity, competitiveness and enabling environments for business. • Financial source: USAID. Implemented by UVG.	2016-2021	8.99 million	The information gathered by the Observatory might be utilized by the RELIVE project. There might also be synergies in joint development of information.
15	Feed Guatemala's Future. Project on innovative solutions for agricultural value chains.	• The objective of this activity is to increase agricultural revenues, improve resilience and improve nutritional outcomes for small farmers and their families in five departments of the Western Highlands. • Provide technical assistance to improved agricultural and post-harvest practices, improve productivity, promote adoption of climatically intelligent practices. • Financial source: USAID. Implementing partner: Agropecuaria Popoyán, S.A.	2017-2022	36.21 million	If there is coincidence in time, learning synergies and experience sharing between both projects might be possible. RELIVE might be able to use the experiences and lessons learned to implement its actions.
16	Feeding Guatemala's Future. Coffee Value Chain Project	• The objective is to reduce poverty by increasing agricultural revenues and improving small farmers' and their families' resilience in the Western Highlands as nutritional outcomes improve. • Financial source: USAID.	2017-2022	19 million	Geographic areas are different, but topics are the same, since the RELIVE project considers that coffee is one of the crops where practices should be promoted as a means of adaptation. Therefore, if there is coincidence in time, learning synergies and experience sharing between both projects might be possible. RELIVE might be able to use the experiences and lessons learned to implement its actions.
17	Improving water quality in the Mam territory and institutional strengthening of MANCUERNA[10].	• Helps prevent chronic malnutrition by proving safe water and basic sanitation services in MANCUERNA partner municipalities. • Financial source: USAID. Implementing partner: MANCUERNA.	2017-2020	3 million	Geographic areas are different, but water management topics for food security and climate change adaptation are the same. RELIVE might be able to learn from the experience and information gained by this project.
18	Recovery of the Natural Capital of the Dry Corridor	• The project's objective was to recover natural resources at the micro basin level to strengthen families', communities' and local governments' resilience and improve their capacities to produce nourishing foods during droughts. It was carried out in the municipalities of Jocotán, Camotán, Olopa and San Juan Ermita in	2013-2015	11 million	Geographic areas and topics are the same. Lessons learned from this project will be used in RELIVE components 1 and 2.

[10] Mancomunidad de la Cuenca del Río Naranjo. Naranjo River Basin Community.

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
	and Climate Adaptation by its Population	Chiquimula. • The actions implemented include forest protection and restoration with access to forest incentives, creation of seed banks, basin management, family vegetable gardens and poultry. • . Financial source: IDB.			
19	Ecosystem-based Adaptation to increase climate resilience in the Central American Dry Corridor and the Arid Zones of the Dominican Republic	• The project's objective is to improve the climatic resilience of rural communities in the Dry Corridor and Arid Zones through: i) implementing integrated watershed management and restoring watersheds; ii) improve hydrological flow and infiltration of rainwater in groundwater reserves through the restoration of forests and ecosystems; and iii) reduce the demand for scarce water resources by implementing efficient technologies in the use of water at the farm and household level. The project will focus on 1. financing mechanisms for EbA, as well as efficient technologies in water and energy and 2. the implementation and integration of EbA, water and energy efficient technologies and businesses based on natural resources. • Financial source: GCF. Implementing partner: CABEI	Under approval. Submitted to GCF on November 2019	286 million	This project will be working on the Dry Corridor and Arid Zones. However, the project sites will not overlap with RELIVE project. There is a high potential for synergies and complementarity between the two projects: On one hand replication of RELIVE agricultural resilient practices by CABEI project areas and on the other hand, RELIVE will explore the suitability of the financial mechanisms promoted by CABEI projects for the specific adaptation solutions and beneficiary groups.
20	Productive Investment Initiative for Adaptation to Climate Change (CAMBio II)	• This Programme's primary objective is to increase resilience to climate change of Micro, Small and Medium-sized Enterprises (MSMEs) in Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama and the Dominican Republic by removing barriers to access financial and non-financial services for adopting and implementing climate change best adaptation measures. By the adoption of ecosystem-based adaptation measures, the Programme is expected to deliver resilient agricultural areas and strengthened ecosystems in response to climate variability and change. • Financial source: GCF and CABEI. Implementing partner: CABEI	Approved 2019	28 million	While this project will also work in the Dry Corridor (intervention areas: Western region and the Dry Corridor), the project sites will not overlap with RELIVE project. As both will work in a similar context, there is a high potential for synergies and complementarity. In particular, on one hand replication of RELIVE agricultural resilient practices by CABEI project areas and on the other hand, RELIVE will explore the suitability of the financial mechanisms promoted by CABEI projects for the specific adaptation solutions and beneficiary groups. While the beneficiaries of CAMBio II are micro, small and medium sized enterprises, the project is serving as a demonstration platform to prove that investments on adaptation practices in agriculture can be attractive to commercial banks and financial institutions previously not experienced in environmental/adaptation projects. the proposed interventions in RELIVE project will not overlap with CABEI projects, but rather synergies and replication of certain practices will be sought as for example: 1) RELIVE project promotes agroforestry, which is an ecosystem-based adaptation measure. The project will explore how the financial mechanisms proposed under CABEI projects may be replicated for the RELIVE project context and beneficiaries in particular for promoting agroforestry; 2) RELIVE project will strengthen value chains and

No.	Initiative / Project	Description	Implementation Period	Amount US$	Relationship with the RELIVE Project
					producers’ associations and seek for opportunities to encourage the formation of MSMEs which may benefit from the financial mechanisms promoted under CABEI projects; 3) CABEI´s projects may explore how the resilient agricultural practices and outcomes from RELIVE project can be integrated and supported by the financial mechanisms relevant for smallholder farmers under poverty conditions.
21	Forest Governance and Livelihoods Diversification	• The project’s objective is to strengthen forest governance and increase access to diversified livelihoods activities for forest-dependent communities in selected areas in Guatemala. The project aim at achieving i) improved level of forest governance in selected areas and institutions; ii) areas under improved forest governance practices and iii) people in targeted forest and adjacent communities with increased monetary or non-monetary benefits from diversified livelihoods. • Financial source: FIP. Implementing partners: IBRD and INAB	Approved on November 2019	11 million	The geographical area isn’t the same but as both projects share common objectives related to institutional strengthening and improving the resilience to climate change of vulnerable communities, learning synergies and experience sharing between both projects might be possible. RELIVE might be able to use the experiences and lessons learned to implement its actions.
22	Sustainable Forest Management	• The project’s objective is to contribute to reducing the rate of deforestation and CO2e emissions. The specific objectives are (i) to improve the efficiency of public forest services; (ii) improve the effectiveness, profitability and social inclusion of incentive programs; and (iii) promote the sustainable use of the forest. The project is expected to contribute to the access of small producers and communities to forest public services and financing; promoting the productivity and profitability of forestry activity along the value chain and technological innovations in the public and private sectors; promoting links with markets; promoting the protection of priority forest ecosystem services for mitigation (reduction of CO2 emissions) and adaptation (regulation of the water cycle) and; strengthening the public forestry administration. • Financial source: FIP. Implementing partners: IDB and INAB	Approved on January 2020	9 million	Not all municipalities targeted by the two projects are the same but water management, climate resilient production and institutional strengthening topics for food security, resilient ecosystem and ecosystem services and climate change adaptation are aligned. RELIVE might be able to learn from the experience and information gained by this project.

B.5. Main Projects currently Implemented by FAO

118. The United Nations Food and Agriculture Organization (FAO) has a long track record in the design and management of projects related to its duties and mission, with a follow-up and evaluation system that makes it possible to state that its performance has been satisfactory in managing financial resources (of a size similar to the ones that will be requested from the CVF), as well as in achieving the results proposed in each initiative. These tasks are performed in cooperation with local partners in implementation countries, including government institutions, national and international organizations and local organizations, according to the needs and requirements of actions to be implemented. Table 17 below contains a summary of projects implemented by FAO in recent years, which shows the experience in different places, objectives/topics and budget management.

Table 17: Projects Implemented by FAO

Project Name	Start Date	End Date	Total Budget (US$)
Immediate technical assistance to strengthen preparation for emergencies against highly pathogenic avian influence (HPAI) (regional activities)	01/10/2014	31/12/2019	17,276,801
Sustained humanitarian assistance to persons seriously affected by drought in rural areas of Somalia	01/01/2018	31/03/2019	13,250,000
Sustained cash assistance to prevent famine and respond to drought in rural areas of Somalia	01/04/2018	30/06/2019	45,000,000
Emergency Livelihood Response Program (ELRP) 2015-2016	17/11/2015	31/12/2018	20,174,701
Sustainable Agriculture for Economic Resilience project (SAFER) in South Sudan	04/08/2017	03/08/2020	37,807,562
Emergency Livelihood Response Program in South Sudan, 2018-2020	01/03/2018	31/12/2020	24,475,118
Emergency agricultural livelihood support to the most vulnerable households in Yemen	11/05/2018	30/04/2019	20,565,000
Restoring and promoting sustainable livelihoods based on agriculture for food security, employment and improved nutrition in the state of Borneo	01/02/2018	31/01/2021	13,867,621
Promoting value chains, Western Afghanistan	19/09/2017	19/09/2020	19,000,000
Information on nutrition, food security and resilience for decision making (INFORMADO)	01/05/2015	30/04/2019	22,123,894
Program of agencies headquartered in Rome to strengthen livelihood resilience in prolonged crisis situations	23/12/2016	31/12/2021	16,671,422
Control of trans border cattle diseases (foot-and-mouth disease and Peste des Petits Ruminants)	03/04/2017	30/04/2019	25,417,807
Famine prevention and response to drought in Somalia	16/01/2017	14/03/2018	14,841,672
Increasing vulnerable farmers' resilience in the south of Haiti by improving landscape management (R2R)	N/D	N/D	17,000,000
Forest resistance in Armenia, improving rural green growth and adaptation through mitigation	01/02/2019	01/03/2027	4,575,424
Public-social-private associations for climate-resistant agriculture	N/D	N/D	25,000,000
Increased climate resistance of rural households and communities through productive landscape restoration in selected localities in the Republic of Cuba (IRES-Cuba)	01/07/2019	01/07/2025	30,000,000
Carbon sequestration through climate inversion in forests and grasslands (CS-FOR)	01/12/2018	30/11/2026	29,985,011
Building a resistant Churia region in Nepal (BRCRN)	01/07/2019	30/06/2026	40,711,091
Transformation of the Indus River Basin with climate-resistant agriculture and climatically intelligent water management	01/10/2018	30/09/2024	49,881,329

Project Name	Start Date	End Date	Total Budget (US$)
Poverty, Reforestation, Energy and Climate Change – PROEZA Project	02/04/2018	31/08/2023	25,060,373
Climate-resilient fishery initiatives for improved livelihoods			15,310,000
Improved climate resilience measures in agricultural ecosystems of the dry corridor in El Salvador (RECLIMA)	01/01/2019	31/12/2023	38,717,581
REDD+ Results-Based Payments	N/D	N/D	60,000,000
Preservation and restoration of ecosystem services focusing on water safety for CC	N/D	N/D	50,000,000
Support for implementation of the NDC in the land and forest use sector.	N/D	N/D	90,000,000
Extending climate change adaptation in agriculture in the Philippines	N/D	N/D	48,500,000
Strengthening subsistence systems in communities in the main watershed of Zone 3	N/D	N/D	52,086,726
Improving climate resilience in steppes and dry forests of the Algerian Green Dam	N/D	N/D	43,000,000
Nexus water, energy and food focus to address the impacts of climate change in central Tunisia	N/D	N/D	28,000,000
Program for global eradication of Peste des Petits Ruminants (PPR-GEP)	N/D	N/D	50,000,000
Strengthening small farmers', ranchers', fishermen's and forest communities' resilience	N/D	N/D	30,000,000
Climate mitigation and adaptation program to increase ecosystems' and communities resilience	N/D	N/D	60,000,000
Ouémé climate resilience initiative	N/D	N/D	50,000,000
Public-private partnerships for climate-resistant agriculture	N/D	N/D	25,000,000
Increasing climate resilience of rural households and communities through productive landscape restoration in selected localities of the Republic of Cuba (IRES-Cuba)	01/07/2019	01/07/2025	30,000,000
Creating food system resilience in prolonged crises (FNS-REPRO)	N/D	N/D	27,303,750
Ensuring resistance to CC in Maya landscapes of Petén, the Verapaces and the Dry Corridor	N/D	N/D	30,000,000
Umbrella program: sustainable management of fall armyworm (FAW) in Africa	18/10/2017	31/10/2022	113,794,500

119. Table 17 shows projects implemented by FAO in Guatemala in close coordination with government agencies that will partner with the RELIVE project. It is worth stating that the relationship between FAO and INAB, MARN and MAGA dates back many years. It highlights the implementation of projects with the forestry service in the 70s and 80s even before INAB (Decree No. 101-96, Forestry Law, 1996) was established.

B.6. Status of Climate Information

120. Monitoring, analysis and evaluation of the effects of climate variability and change are extremely important issues in Guatemala, since the country's economy depends to a large extent on the natural capital and environmental services, where sensitive sectors to such climate variations and changes are found. These include agriculture, coastal resources, water resources, infrastructure and others. Therefore, evaluating and monitoring vulnerability and the adaptation to natural disasters, as well as the analysis of measures to mitigate and adapt to the effects of climate variability represent one of the main points for the development of political agendas.

Table 18: Projects Implemented by FAO Earlier with Partners in this Project

Project Name	Country Partner	Implementation Period	Budget (USD)
Organization of Forestry Cooperatives	INAB	1977-1978	61,000
Support to the Evaluation of Forest Resources in the East	INAB	1985-1986	74,960
Support to the Government in implementing the National Forestry Institute	INAB	1998-1999	245,500
Support to the National Forestry Program	INAB/MARN	2002-2015	36,610,273
Support the development of a regional cooperation strategy for the prevention, control and fight of forest fires	INAB	2004-2006	243,927
Support to the National REDD+ Action	MARN/INAB/MAGA	2011-2018	47,864,408
Promoting sustainable forest management in small forest producers: building on the Von Carlowitz legacy	INAB	2013-2016	1,193,377
Forest and Farm Facility	INAB-MAGA	2013-2018	15,380,008
Restoration of degraded lands	INAB	2014-2018	1,329,089
Implementation of the Forest Landscape Restoration Mechanism (FLR)	INAB	2014-2020	3,380,102
FAO Forest Law Enforcement, Governance and Trade Program-Phase III	INAB	2015-2018	14,905,508
FAO Forest Law Enforcement, Governance and Trade Program-Phase III	INAB	2016-2020	36,882,353
ATLAS project 00103787 - Baby 03	MARN-INAB-MAGA	2016-2020	9,707,099
FMM support to SO 3 - OO 301 (MTP 2014-2017) Strengthening forest and agricultural producers through Forestry and Agricultural Support	INAB-MAGA	2017-2018	758,853
Adaptation of rural communities to climate change and variability to improve their resilience and livelihoods in Guatemala	MARN	2018-2021	5,000,000

Source: In-house development with FAO information.

121. In this regard, climate information was developed in Guatemala after the creation of the National Seismology, Volcanology, Meteorology and Hydrology Institute (INSIVUMEH) in 1976. This is the official agency that generates information on surveillance of the main systems associated with atmospheric, geophysical and hydrological sciences at the national level; coordinates actions with the private sector and academia and acts as the government's technical advisor on natural disasters.

122. Later, the Framework Law for Regulating Vulnerability Reduction, Mandatory Adaptation to the Effects of Climate Change and Greenhouse Gas Mitigation (Decree 7-2013) created the National Climate Change Information System (SNICC) and placed it under the Ministry of the Environment and Natural Resources (MARN). In general, this Law establishes the mandates and guidelines for designing, developing and implementing policy tools on the matter and assigns powers that go beyond those of the Ministry of the Environment and Natural Resources to other governmental and non-governmental sectors; establishes the guiding principles and guidelines for public action on climate change (National Climate Change Plan of Action) (PANCC), 2016). It also stipulates that all public and private entities must provide information related to climate change, emissions and greenhouse gas emission reduction, climate change vulnerability and adaptation needed for the national communications that the country must provide.

123. INSIVUMEH has a network of meteorological and hydrological stations in different points of the country. However, according to the World Meteorological Organization (WMO) criteria, the density of these is not enough for climatological studies(Alfaro & Gómez, 2019). Synergies have therefore been created with other government, private and civil society institutions that have their own climate monitoring stations to develop and model information. These include the National Coffee Association (ANACAFÉ), the Private Institute for Climate Change Research (ICC), the Authority for Sustainable Management of the Lake Amatitlán basin, several universities and others. However, the country does not have the appropriate number of meteorological stations to address the problem of climate change.

124. Coordination platforms for developing and analyzing climate change-related information have been created in the country. These support decision-making and include the Interagency Climate Change Committee (CICC), the National Climate Change Council (CNCC), the Group on Forests, Biodiversity and Climate Change (GBByCC), Interagency Coordination Group (GCI), Interagency Forest and Land Use Monitoring Group (GIMBOT), National Climate Change Working Group (MNCC), Sector Coordinating Office on Environmental Statistics (OCSE-Ambiente), Guatemalan Environmental and Economic Accounting System (SCAEI), Guatemalan Climate Change Science System (SGCCC), etc. (Verweij & Winograd, 2018).

125. As part of the platforms for coordinating information generation and climate variability and change analysis, SGCCC is the agency in charge of reviewing and generating scientific information and sharing it with political decision makers with regard to the main components of climate change, which are: climate science, adaptation and vulnerability, GHG mitigation and inventories. It also supports interagency coordination and integration of scientific aspects into the operational framework of the National Climate Change Council. The SGCCC is made up of the Association for Social Research and Studies (ASIES), the Latin American School of Social Sciences (FLACSO, the National Seismology, Volcanology, Meteorology and Hydrology Institute (INSIVUMEH), the Private Institute for Climate Change Research (ICC), the Ministry of the Environment and Natural Resources (MARN), Universidad del Valle de Guatemala University (UVG), San Carlos University of Guatemala (USAC), Galileo University (UG), Mariano Gálvez University (UMG) and Rafael Landívar University (URL) (Guatemalan Climate System of Climate Change Sciences).

126. On the other hand, according to a diagnosis of the status of climate change information management in Guatemala (Bouroncle, Medellín & Winograd, 2018), there are more than fourteen systems in the country, including platforms and geoportals, for dissemination of climate change MRV information, managed by different institutions, with different objectives, backgrounds and responsibilities in informing, monitoring, verification and decision making. This has led to many uncoordinated initiatives and projects and a proliferation of these information systems, which might also lead to duplication of efforts

and poor use of human, technological and financial resources. At the same time, many of these initiatives cease to be utilized at the short term, due to the high cost of maintaining them, the absence of financial and human capacities for updating them and changes in political and institutional priorities. Furthermore, none of these initiatives provides information in an appropriate language, format and time to small farmers to be able to react as speedily as climate change requires.

127. Given the number of initiatives in the country that develop and disseminate information, it is important that there is coordination among institutions and/or platforms, as well as interactions among them for better use of each of their capacities and functionalities, optimizing resources, avoiding duplication of efforts and providing greater added value to all the initiatives and information developed. In view of these limitations, attention should be focused on the use of national financial resources, definition of roles to prevent duplications, improving the efficiency for the procurement, adoption and processing of information (including consultancies), sound use of local human resources such as technicians of Environmental Management Units (UGAs) and staff training based on the knowledge and experience generated by the institutions themselves (Bouroncle, Medellín & Winograd, 2018). As well as enhancing the existing initiatives to ensure that information exits the scientific sphere and reaches small farmers who need it in the field to support the resilience of their crops and livelihoods.

SECTION C. Context

128. This section was designed to offer a general description of climate issues in Guatemala and in the project areas. Its structure comprises five sections: (1) Introduction; (2) Historical climate trends in Guatemala; (3) climate projections; (4) Temperature, precipitation, bioclimatic variables, and aridity projections; and (5) climate impacts and vulnerability. These are described below.

129. It is worth mentioning that this is a general description, the specific problems that will be addressed by the project are discussed in section C.1 (The problem to be addressed).

C.1. Introduction

130. One of the main economic activities generating foreign exchange and sustaining the livelihood of millions in Guatemala is agriculture, which depends greatly on the availability of water resources from precipitation (Pons, Taylor, Griffin, Castellanos and Anchukaitis, 2017). Guatemala is listed as one of the most vulnerable countries to the effects of climate variability and change (Eckstein, Künzel and Schäfer, 2018). This situation is reflected in the high human and economic costs that extreme meteorological events have had in the country (INSIVUMEH, 2002; CEPAL, 2005; EMDAT, 2017) and the limited resilience of affected communities to face these challenges. Recently, the drought conditions associated with El Niño / Southern Oscillation (ENSO) in Central America reduced the production of basic grains (especially corn and beans) in agricultural communities dependent on precipitation for crop irrigation (UNOCHA, 2016; Network [FEWS NET], 2016). Although interannual climate variability (as determined by ENSO events) represents a major challenge for farmers, the climate change scenarios for Guatemala suggest impending challenges in the medium and long term for agricultural productivity and other economically important sectors such as hydroelectric production. These climate scenarios consistently suggest an increase in air temperature with repercussions on evapotranspiration processes(Nastos et al., 2015; Imbach et al., 2018). In the same way, although with greater uncertainty, intensification of the water cycle with reduced precipitation in some regions and increased precipitation in others is expected for the region (Neelin, Münnich, Su, Meyerson and Holloway, 2006; Karmalkar et al., 2011; Imbach et al., 2012; Magrin, et al., 2014; Depsky & Pons 2020).

131. On the other hand, the Second Communication on Climate Change in Guatemala suggests that the average temperature has already suffered an increase throughout the national territory compared to the climatological baseline of the period 1970-2000 (Ministry of Environment and Natural Resources [MARN], 2015; INSIVUMEH,2018). The increase between 2.2% and 10.3% has been more evident in mountainous regions such as the upper part of Quetzaltenango and Huehuetenango with up to 1.4 ° C increase (MARN 2015, INSIVUMEH 2018). However, the historical increasing trends on mean temperature estimaded using CRU TS v 4.01 are widely evident in the projects' intervention areas (Mayan Lowlands and Dry

Corridor areas) and are consistent with the instrumental data analysis reported by MARN 2015). We further show the historical (1960-1990) climatology against the current (1990-2016) climatology for the two geographic areas of influence from the project using the University of Eas Anglia -Climate Research Unit (CRU) data set. This dataset allowed a 30-year period comparison of both the mean temperature and the monthly accumulated precipitation. CRU reanalysis data incorporates weather stations data and has been used for previous climatological studies in Guatemala (e.g. Anchukaitis et al., 2015) and elsewhere in the world (e.g. Cook et al., 2012;Touchan et al., 2017) including studies on climate variability (e.g. Wang et al.,2013) . The CRU selected observation-based gridded areas used here in the climate analysis incorporate 8 weather stations each, for a total of 16 stations which is included in the TS v 401. Version of CRU used in the assessment, which allows for the trend analysis to be carried out (Harris et al., 2020).

132. The projections from General Circulation Models (GCMs) also suggest an increase in temperature towards the 2030s of up to 2.2 ° C (Imbach et al., 2012;2018) under the RCP4.5 scenario for all the seasons in Guatemala (DJF, MAM, JJA and SON). This potential increase in temperature added to a possible reduction of precipitation (Karmalkar et al., 2011), can have serious negative consequences on agriculture and forest cover in the country due to an increase in aridity and its effects on the phenology and water requirements of plants (Lyra et al., 2016). Due to the dependence on rainfed agriculture in Guatemala, potential increases in aridity in agricultural regions of the country where rain-fed dependent staple crops represent the livelihood of millions of famers could have severe impacts on the production of this sector reaching reductions of up to 57% in certain crops (Hannah et al., 2017; CEPAL 2018).

133. In this study, the average monthly temperature and average annual precipitation have been projected towards the end of the century to calculate aridity at the national level for the years 2030, 2050 and 2070. The present analysis suggests significant changes in the semi-arid regions of the country where the dry corridor would present areas that go from being semi-arid to being arid (a category that does not yet exist for the country) towards the decades of 2050 and 2070. However, the analysis also suggests that traditionally humid regions located in the center-north of the country, such as the department of Petén and Alta Verapaz and regions of the southern coast, could also see important changes in the water regime. Such changes could involve potentially serious consequences such as reduced agricultural productivity and reduction of forest cover for a country that depends on these sectors. These possible scenarios suggest that the food security of Guatemalans, especially in the most socially vulnerable areas, could be compromised. This is because in Guatemala both the quantity and the temporal distribution of the rains they are critical to subsistence farming systems.

Climate in Guatemala

134. Guatemala experiences a bimodal seasonal rainfall climate, with a rainy boreal summer season and a dry boreal winter season. The country receives strong influence from the

Intertropical Convergence Zone (ITCZ) during the boreal summer generating precipitation. The rainy season, dominated by vetting storms, generally begins in April or early May with two peak peaks near June and September and a period of decreased rainfall called the canicula or midsummer drought (MSD) between the months of July and August that can last from 5 to 15 days or even more. A recent study by Anderson et al., 2019 suggest that the MSD has experienced an increment in duration and a trend towards a dryer period during the June-July-August seasons, one that is critical for determining agricultural calendars across Guatemala.

135. The rainy season lasts until October in most of the country, but persists until March in the northern part of the country due to the influence of cold fronts. The dry season runs from November through April. In addition to these processes, the topographic complexity of the Guatemalan mountains and volcanoes causes significant spatial heterogeneity in average climatic conditions. Annual rainfall in parts of the Northwest Lowlands and the South Coast exceeds 4,000 mm, while in the so-called Dry Corridor the historical annual rainfall is less than 800 mm (INSIVUMEH 2018). These complex conditions are related to various climatic mechanisms and their interaction with the country's topography (Karmalkar et al., 2011).

Climate data and information availability at the country level

Climatic data in Guatemala are scarce at both temporal and spatial scales (Anchukaitis et al., 2013; Pons et al., 2017). Unfortunately, the availability of official weather stations is decreasing in the Central America region (Giannini et al., 2001), which limits the understanding of the effect of the various climatic mechanisms previously discussed on the territory (Hannah et al., 2017; Pons et al., 2017). In addition to the limitations of the spatial and temporal scale of official instrumental data, there are interactions between several climatic mechanisms that are just beginning to studied and understood (Li et al., 2011; Hannah et al., 2017). In this study, we are presenting a decomposition of the climatic signal on historical precipitation for Guatemala which allows to identify the different components of the precipitation regime at decadal and interannual scales. This decomposition suggests that interannual mechanisms like ENSO still account for up to 85 percent of the variance on precipitation

El Niño/Southern Oscillation effects on temperature and precipitation in Guatemala

136. The influence of El Niño-Southern Oscillation on Guatemala's climate has an important influence on the territory's precipitation and temperature (Steinhoff et al., 2015). On an interannual scale, this is the most determining mechanism of climate in Guatemala. It has been attributed around 25% of the variability in the temperature and up to 85% on precipitation scales (figure 2) (Díaz et al., 2001). To demonstrate this, we used the tool provided by Green et al., 2011. In order to demonstrate how much of the historical variance in precipitation in Guatemala can be explained by different climate signals, we decomposed the historical precipitation timeseries for the country. We highlight the trend (non-significant at 0.05), the decadal component of the signal, and the interannual factor (attributed mostly to ENSO events). The Map in figure 13 shows that up to 85 % of the historical variance in the

precipitation record can be attributed to interannual processes like ENSO. Current research suggests that the different phases of ENSO will remain the most influential climate mechanism for the region. When the ocean waters heat up in region 3.4 of the Pacific Ocean, the effect of this system can affect precipitation in regions as far away as the highlands of Huehuetenango (Anchukaitis et al., 2014). However, its non-stationary behavior and the little-known interactions of this system with other climate mechanisms in the region still limit the ability to predict the next event and its magnitude in the territory of Guatemala (Cid-Serrano et al., 2015).In fact, recent studies on the climate mechanisms modulating future changes in the sea surface temperature (SST) in ENSO regions suggest that models tend to disagree on the interaction between the eastern Pacific and the tropical Atlantic interactions. The models from the NMME disagree about the magnitude and the sign of future SST in response to atmospheric forcing (Bhattacharya & Coats 2020). The uncertainties associated to the future behavior of ENSO and its associated impacts remain high. There is no conclusive evidence in how ENSO properties may change in the future (Vecchi and Wittenberg 2010). Atmospheric forcing prescribed in GCMs has failed to describe observed ENSO conditions. This is mostly due to a short observational record and the complexities between various ocean-atmosphere processes (Ballenger et al., 2014)

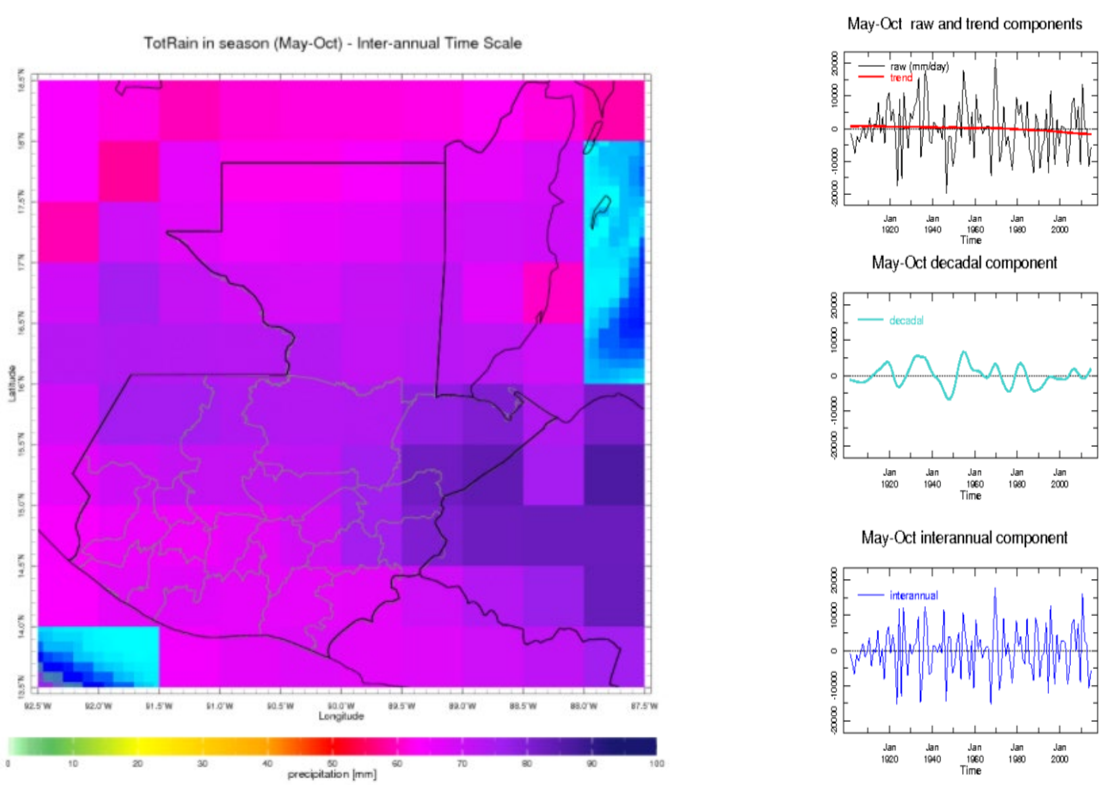


Figure 13. Decomposition by time scale of twentieth-century precipitation variations for Guatemala for the rainy season May to October. The upper right image shows the non-significant trend (0.05) for precipitaiton for the country.

C 2. Historical trends of the climate in Guatemala

137. Sub-recording of meteorological data at adequate time and spatial scales complicates the analysis of meteorological and climatological information in the territory as described in the previous sections. Despite these limitations, the National Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH), maintains a record of temperature and precipitation (among others metrics) included in a set of reanalysis products like CHIRPS or CRU datasets. To assess changes in historical mean temperature and monthly accumulated precipitation in the intervention areas of the project (Mayan Lowlands and Dry Corridor) we decided to work with the CRU temperature and precipitation dataset for the 1960-1990 and 1990-2016 climatologies for temperature and precipitation.

Temperature

138. The following decomposition of the climate signal[11] in Guatemala has been performed to show the percentage of the historical variation in the mean temperature that can be explained by the trend in temperature, decadal climate mechanisms and interannual processes like ENSO (figure 14). This map shows the percentage of the historical variation of temperature that can be explained by the trend (red line in first chart). This suggest that around 50 % of the historical changes in the mean temperature can be explained by the increase in temperature. The other decadal (green) and interannual (blue) signals explain 5% and 47% of the observed historical variance in temperature for the 20th century.

139. In order to calculate this, we used the tool provided by Green et al., 2011, which uses the global temperature calculations to detrend fluctuations in the Earth's climate which has many sources, including "natural" variability — intrinsic variations that are not associated with anthropogenically-induced climate change. The tool uses a model ensemble of 23 general circulation models (GCMs). These models, which constitute a comprehensive representation of our current understanding of the mechanisms of climate variability and change, underlie much of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007). The multimodel mean signal is further processed, by lowpass filtering (Green et al., 2011).

140. To demonstrate historical trends in temperature in the territories where the project is to be implemented, we computed an assessment of historical mean temperature anomalies for the Mayan Lowlands and Dry Corridor Area for the 1960-1990 and 1990-2016 climatologies. The upward trend suggests increasing mean temperature anomalies in the two regions with an average annual temperature increase of 0.6 C since 1971.

[11] Climate signals is a term used to express long-term trends and projections related to climate change. Examples of observed long-term trends linked to climate change include rising sea levels, increasing extreme precipitation, and warming sea surface temperatures.

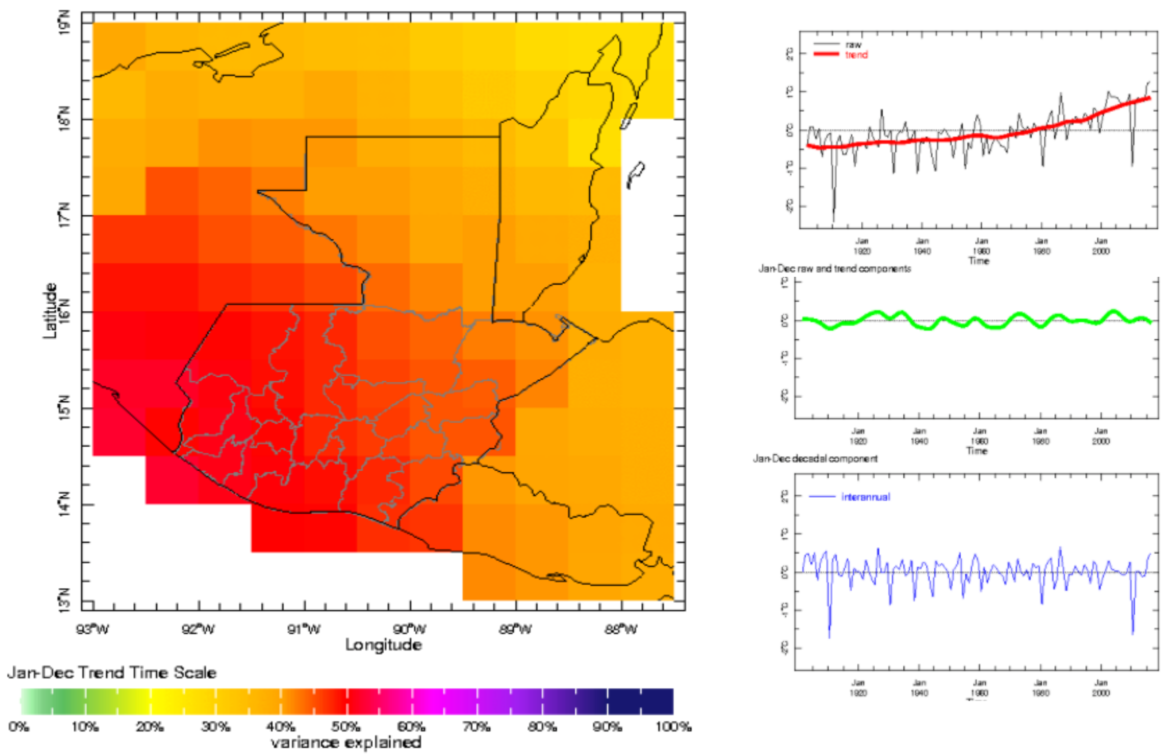


Figure 14. Historical 20th century time series decomposition for temperature. The upper right image shows the statistically significant trend for temperature for the country (0.05).

141. The above analysis suggests that up to 50% of the variance in historical mean temperature experienced in Guatemala can be explained by the trend in the time series (upper right figure), which is attributed to anthropogenic energy forcing in the climate system generated by greenhouse gas emissions (Green et al.,2011). In the following figures, we show the historical mean temperature standardized anomalies for the 1960-1990 climatology (figure 15) and the 1990-2016 climatology (figure 16) the Dry Corridor area. Similarly, we show the same information for the Mayan Lowlands (figure 18 and 19). For both the Dry Corridor and Mayan Lowlands we also show the complete mean temperature standardized anomalies for the 1960-2016 period (figures 17 and 20) to put in context the increasing trend in the mean temperature in the two areas and to demonstrate the increase in extreme events associated to the standard deviations observed in temperature when compared to the long-term average. The information suggests that the study regions have already experienced and increase in mean temperature standardized anomalies which starting in the early 70's. Although the official dataset used by Guatemala's government on their official assessment of historical climate trends had less years available for the study, the information provided here matches the findings from the official data from Guatemala's government provided on the Second Climate Change Communication and based solely on the official available weather stations (MANR 2015).

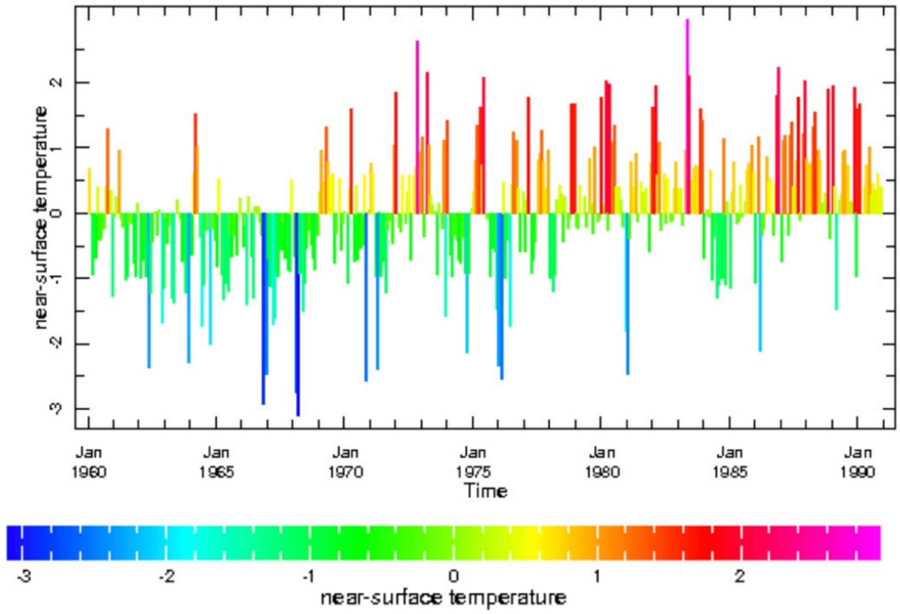


Figure 15. Mean temperature standardized anomalies for the 1960-1990 climatology for the Dry Corridor region (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

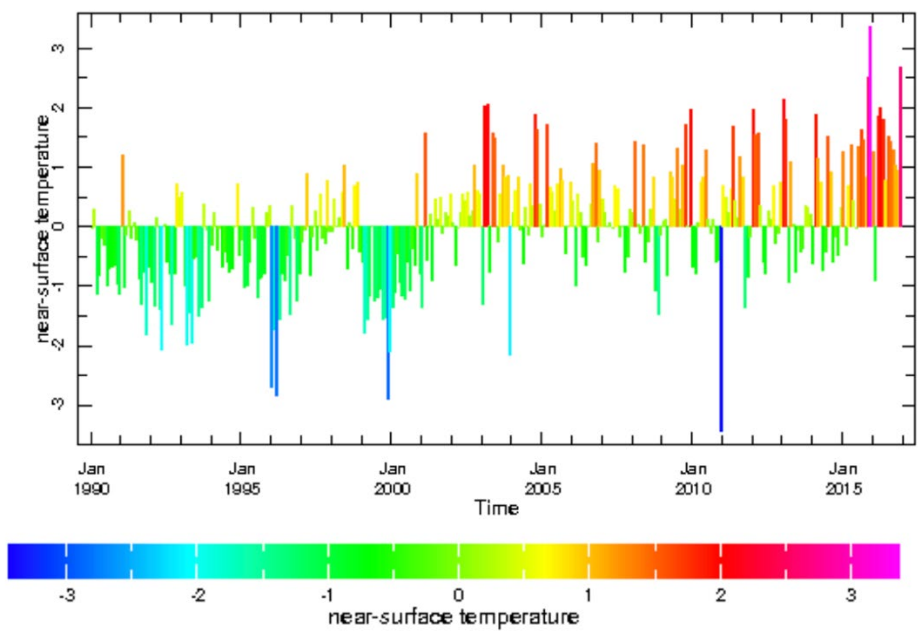


Figure 16. Mean temperature standardized anomalies for the 1990-2016 climatology for the Dry Corridor region (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

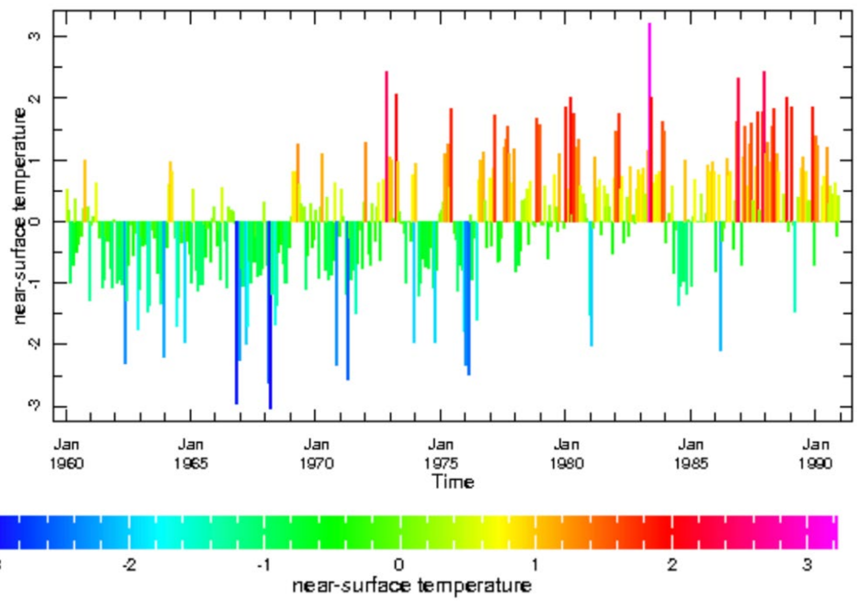


Figure 17. Mean temperature standardized anomalies for the 1960-2016 climatology for the Dry Corridor region. (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

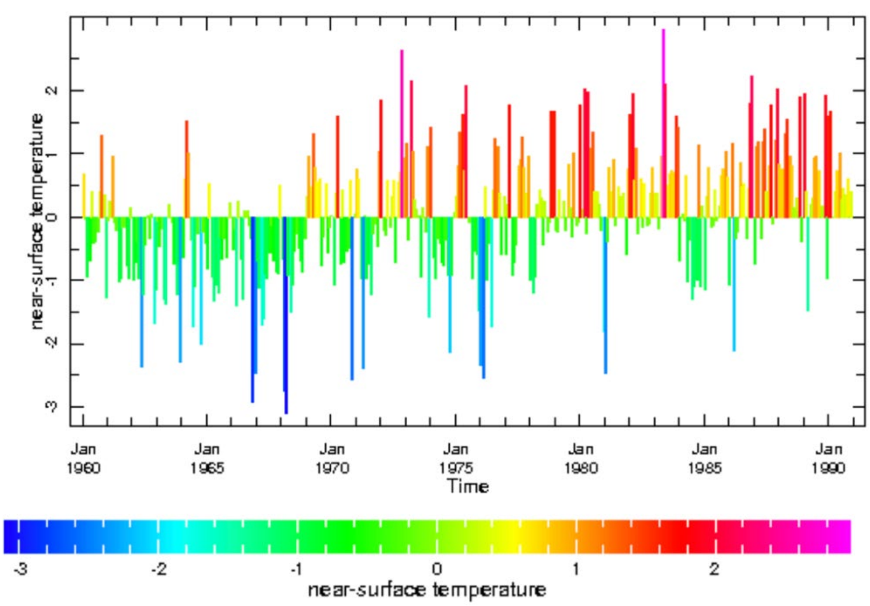


Figure 18. Mean temperature standardized anomalies for the 1960-1990 climatology for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

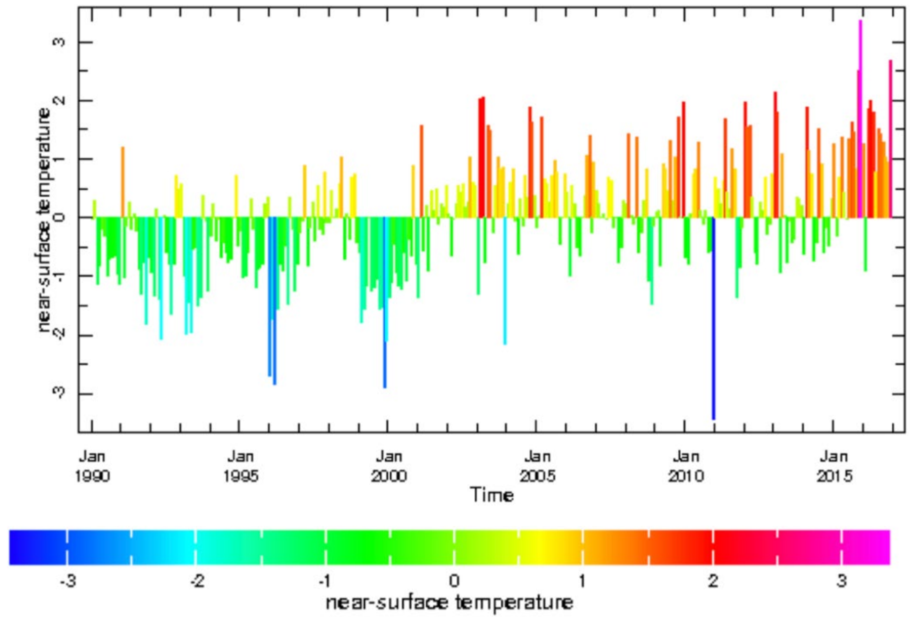


Figure 19. Mean temperature standardized anomalies for the 1990-2016 climatology for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

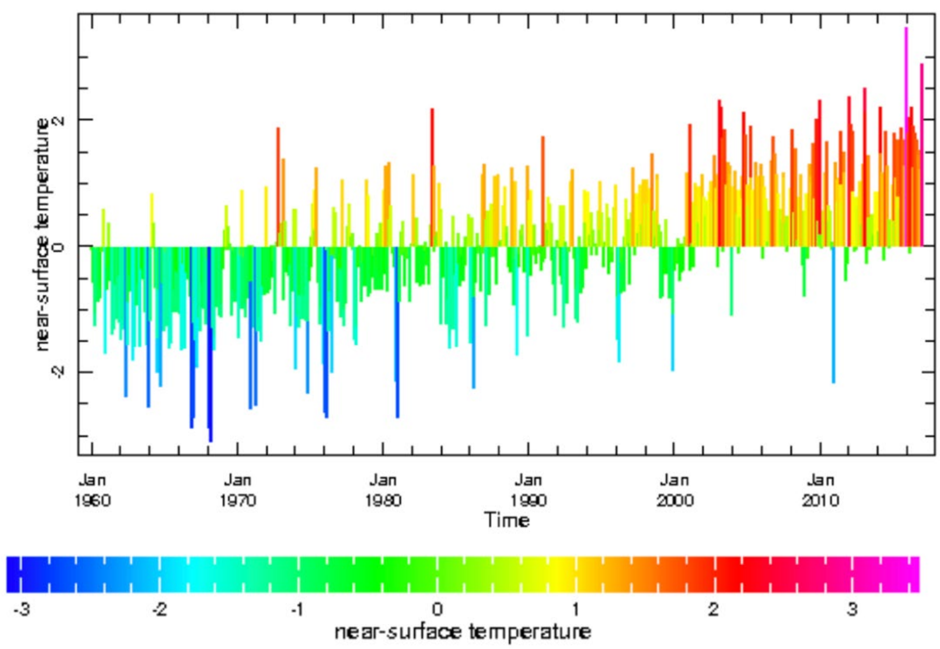


Figure 20. Mean temperature standardized anomalies for the 1960-2016 period for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations). The analysis suggests an increment in the extreme anomalies (measured by the standar deviaton from the long term mean)

142. In order to show the intra-annual distribution of the changes in mean temperature we also provide the monthly climatology for the 1960-1990 period (figure 21) as well as the monthly climatology for the 1990-2016 period (figure 22) and the overall differences (figure 23) for the Dry Corrido Area. In the same way, we estimated the monthly climatology for the 1960-1990 and 1990-2016 climatologies (figures 24 and 25) and the total differences between the mean temperature among the two periods (figure 26) for the Mayan Lowlands. We considered this assessment critical to the understanding of historical trends in mean temperature because the different climate regimes at seasonal timescales in Guatemala are intrinsically associated to agricultural practices that determine the sowing and harvesting periods. Understanding the mean temperature anomalies at a monthly scale between these two different periods in the areas of interest to the project, allows for a better understanding on how these experienced changes have historically affected the livelihoods of the agricultural communities in the regions. For instance, figures 21 and 22 might look similar in terms of the mean temperature for any particular month. However, figure 23 shows that aside from May and November, every other month has experienced an increase of at least 0.5 °C in the Dry Corridor area. The months of June and December have already exhibited an increase of more than 0.7°C, and January of more than 0.8 °C. Despite precipitation exhibiting a less clear trend in the historical record, these increases in mean temperature would naturally increase evapotranspiration with potential negative effects to agriculture. In this region of Guatemala, the temperature in June is critical for the development of the crops planted around May 15th. A decrease in soil moisture due to increased temperatures could negatively impact the development of the staple crops like Maize. The same is true for the Mayan Lowland region, where January and February temperatures have exceeded the 0.7°C anomaly during the same period (figures 24, 25 and 26).

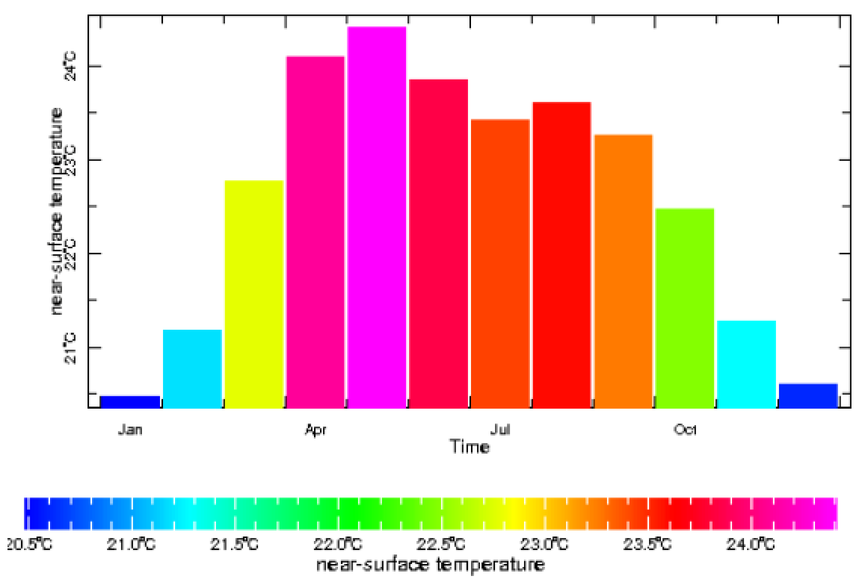


Figure 21. 1960-1990 Monthly mean temperature climatology for the Dry Corridor Intervention Area (14.5N,15.5N – 90.0W,89.0W)

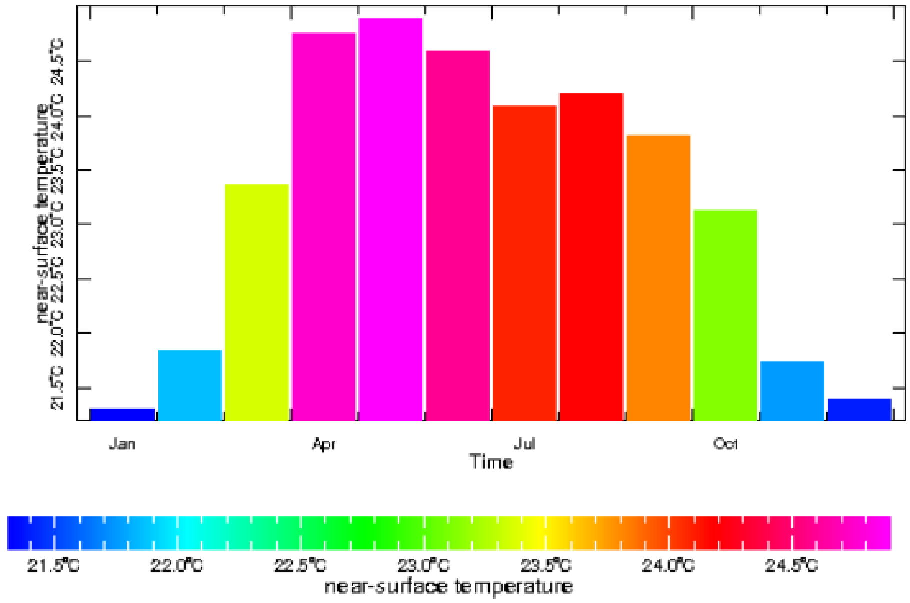


Figure 22. 1990-2016 Monthly mean temperature climatology for the Dry Corridor Intervention Area (14.5N,15.5N – 90.0W,89.0W)

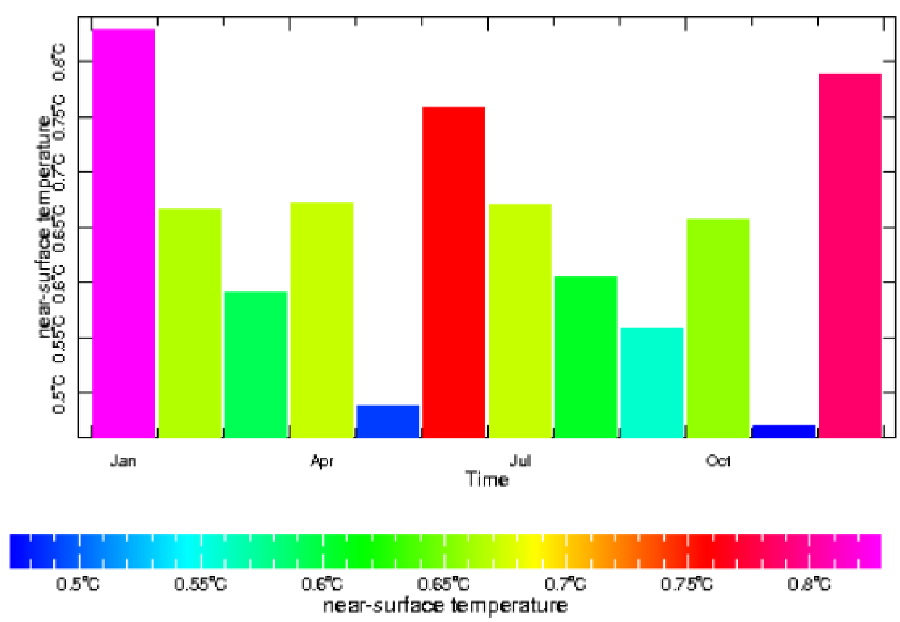


Figure 23. Difference between 1960-1990 and 1990-2016 Monthly temperature climatology for the Dry Corridor Intervention area (14.5N,15.5N – 91.0W,89.0W)

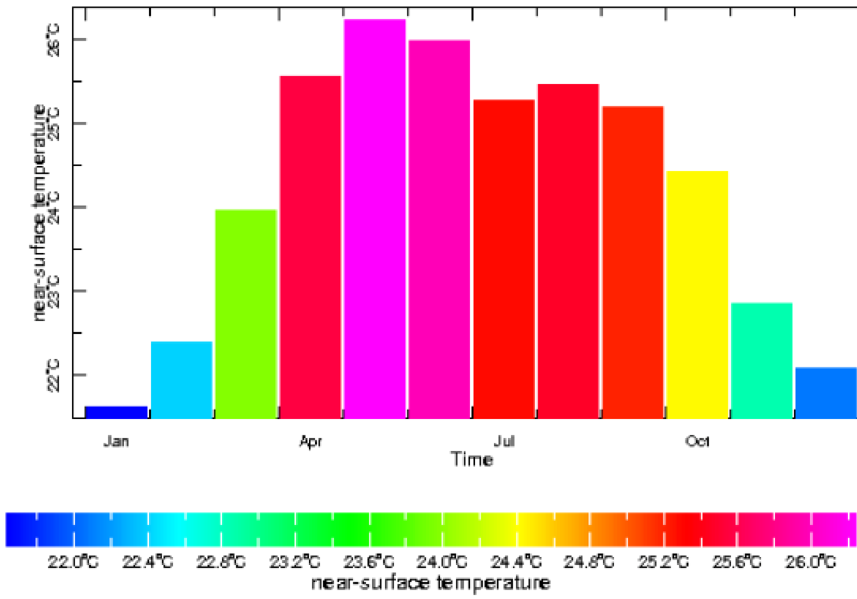


Figure 24. 1960-1990 Monthly mean temperature climatology for the Mayan Lowlands Intervention Area (17,5N,15.0N – 91.0W,89.0W)

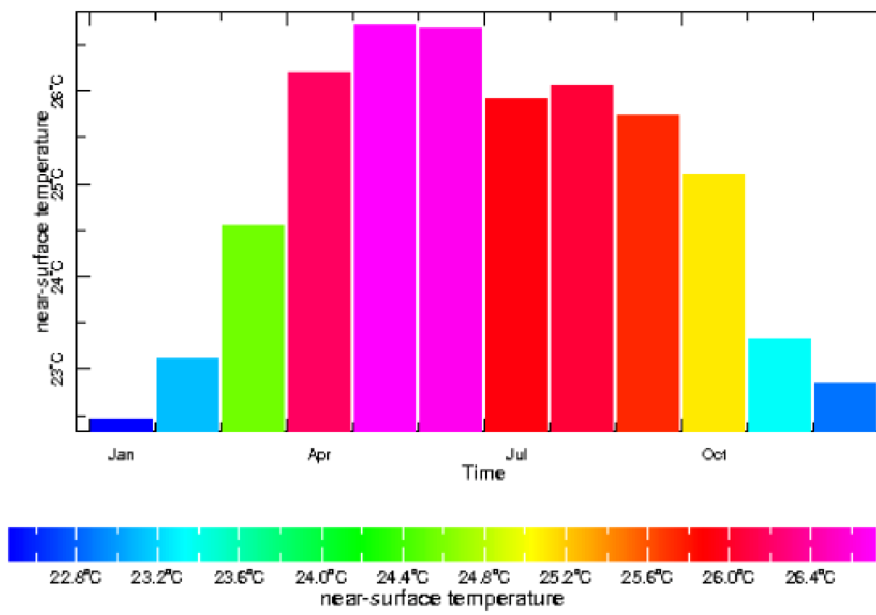


Figure 25. 1990-2016 Monthly mean temperature climatology for the Mayan Lowlands Intervention Area (17,5N,15.0N – 91.0W,89.0W)

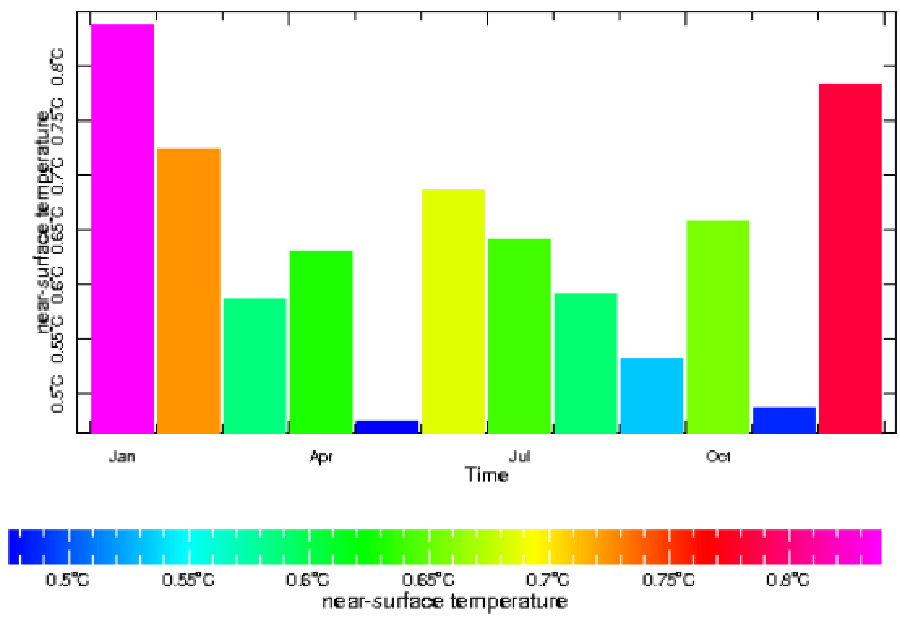


Figure 26. Difference between 1960-1990 and 1990-2016 Monthly temperature climatology for the Mayan Lowlands Intervention area (17,5N,15.0N – 91.0W,89.0W)

Precipitation

143. Similarly to the assessment of historical mean temperature, for precipitation we use the CRU dataset for the same 1960-1990 and 1990-2016 climatologies. When it comes to precipitation, the overall historical patterns at a monthly scale show a less clear trend for both the Dry Corridor and the Mayan lowlands regions (figures 27 to 32). However, the monthly climatology estimated for each of the intervention areas shows some overall variation in particularly critical seasons for agriculture (figures 33-36). For instance, despite a non-significant upward trend in precipitation for the country, the monthly assessment allows to visualize that certain months have experienced a decrease in the total precipitation for that month. For instance, August precipitation or August has seen an overall reduction, probably associated to the drying trend of the Midsummer Drought (Anderson et al., 2019) as seen in figures 33 and 36.

144. In the last 20 years, the occurrence and intensity of extreme weather events has increased, especially droughts, extreme temperature and floods.[12] Between 1988 – 1999 altogether 17 extreme events occurred, while in the period 2000 – 2017 altogether 53 events occurred. The 2014 drought caused the yield loss of 80% for maize and 63% for beans, which led to an economic loss of USD 61 million for the country. The drought affected 40% (12,090 ha) of the project area causing partial or total crop losses of 58,636 subsistence families, resulting in USD

[12] EM-DAT 2017. The international Disaster database. URL: https://www.emdat.be [Accessed December 2018]

11.6 millions of economic impact.[13] The high temperatures and rainfall variation in September in 2012, led to a severe outbreak of coffee rust which led to the loss of 15% of the coffee production.[14]

145. The official MARN analysis (2015) suggests that the most pronounced trends are seen in the dry corridor, which includes the departments of Baja Verapaz, Chiquimula and Zacapa, where this project will intervene. The same analysis shows that the average annual precipitation has increased significantly throughout the country when comparing the baseline (1971 – 2000) with the current period (2001 – 2014), regions where the average annual precipitation has experienced a lower relative increase are the climate regions of the Caribbean and the Northern Transversal Strip with 2.3% and 9.6%, respectively. However, in general, projections indicate that precipitation will drop throughout the country.

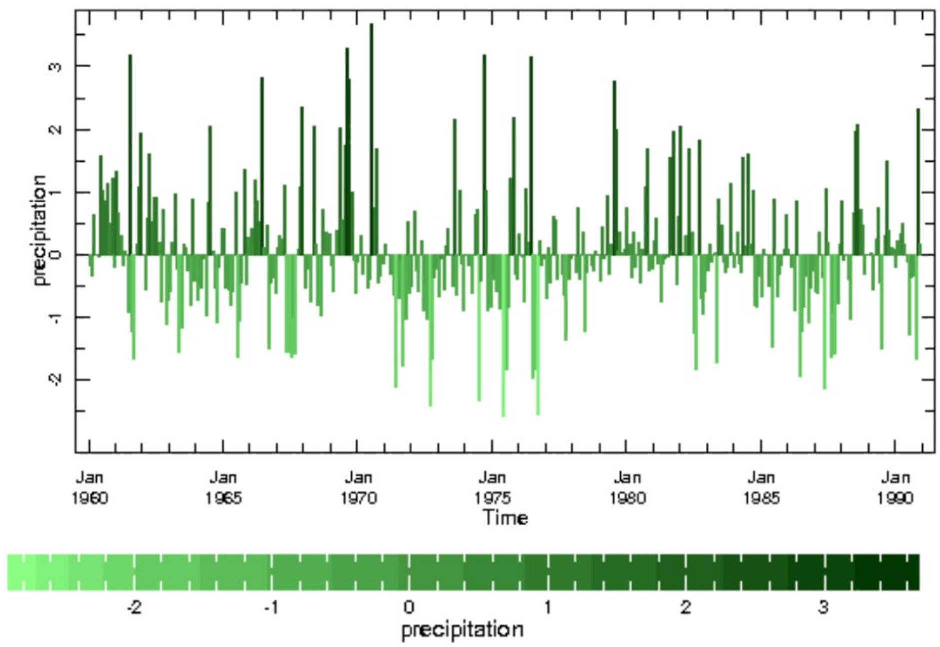


Figure 27. Precipitation standardized anomalies for the 1960-1990 climatology for the Dry Corridor region (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations).

[13] SESAN, 2014. *Informe de daños ocasionados por la canícula prolongada 2014.* Guatemala: SESAN.

[14] Cerda et al., 2014. Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. Agroforestry Systems, 88(6), 957-981. doi:10.1007/s10457-014-9691-8

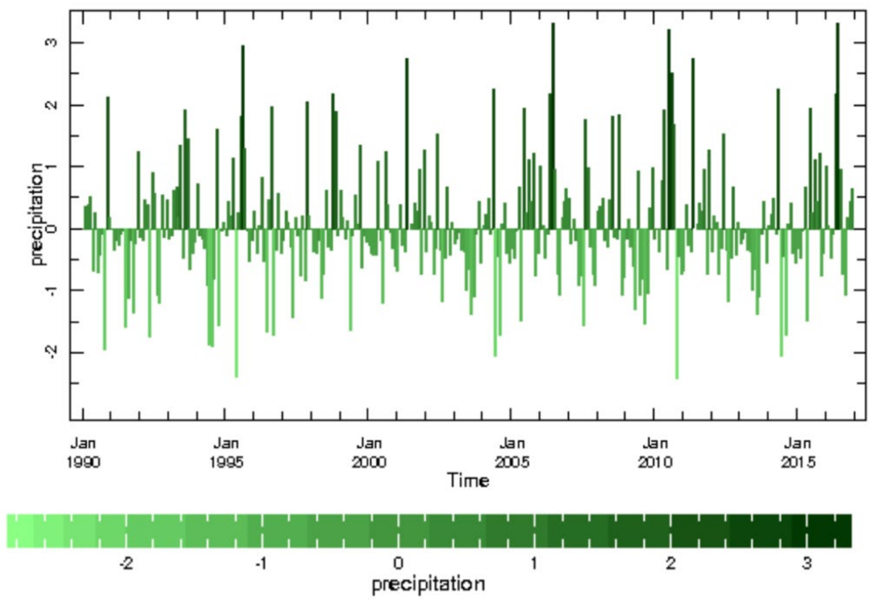


Figure 28. Precipitation standardized anomalies for the 1990-2016 climatology for the Dry Corridor region (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations).

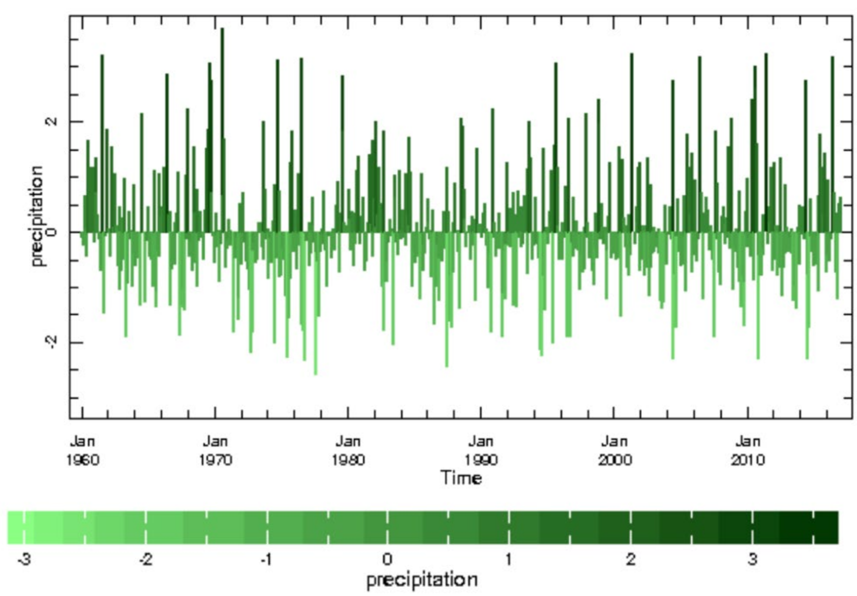


Figure 29. Precipitationstandardized anomalies for the 1960-2016 climatology for the Dry Corridor region (14.5N,15.5N – 90.0W,89.0W) using CRU (8 weather stations).

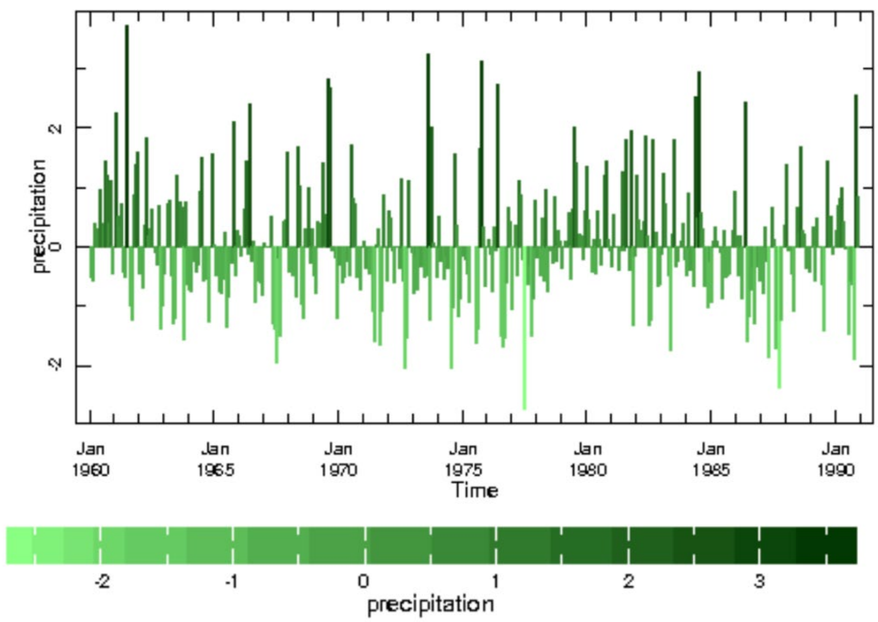


Figure 30. Precipitation standardized anomalies for the 1960-1990 climatology for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations).

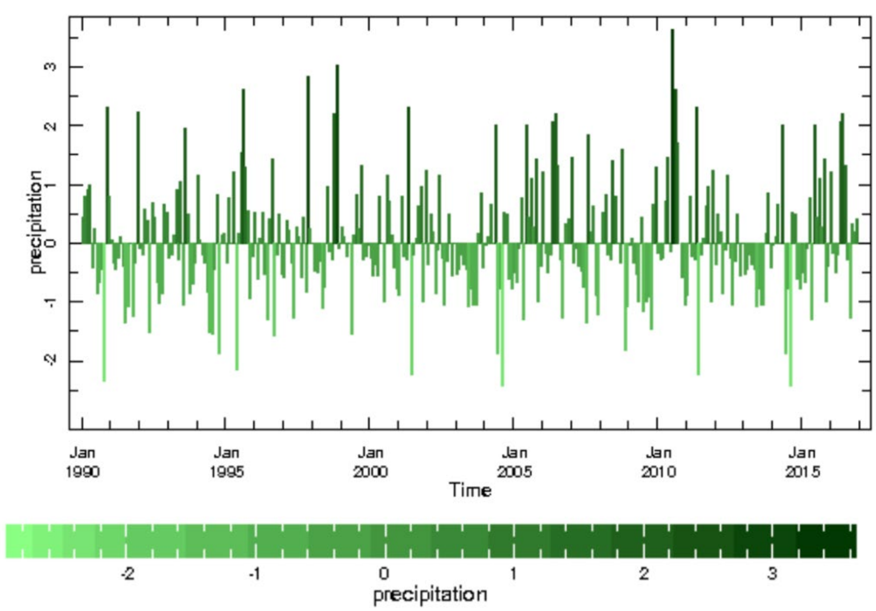


Figure 31. Precipitationstandardized anomalies for the 1990-2016 climatology for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations).

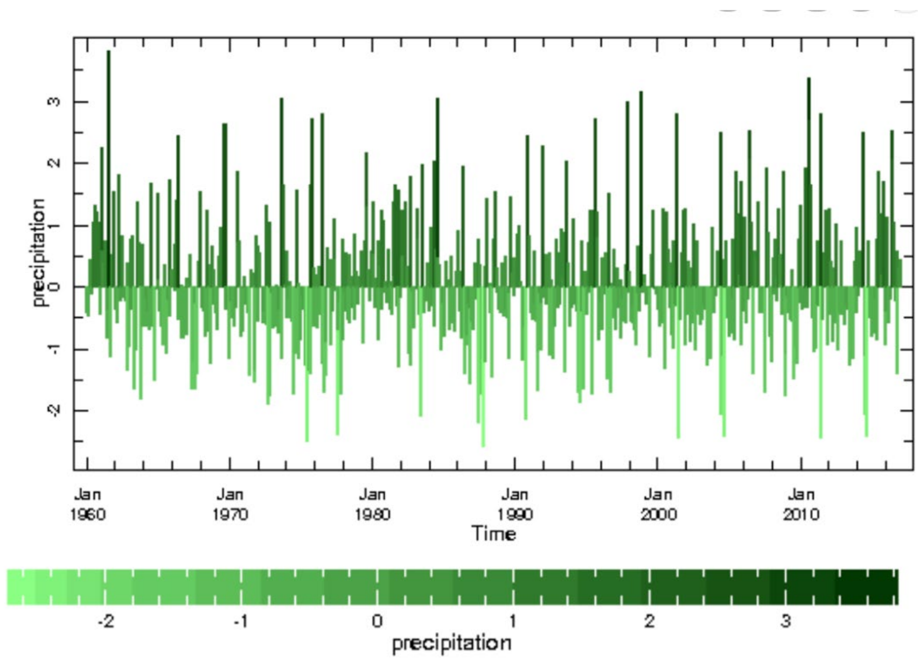


Figure 32. Precipitation standardized anomalies for the 1960-2016 period for the Mayan Lowlands region (17,5N,15.0N – 91.0W,89.0W) using CRU (8 weather stations).

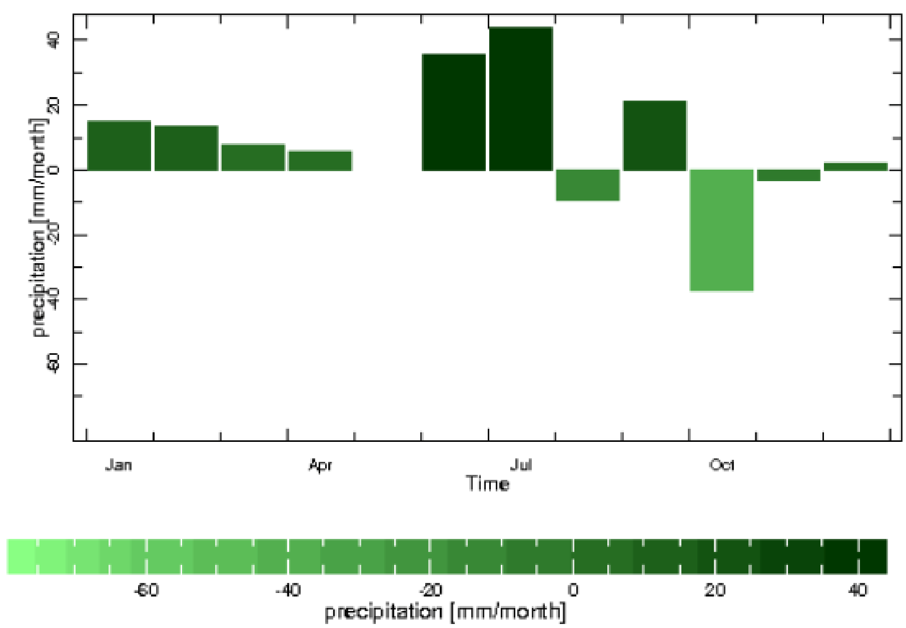


Figure 33. Difference between 1960-1990 and 1990-2016 Monthly precipitation climatology for the Dry Corridor Intervention Area (14.5N,15.5N – 90.0W,89.0W)

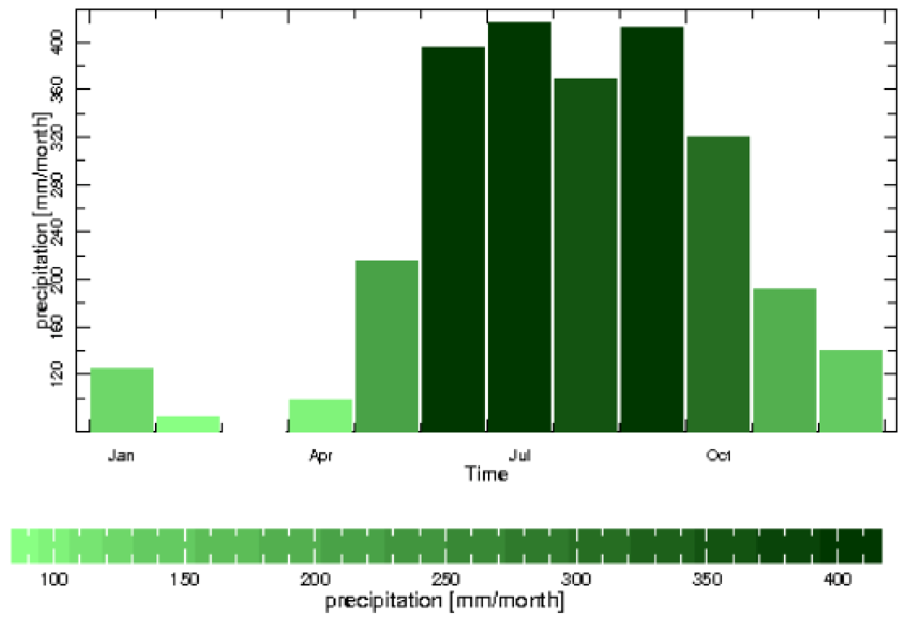


Figure 34. 1960-1990 Monthly climatology for the Mayan Lowlands Intervention Area (14.5N,17.5N – 91.0W,89.0W)

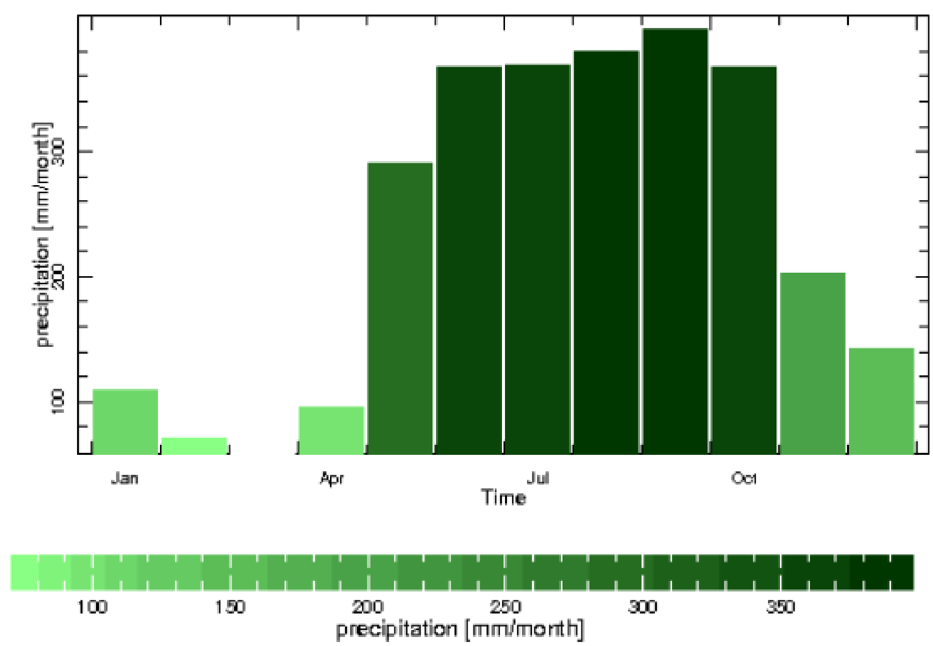


Figure 35. 1990-2016 Monthly climatology for the Mayan Lowlands Intervention Area (1455N,17.5N – 91.0W,89.0W)

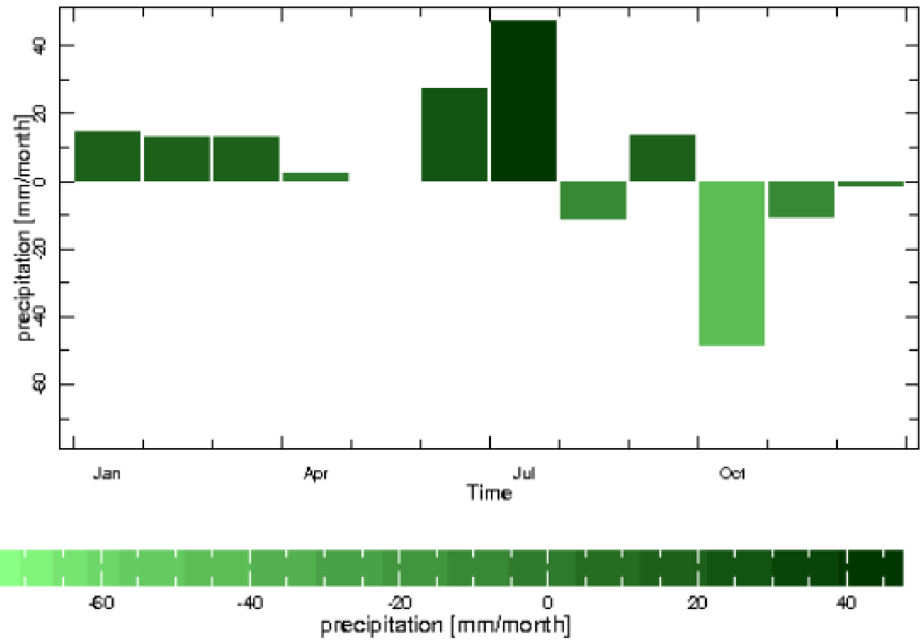


Figure 36. Difference between 1960-1990 and 1990-2016 Monthly climatology for the Mayan Lowlands Intervention area (14.5N,17.5N – 91.0W,89.0W)

C.2. Climate projections

146. Oglesby and Rowe (2014), present a summary on preliminary results of the different IPCC AR5 global and regional climatic scenarios in Guatemala.

147. In the IPCC Special Report (2007) on Emission Scenarios, four evolutionary lines (SRES: A1, A2, B1 and B2) were prepared, where the determining forces in GHG emissions are described, as well as their evolution during the 21st century, both globally and from different regions. Each evolutionary line represents a divergent level of development in demographic, social, economic and technological questions. Evolutionary lines A present a pessimistic scenario where GHG emissions are maintained or increase, while evolutionary lines B represent an optimistic scenario in which GHG emissions were reduced worldwide[15.]

Emissions scenarios

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income.

[15] Intergovernmental panel on climate Change (IPCC). 2000. IPCC special report Emissions Scenario. P.4. Available at https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf)

• The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.
• The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid- century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
• The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Source: Intergovernmental panel on climate Change (IPCC). 2000. IPCC special report Emissions Scenario. P.4. Available at https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf)

148. In the Second National Communication of Guatemala on Climate Change was published (2015), the scenarios proposed by the IPCC's fourth report on climate change were used. The projections generated by the National Institute of Seismology, Volcanology, Meteorology and Hydrology of Guatemala (INSIVUMEH) for the years 2030, 2050, 2070 and 2090 were used from the outputs of the general circulation model HADAM3P under SRES A2 and B1 (Figure 14 and Figure 15)[16].

149. Projections show overall decrease of rainfall starting from 2030. It is expected that by 2050, rainfall will decrease between 9.5% and 12.4%, and 18.4% and 28.9% by 2070[17]. The same

[16] Government of Guatemala. Ministry of Environment and Natural Resources/ Ministerio de Ambiente y Recursos Naturales (MARN). 2015. Second National Communication on Climate Change */Segunda comunicación nacional sobre cambio climático Guatemala.* Guatemala. *in* Rivera, P. F., Bardales Espinoza, W. A., & Ochoa, W. (2019). Escenarios futuros de cambio climático para Guatemala. En E. J. Castellanos, A. Paiz-Estévez, J. Escribá, M. Rosales-Alconero, & A. Santizo (Eds.), *Primer reporte de evaluación del conocimiento sobre cambio climático en Guatemala.* Guatemala: Editorial Universitaria UVG.

[17] Pons, Brincker, & Castellanos, 2018. Asegurando la resiliencia ante el CC en los paisajes Mayas de Petén, Verapaces y el Corredor Seco. Producto 1. Documento de análisis de los efectos del Cambio climático a nivel nacional y local. Documento de consultoría. Guatemala.

behavior is observed in both projections, but in scenario A2 the changes are more abrupt compared to scenario B1 (MARN, 2015)[18].

150. Temperature projections show an increasing trend in both scenarios (Scenario A2 presents a greater change compared to scenario B1). Trends show temperature changes between 1.1 and 1.2 ° C for the 2020s, between 1.3 and 1.5 ° C for the 2030s, between 2 and 2.7 ° C for the 2050s, between 2.5 and 4.1 ° C for the 2070s, and between 3.3 and 5.4 ° C for the 2090s[19].

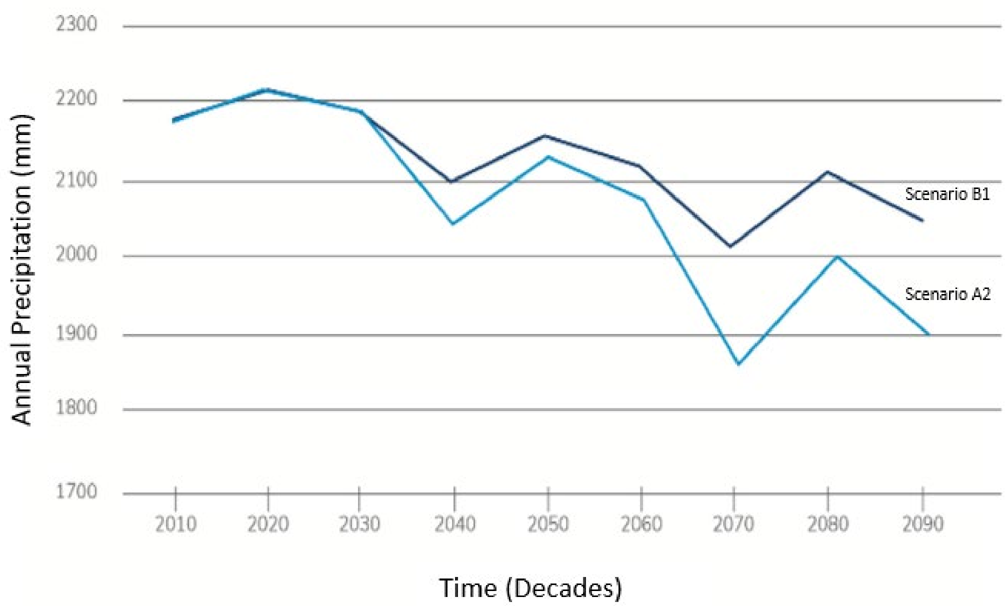


Figure 37. Annual rainfall trend for scenarios B1 and A2 by decade in Guatemala
Annual precipitation projections for scenarios B1 and A2 by decade in Guatemala. Scenario B1 considers the generation of greenhouse gas emissions to be stable, while scenario A2 considers an increase in emissions. Adapted from MARN (2015)[20].

---

[18] Government of Guatemala. Ministry of Environment and Natural Resources/ Ministerio de Ambiente y Recursos Naturales (MARN). 2015. Second National Communication on Climate Change */Segunda comunicación nacional sobre cambio climático Guatemala.* Guatemala. Available at: https://unfccc.int/sites/default/files/resource/gtmnc2.pdf

[19] Rivera, P. F., Bardales Espinoza, W. A., & Ochoa, W. (2019). Escenarios futuros de cambio climático para Guatemala. En E. J. Castellanos, A. Paiz-Estévez, J. Escribá, M. Rosales-Alconero, & A. Santizo (Eds.), Primer reporte de evaluación del conocimiento sobre cambio climático en Guatemala. Guatemala: Editorial Universitaria UVG

[20] Rivera, P. F., Bardales Espinoza, W. A., & Ochoa, W. (2019). Escenarios futuros de cambio climático para Guatemala. En E. J. Castellanos, A. Paiz-Estévez, J. Escribá, M. Rosales-Alconero, & A. Santizo (Eds.), *Primer reporte de evaluación del conocimiento sobre cambio climático en Guatemala.* Guatemala: Editorial Universitaria UVG. Adapted from: Government of Guatemala. Ministry of Environment and Natural Resources/ Ministerio de Ambiente y Recursos Naturales (MARN). 2015. Second National Communication on Climate Change */Segunda comunicación nacional sobre cambio climático Guatemala.* Guatemala. Available at: https://unfccc.int/sites/default/files/resource/gtmnc2.pdf

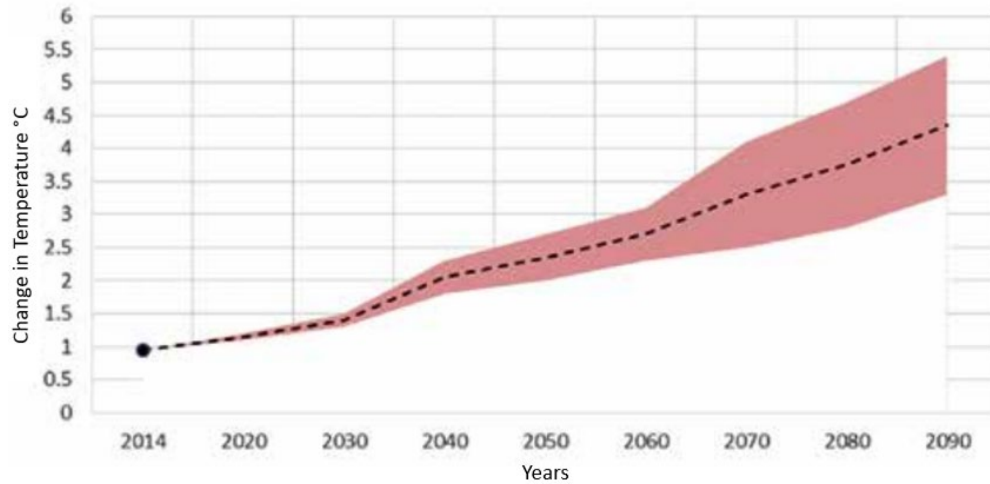


Figure 38. Temperature projections for scenarios B1 and A2 by decade in Guatemala.

Temperature projections for scenarios B1 and A2 by decade in Guatemala. Scenario B1 considers that the generation of greenhouse gas emissions remains stable, while scenario A2 considers an increase in emissions (MARN (2015))[21].

151. Among the most recent climate change scenarios generated for Guatemala, are the scenarios carried out in 2015 by the Ministry of Environment and Natural Resources (MARN) and the University of Nebraska of the United States (based on the fifth report of the Intergovernmental Group of Experts on Climate Change- IPCC AR5 report)[22]. Factors such as population, economic development, the use of environmentally friendly technologies, the type development (global) and environmental policy decisions were used to estimate greenhouse gas emissions and after, the scale of these was reduced from global to national projections and, future precipitation and temperature maps were generated for Guatemala. The spatial resolution scale was reduced to four kilometers and the time scale used was in months. The most pessimistic scenario on GHG emissions generated for the IPCC AR5 report was the one used (global RCP8.5 emissions scenario).

152. Based on the results of the aforementioned studies, increases in temperature of up to 3.3 ° C are projected for the year 2050 and up to 6 °C for the end of the century, starting from the common baseline from 1980 to 2010. Most of the studies estimate a 30% decrease in annual precipitation by the end of the century in the worst case scenario. In general, the potential impacts on the climate are reflected in droughts that could be longer and less rainy, but more

[21] Government of Guatemala. Ministry of Environment and Natural Resources/ Ministerio de Ambiente y Recursos Naturales (MARN). 2015. Second National Communication on Climate Change */Segunda comunicación nacional sobre cambio climático Guatemala.* Guatemala. Available at: https://unfccc.int/sites/default/files/resource/gtmnc2.pdf

[22] Bardales Espinoza, W. A., Castañón, C., & Herrera Herrera, J. L. (2019). Clima de Guatemala, tendencias observadas e índices de cambio climático. En E. J. Castellanos, A. Paiz-Estévez, J. Escribá, M. Rosales-Alconero, & A. Santizo (Eds.), *Primer reporte de evaluación del conocimiento sobre cambio climático en Guatemala.* Guatemala: Editorial Universitaria UVG.

intense[23]. In the 'First report on the evaluation of knowledge about climate change in Guatemala' (Rivera, P. F., Bardales Espinoza, W. A., & Ochoa, W. (2019)), different studies were consulted and a summary table was generated for the values of temperature increase in degrees Celsius and the values of increase or decrease of precipitation in percentage. The tables with studies consulted (Table 20), increases in temperature (Table 21) and variation in precipitation (Table 22) are reproduced below:

Table 20: Consulted documents

	SCENARIO DOCUMENTS FOR GUATEMALA	SCENARIO	BASELINE	YEAR
MARN1_o	First Communication on Climate Change in Guatemala - MARN	Optimistic	1961-1990	2001
MARN1_p	First Communication on Climate Change in Guatemala - MARN	Pessimistic	1961-1990	2001
CATHALAC_B2	Potential impacts of climate change in the biodiversity in Central America, Mexico and the Dominican Republic -CATHALAC	B2	1961-1990	2008
CATHALAC_A2	Potential impacts of climate change in the biodiversity in Central America, Mexico and the Dominican Republic -CATHALAC	A2	1961-1990	2008
IARNA_B2	Climate change and biodiversity -IARNA-URL	B2	1950-2000	2011
IARNA-A2	Climate change and biodiversity -IARNA-URL	A2	1950-2000	2011
CEPAL_B2	Economics of Climate Change in Central America -CEPAL	B2	1950-2000	2011
CEPAL_A2	Economics of Climate Change in Central America -CEPAL	A2	1950-2000	2011
CEPA_otros_A2	Climate Change in Central America: Potential Impacts and Public Policy Options- ECLAC, CAC, COMISCA, CCAD, COSEFIN, SIECA, SICA, UKAID, DANIDA	A2	1950-2000	2011
MARN_INSIVUMEH_B1	Second National Communication on Climate Change	B1	1961-1990	2015
MARN_INSIVUMEH_A2	Second National Communication on Climate Change	A2	1961-1990	2015
BID_MARN_RCP8.5	Climate impacts for Guatemala: Preliminary results of global and regional climate models - IPCC AR5	RCP8.5	1971-2010	2015

Table 21: Temperature increase projections in different studies in Guatemala

	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
MARN1_o			1.2		2.5					
MARN1_p			2.4		3.3					
CATHALAC_B2	0.3	1.0						2.0		
CATHALAC_A2	1.2	2.0						3.0		
IARNA_B2		0.1			2.0					
IARNA-A2		1.0			2.5					
CEPAL_B2					1.1			1.4		2.2
CEPAL_A2					3.0			4.5		4.7
VAR_A2		0.0			3.0					6.0

[23] Rivera, P. F., Bardales Espinoza, W. A., & Ochoa, W. (2019). Escenarios futuros de cambio climático para Guatemala. En E. J. Castellanos, A. Paiz-Estévez, J. Escribá, M. Rosales-Alconero, & A. Santizo (Eds.), *Primer reporte de evaluación del conocimiento sobre cambio climático en Guatemala.* Guatemala: Editorial Universitaria UVG.

MARN_INSIVUMEH_B1		1.0	1.3		2.0		2.5		3.3	
MARN_INSIVUMEH_A2		1.2	1.5		2.7		4.1		5.4	
BID_MARN_RCP8.5					2.5	3.0				

Table 22: Projections on variation of precipitation in different studies in Guatemala

	2020	2030	2040	2050	2060	2070	2080	2090	2100
MARN1_o		-1.00		-2.00					
MARN1_p		-18.00		-28.00					
CATHALAC_A2	-10.00						-30.00		
IARNA_B2				-10.00					
IARNA-A2				-20.00					
CEPAL_B2				-7.00			-9.00		-7.00
CEPAL_A2				-19.00			-29.00		-32.00
MARN_INSIVUMEH_B1		-8.00		-9.00		-18.00			
MARN_INSIVUMEH_A2		-9.00		-12.00		-29.00		5.4	
BID_MARN_RCP8.5					-15.00	-25.00			

153. Most general circulation models agree that temperatures in Guatemala will increase in the coming decades and that long-term rainfall will drop in most of the Central American territory (Karmalkar et al., 2011, Imbach et al., 2012;2018). A recent assessment for mean temperature and precipitation for Central America suggests an increase in temperature across all the seasons in the region with the highest increases expected in Guatemala (Imbach et al., 2028). Figure 16 shows the temperature increase in Guatemala for all the seasons and suggests temperature increases for the intervention areas towards 2030 and under the RCP 4.5. Figure XX shows the potential mean precipitation changes for all the seasons (in mm/day for the year2030 under the RCP4.5 scenario.

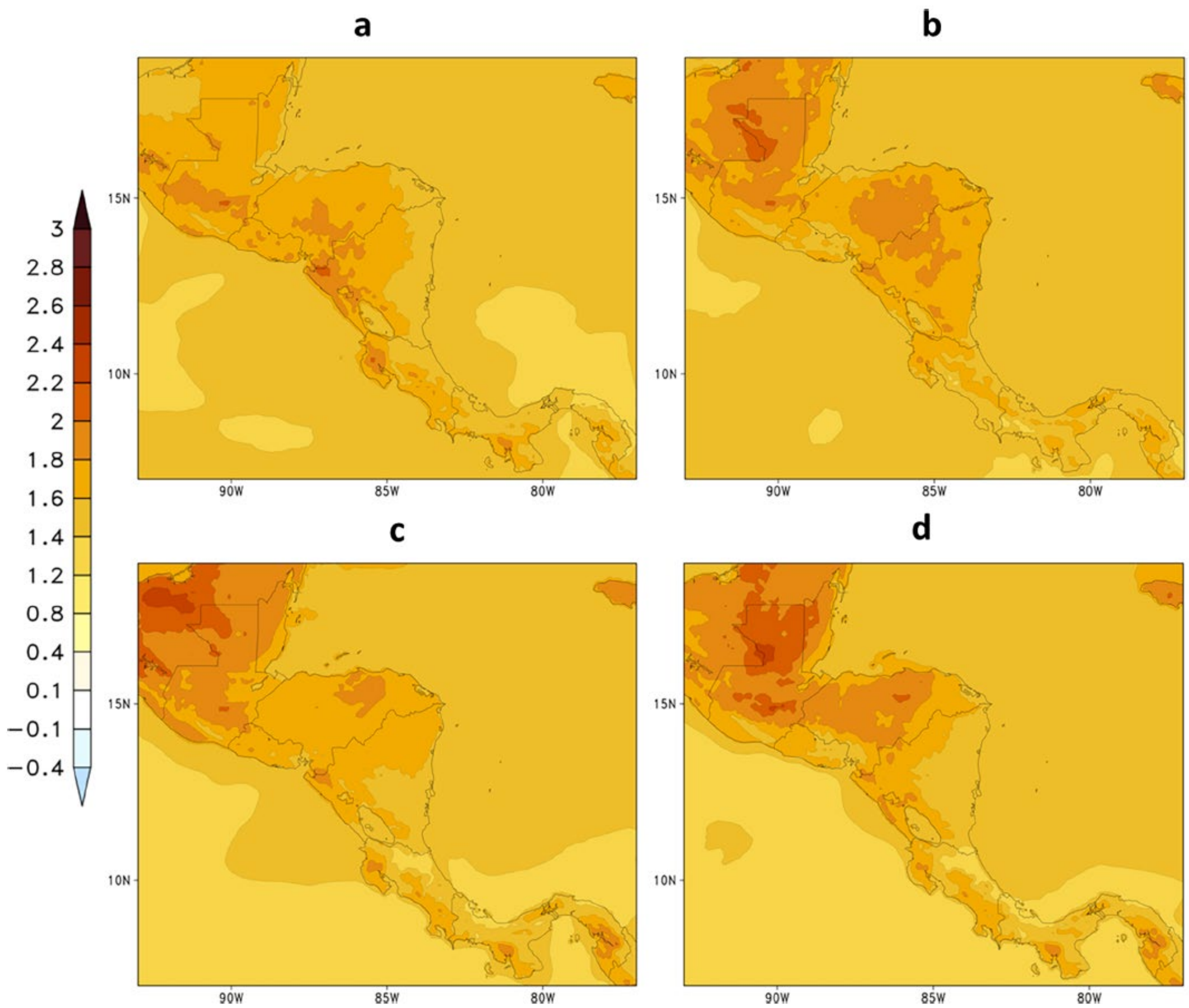


Figure 39. Temperature change in degrees Celsius for Central America for the (a) DJF, (b) MAM, (c)JJA, and (d) SON seasons. Taken from Imbach et al, 2018

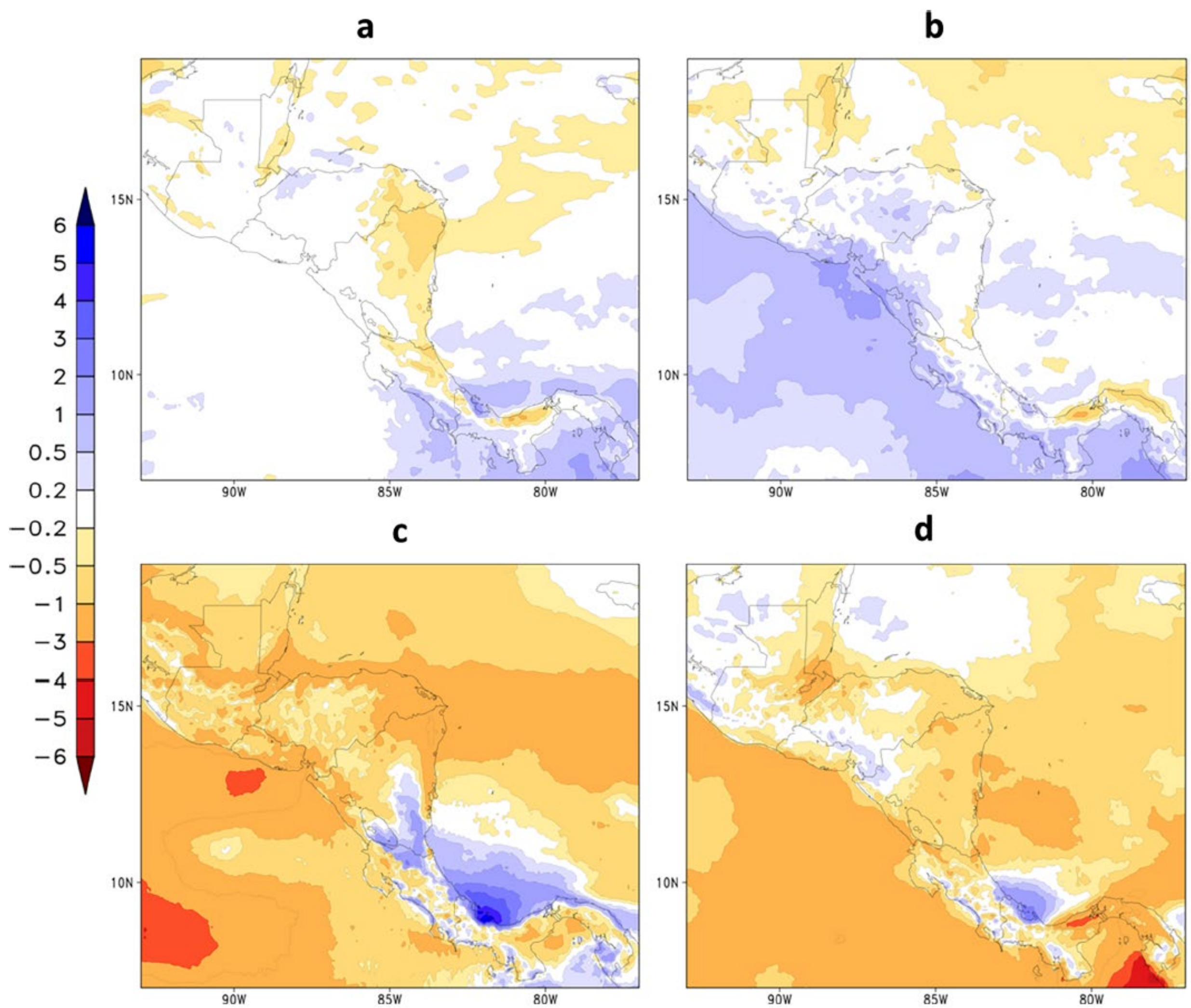


Figure 40. Mean precipitation change (mm/day) projected for Central America for the (a) DJF, (b) MAM, (c)JJA, and (d) SON seasons. Taken from Imbach et al, 2018

C.4. Temperature, precipitation, bioclimatic variables, and aridity projections using a GCM

154. Adequate management of water resources is a critical factor for sustainable development worldwide (Villanueva-Díaz et al., 2005; Oki and Kanae, 2013). An important component in hydrological modeling is potential evapotranspiration that together with precipitation make up the water balance (Xu, Pan, Fu, Tian, and Zhang, 2013; Nastos, Kapsomenakis, Kotsopoulos and Poulos, 2015). When precipitation exceeds evapotranspiration there is a surplus of water and when the evapotranspiration is greater than precipitation, a deficit is obtained. For measuring and comparing this relationship, a series of aridity classes have been generated that represent different relationships between these variables and that serve to determine in a theoretical way the differences between a hyper-arid region and a sub-humid region for example (United

Nations Environment Program [UNEP], 1992). These classes define the level of aridity of a particular region and can serve to guide efforts in the management of water resources.

155. In general, the projections from climate models suggest an increase in mean temperature and a decrease in precipitation which could subsequently generate an increase in aridity across the country. In order to project the mean temperature and average annual precipitation for the years 2030, 2050 and 2070, a general circulation model (GCM) whose physical basis and high capacity to integrate most of the climatic components in the region (including correct interpretation to ENSO teleconnections) is needed. There are many computational models with relatively good skill to estimate global changes with some precision; however, there are models whose algorithmic skills can explain better the observed changes in the climate in one or another region depending of the parameters that have been used to build the models (Oglesby, 2016). Before using a GCM for a particular region a skill assessment needs to be performed to evaluate the model's skill to reproduce historical climate in the study domain. Due to time and computational constrains, we did a literature review in this study to determine the best model to use for this assessment. We found that Hidalgo and Alfaro (2015) have recently evaluated the skill of 48 global scale circulation models generated by multiple meteorological and climatological agencies around the world under the Fifth Report of IPCC Assessment (AR5) for Comparison Project of Coupled Models 5 (CMIP5) for the Central American region. The CMIP5 project has generated the latest GCMs incorporating the latest weather information available (Intergovernmental Group of Experts on Climate Change [IPCC], 2013).

156. The evaluation carried out by Hidalgo and Alfaro (2015) consisted in measuring the ability of these models to reconstruct basic characteristics of the climate in the Central American region during the 20th century. The study evaluated certain metrics such as the ability of models to estimate the mean and standard deviation of precipitation and the air surface temperature as well as their ability to interpret correctly the influence of ENSO on these climatic variables in the region. The latter is of utmost importance given the high correlation between ENSO and climate in Central America and the impacts of this on agriculture and productivity hydroelectric in Guatemala (INSIVUMEH, 2002; MARN, 2015). Consistent with other studies (Kalmarkar et al., 2011), Hidalgo and Alfaro (2015) found that the majority of models present better abilities to reproduce the temperature compared to the ability of the models to reproduce precipitation. This could be due to high variability of precipitation in the region, the interaction of the multiple mechanisms involved and the topography of the region. However, the new agglomerate of models generated by CMIP5 seems to better capture certain precipitation values in tropical regions compared to models generated at CMIP3 (Knutti & Sedlácek, 2013).

C.4.1. Methods

157. Under the above considerations, we selected the cesm1_cam5 model (Hidalgo and Alfaro, 2015). This model was used to perform the precipitation calculations, temperature and aridity projected towards the 2030s, 2050 and 2070 under the concentration paths Representative (RCP) 2.6, 4.5and 8.5 of the IPCC (2013). This model has been cataloged as the one that best reproduces the basic characteristics of the 20th century climate for the Central American region (sum of the metrics evaluated). Given the wide spatial scale of the cesm1_cam5 model, a regionalized model was derived using the method Delta for the Guatemala domain to a resolution approximately one kilometer (Ramirez-Villegas and Jarvis, 2010). The Delta regionalization method was generated thinking about the need to model behavior of crops, biodiversity niches and for assess the potential impacts of climate change on farming systems so it was deemed adequate for use in this project (Ramirez-Villegas & Jarvis, 2010).

158. Using the scale reduction of 1 km resolution of the general circulation model cesm1_cam5 discussed above, monthly temperature projections were derived nationwide for the years 2030, 2050 and 2070 under the Representative Concentration Pathways (RCP) for optimistic scenarios (RCP 2.6), moderate (RCP 4.5) and pessimistic (RCP 8.5) according to the IPCC (IPCC, 2013). In the same way, annual precipitation was projected for the same years and under the same scenarios. From this information, the aridity index was calculated using Thornthwaite's evapotranspiration equation (1948) presented in paragraph 147.

159. Finally, the aridity index was categorized under the classes defined by UNEP (1992), which has been used by the Republic of Guatemala for its own aridity estimates (MAGA, 2002). A baseline was also generated in the same scale of the other metrics using climatology Worldclim 1961-1990 (Hijmans, Cameron, Parra, Jones and Jarvis, 2005). The reasoning behind the use of an aridity index as an important component for assessing climatic risk in the country is because aridity is a good indicator of the regional climate (Marengo and Bernasconi, 2015). The aridity index allows to establish changes in the hydrological cycle that can be easily related to both natural (e.g. forests) and anthropogenic systems (for example agriculture) since it incorporates the potential evapotranspiration. Also, the index can be built with only two variables: temperature and precipitation. This simplifies the process of calculating the index aridity for the region since there are no reliable records in the country of other environmental metrics such as vapor pressure, wind direction and speed that might be needed for other PET equations. High resolution data was used for the monthly temperature baseline and annual precipitation data from WorldClim v1.4 for the average weather of 1960-1990. The future data of the same variables for the RCP 2.6, RCP 4.5 and RCP 8.5 scenarios of the model cesm_cam5 were extracted from regional extension B2, available on the CCAF data portal (http: //www.ccafsclimate.org/data/).

160. The aridity indices presented hey are annual, and were calculated with the formula:

$$\mathrm{AI} = \frac{\mathrm{PA}}{\mathrm{PET}}$$

161. Where PA is the annual precipitation and PET is the estimate of the combined annual evapotranspiration potential, and both amounts are in the same dimensional (height of evaporated water, mm). The monthly PET was calculated using Thornthwaite's equation (1948):

$$\mathrm{PET} = 16\left(\frac{L}{12}\right)\left(\frac{N}{30}\right)\left(\frac{10T_a}{I}\right)^{\alpha}$$

162. In this expression, L is the average number of hours/day in that month, N is the number of days in the month, T_a is the average temperature, I is the heat index and α is defined from I. On the other hand, I depends on the average temperature of each month of the year T_ai:

$$I = \sum_{i=1}^{12}\left(\frac{T_{ai}}{5}\right)^{1.514}$$

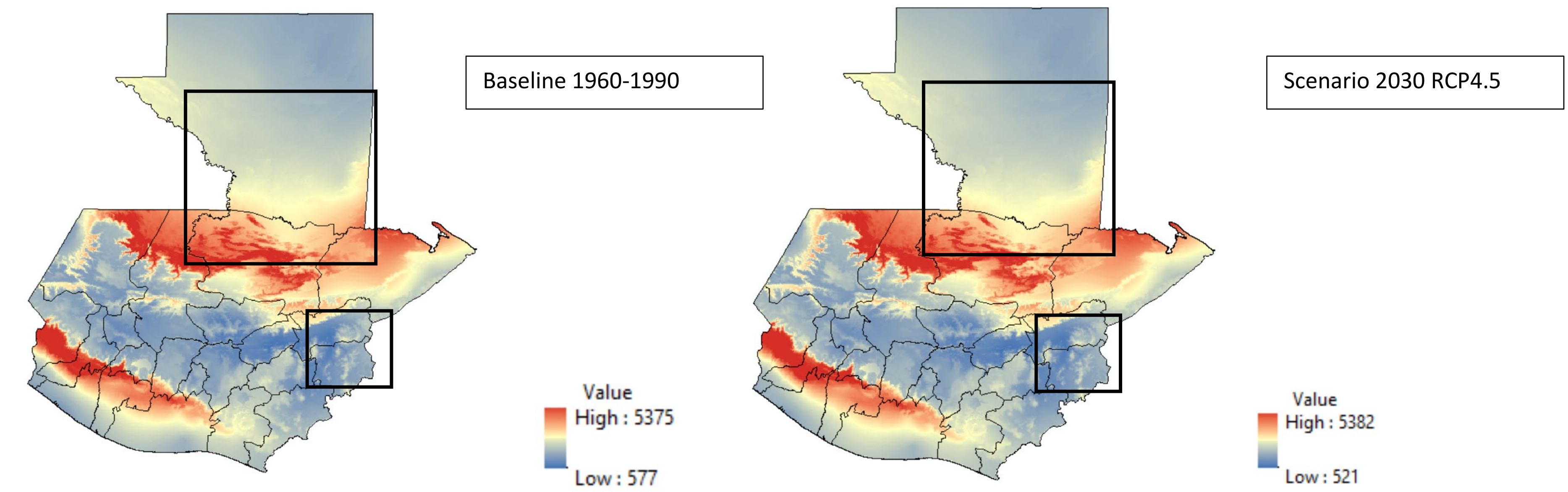
In addition to the variables used to calculate aridity, we also generated the following bioclimatic variables using the same model towards the year 2030 and under the RCP 4.5 scenario (O'Donnell and Drew A. Ignizio 2012):

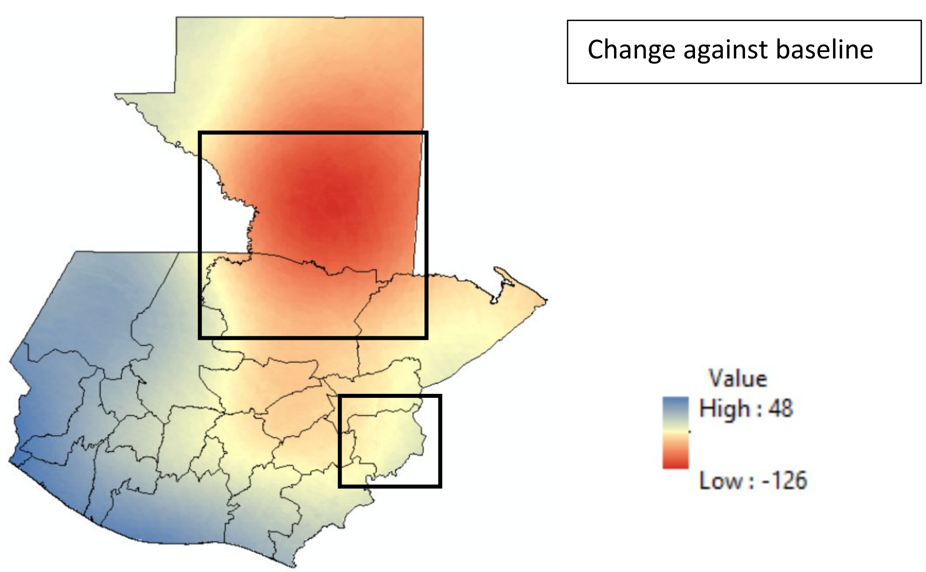
Box 1. List of bioclimatic variables downscaled from the cesm1_cam5 GCM using the Delta method for Guatemala for the year 2030 under the RCP 4.5 scenario.

Bioclimatic Variable
Annual Mean Temperature
Mean Diurnal Range
Max Temperature of Warmest Month
Min Temperature of Coldest Month
Mean Temperature of Wettest Quarter
Mean Temperature of Driest Quarter
Mean Temperature of Warmest Quarter
Mean Temperature of Coldest Quarter
Annual Precipitation
Precipitation of Wettest Month
Precipitation of Driest Month
Precipitation of Wettest Quarter
Precipitation of Driest Quarter
Precipitation of Warmest Quarter
Precipitation of Coldest Quarter

C.2.1. C.4.2. Results

163. Figures 41-43 show projections for the average annual rainfall (Figure 41), average annual temperature (Figure 42) and aridity (Figure 43) for the years 2030 and 2050 under the RCP 4.5 scenario and compared with the baseline 1960 – 1990 (Please note the project intervention areas are outlined in red). However, to visualize important changes in the water regime of traditionally humid regions that are not included in this classification and that lose an important fraction of the resource classes have been generated artificial adding changes in increments of 0.5 from the values of 0.65. This in order to evidence that regions classified as wet by UNEP could lose a lot of that moisture and without. However, continue to be classified as wet sites. These traditionally invisible humidity changes by the traditional classification are evidenced in this study, especially due to the implications in regions of agricultural importance for the country and conservation of forests.





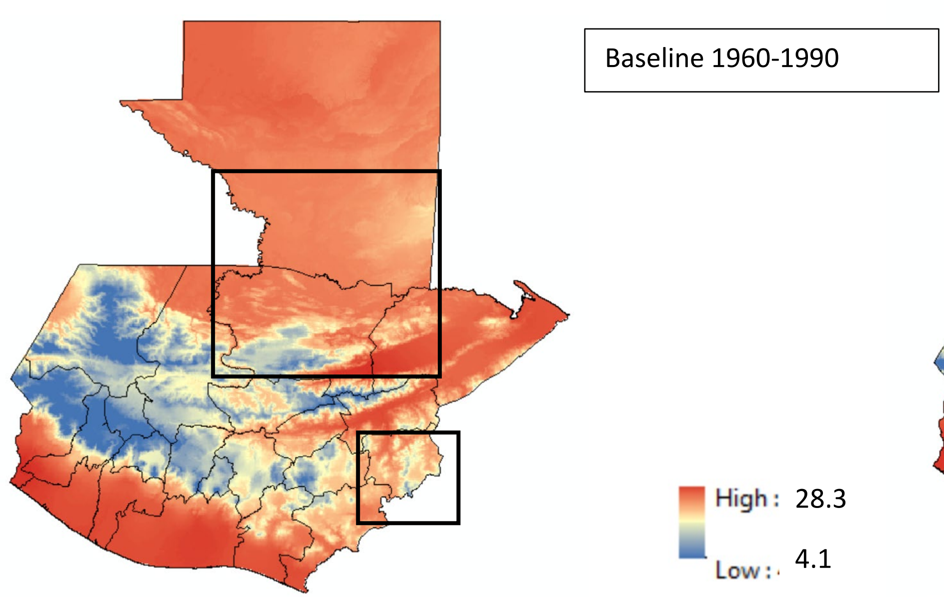
Annual Precipitation (in mm)

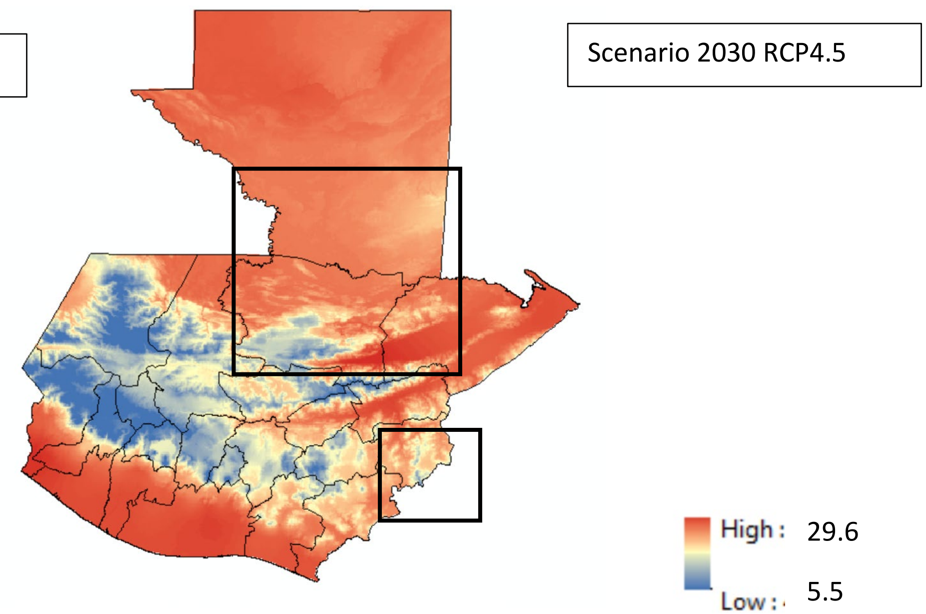
When it comes to precipitation, both the Dry corridor area and the Mayan Lowlands are expected to see decreases in annual precipitation of up to 126 mm. This is particularly true for the Mayan Lowlands.

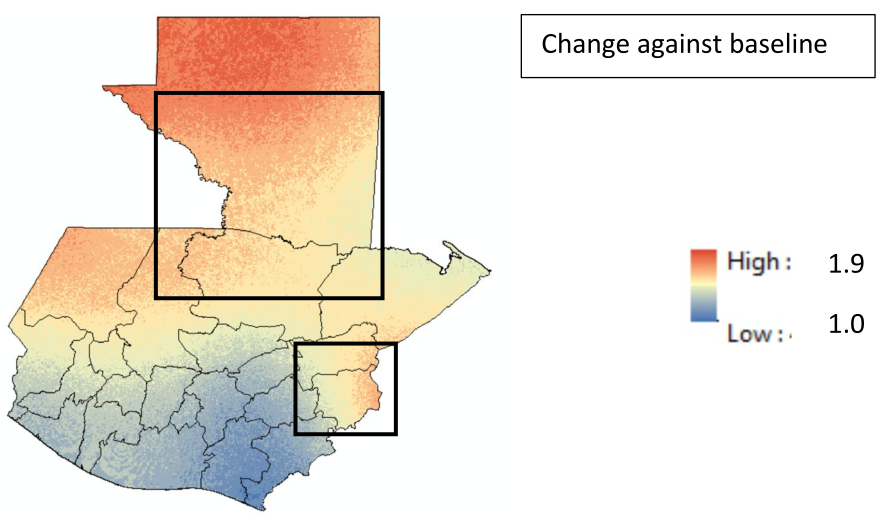
Agricultural Relevance

One of the variables that determines the overall suitability of a crop to a certain region is the total annual precipitation. The substantial reductions of up to 126 mm of precipitation a year could impact the overall water availability for staple and cash crops, particularly in the Mayan Lowlands where a large part of the Maize is produced in the country. The following metrics allow us to delve dipper into the timing of these

Figure 41. Average annual precipitation differences for the decades of 2030 RCP 4.5, compared to 1960-1990 .







Annual Mean Temperature (° C)

The annual mean temperature towards the 2030 suggests an increase on temperature for the intervention areas (highlighted areas in black squares) under the RCP 4.5. Changes in the Mayan Lowlands and the Chiquimula region in the dry corridor area show the highest increments of up to 1.9° C.

Agricultural Relevance

Annual mean temperature determines the overall suitability for certain crops included coffee with a reduced optimal temperature range of 18-22° C. An over all increase in temperature in the Dry Corridor region could be detrimental to coffee productivity.

Figure 42. Average annual temperature differences for the decades of 2030 and 2050 under the RCP 4.5, compared to 1960-1990 baseline.

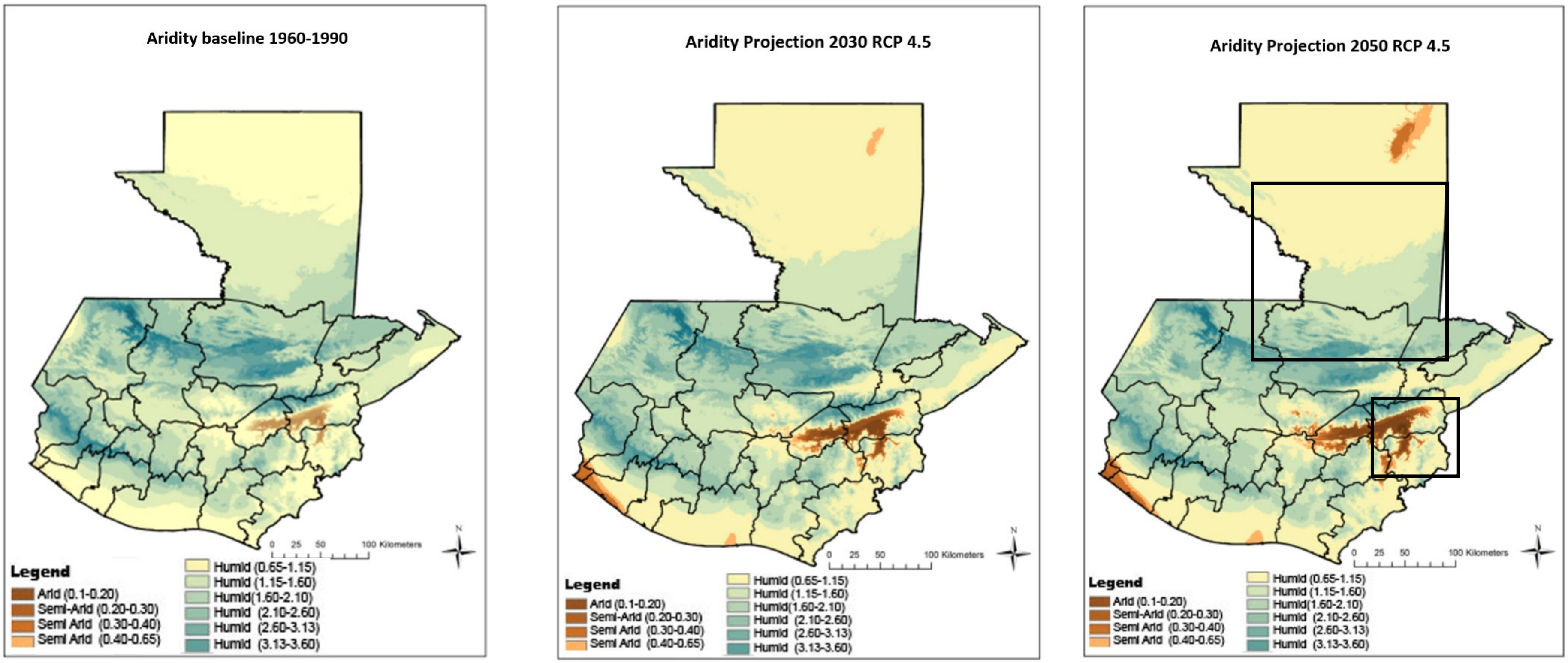


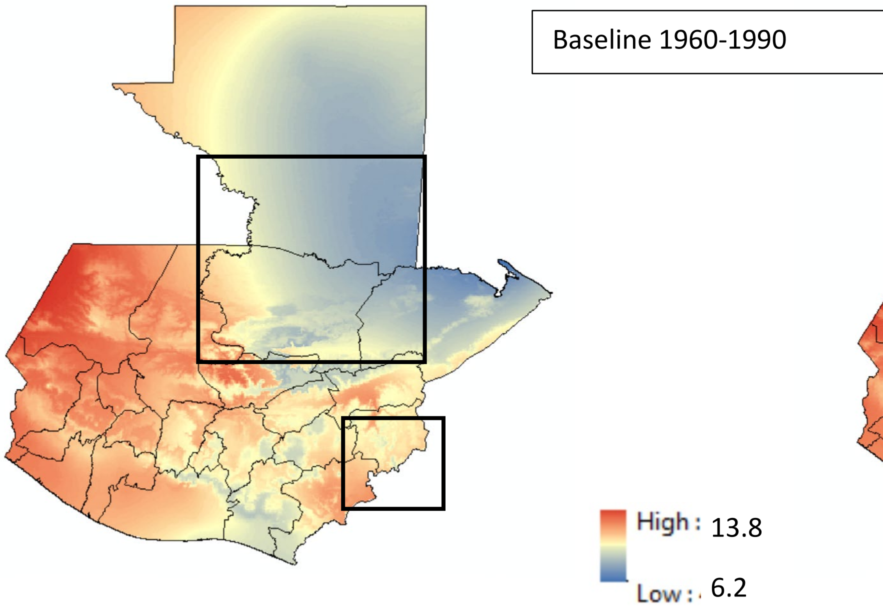
Figure 43. Aridity differences for the decades of 2030 and 2050 under the RCP 4.5, compared to 1960-1990 baseline

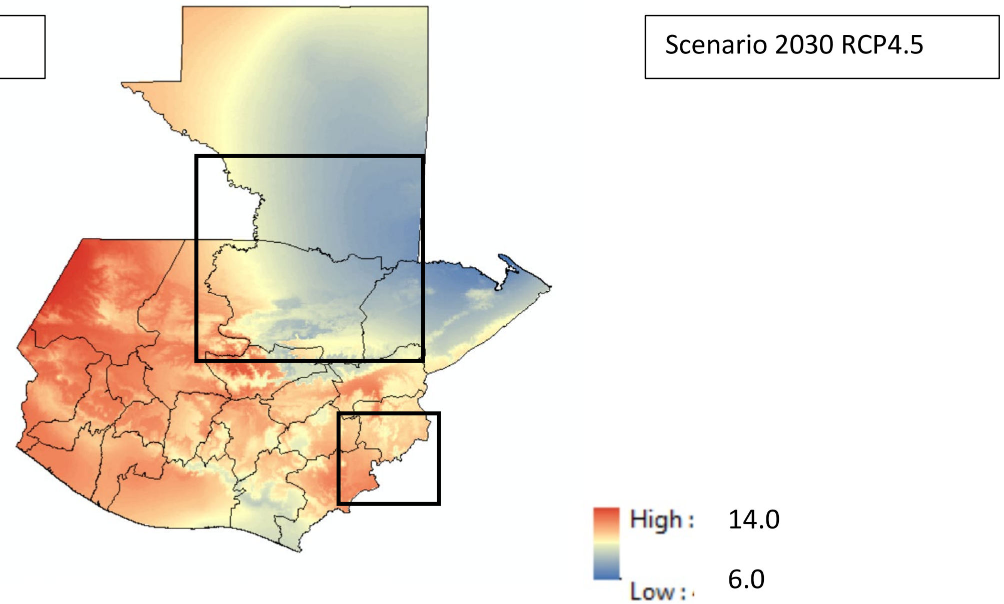
164. Climatic simulations of the model used in this study suggest changes in precipitation and increased temperature used to estimate aridity could see an increase towards the 2030, 2050, and 2070 scenarios under the different RCPs. This could potentially have a negative impact in the main agricultural production systems of the country. These changes could have an impact on both subsistence crops and the case of corn in the southern department of Petén and northern Alta Verapaz as in agro-industrial crops like sugar cane and banana on the south coast. If these changes occur, they could be associated with an increase in drought stress (Malhi et al., 2009), drying or regressive death in plants and trees (Cox, Betts, Jones, Spall and Totterdell, 2000). These possible changes could also have impacts indirect in vegetation, such as higher frequency of fires (Scholze, Knorr, Arnell and Prentice, 2006). At the same time, the simulations suggest an expansion from the eastern dry corridor area to the western dry corridor and increased aridity in certain areas of El Progreso and Zacapa that go from the "semi-arid" class to the "arid" class, that is to say, one could increase the water deficit in these regions in scenarios as close as 2050 in under the moderate path (RCP 4.5) and which are exacerbated towards the year 2070 under the same scenario. In others regions of the country such as Sarstún-Motagua (near the Polochic River and the border area with Honduras) could see a significant increase in aridity. Guatemala may also be subject to loss significant forest biomass under scenarios drying and warming air temperature potentially increased in the 21st century in regions of the Maya Biosphere Reserve (RBM) and in highland mountainous regions such as forests of pinabete (Abies guatemalensis) in Totonicapán (Imbach et al., 2012; Cox et al., 2004; Betts et al., 2004; Anderson et al., 2018). A decrease in forestry sector could happened due to potential temperature rise, potential reduction of precipitation and increases in dry periods (Lyra et al., 2016). Regardless of precipitation reduction and its direct impact on runoff and river flows, increased aridity and subsequent forest landscape degradation could lead to indirect reduction of streamflow in the country's rivers. The increase water evaporation could act on the bodies of water directly transporting more water vapor to the atmosphere. At the same time, the loss of forest cover could have a net negative impact on runoff and soil infiltration and finally in the discharge of rivers. These factors could eventually lead to water availability reductions in regions already prone to droughts and have others strong impacts on biodiversity and other equally important sectors. Although the future scenarios generated in this study suggest changes in the country's water regime, it should not be forgotten that climatic variability and extreme weather events that occur between both scenarios at inter and intra-annual scales has a significant impact equal or greater on productive systems of the country (INSIVUMEH, 2002).

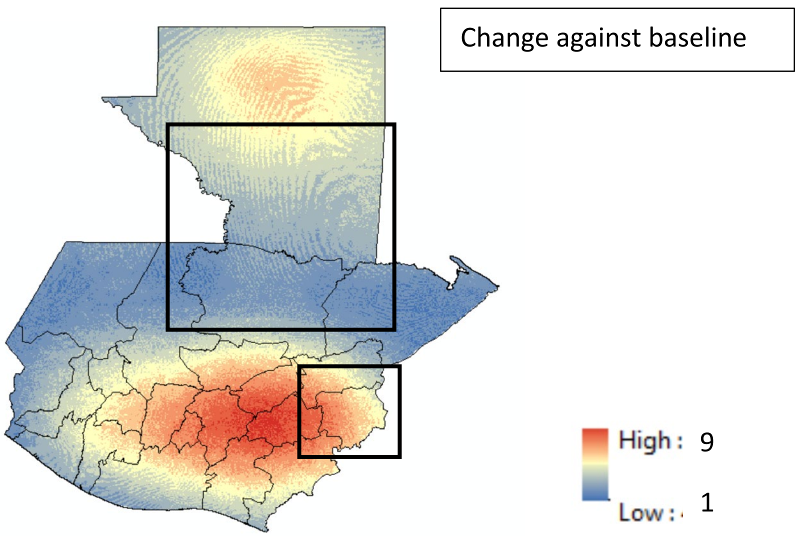
165. That is, although the scenarios suggest that, for example, the northern lowlands could suffer an increased aridity, this does not mean that during La Niña years don't expect torrential rains and floods in the same region. In the same way, the south coast could continue experiencing landslides during extreme precipitation and drought events Meteorological events during El Niño events. In other words, natural climate variability and anthropogenic

changes should continue to be considered among the baseline and the scenarios generated and between these themselves.

166. These aridity projections for Guatemala are consistent with other scenarios published in the literature for the country (see MARN, 2015; INSIVUMEH, 2018), and can be used as a reference for policy formulation to better manage the resource water in the country, especially in critical regions for agriculture and forest, but also in basins of hydroelectric importance. It must be considered, in addition to adaptation strategies to long-term climate change, a management plans for water resource in the country that allow to adapt to climate variability in the short term. Developing short term adaptation strategies to water allocation and management could generate lessons learned with the potential to increase the resilience of climate vulnerable communities in the future. It is necessary to expand the network of meteorological stations throughout the country, but especially in the regions where the most severe changes are projected. Doing this allows for the establishment of a monitoring system for climatic variables critical for water management. This will allow not only to identify changes in the climate (long-term) through trend analysis but also to establish an early warning system (short term) that can help risk management of climate variability and extreme meteorological events. On the other hand, new experiments with model ensembles must be performed to estimate the uncertainty associated with aridity projections.





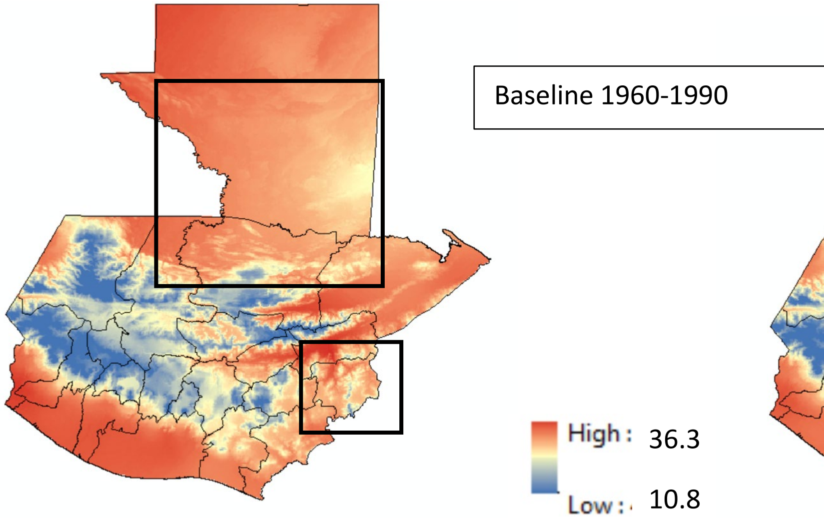


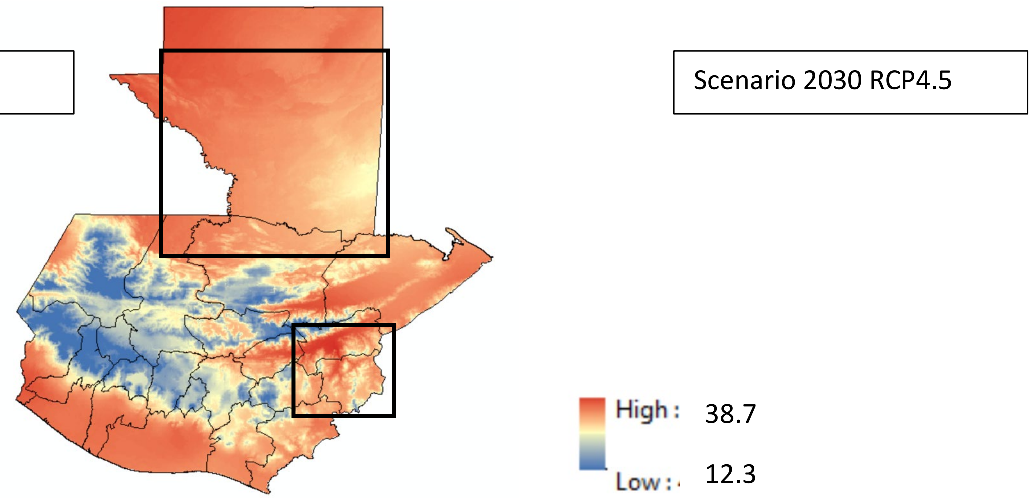
Mean Diurnal Range (° C)

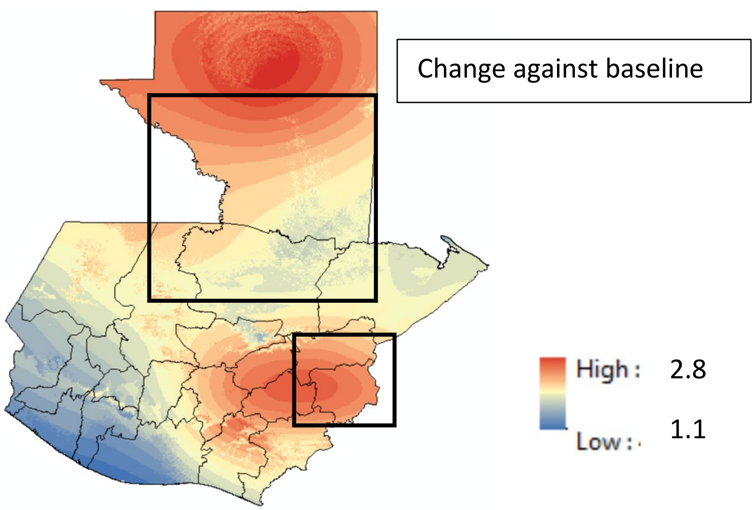
This variable suggests a decrease of the diurnal temperature range for most of the Mayan Lowlands and an increase in the dry corridor area.

Agricultural Relevance

This index can help provide information regarding the relevance of temperature fluctuation for different species.





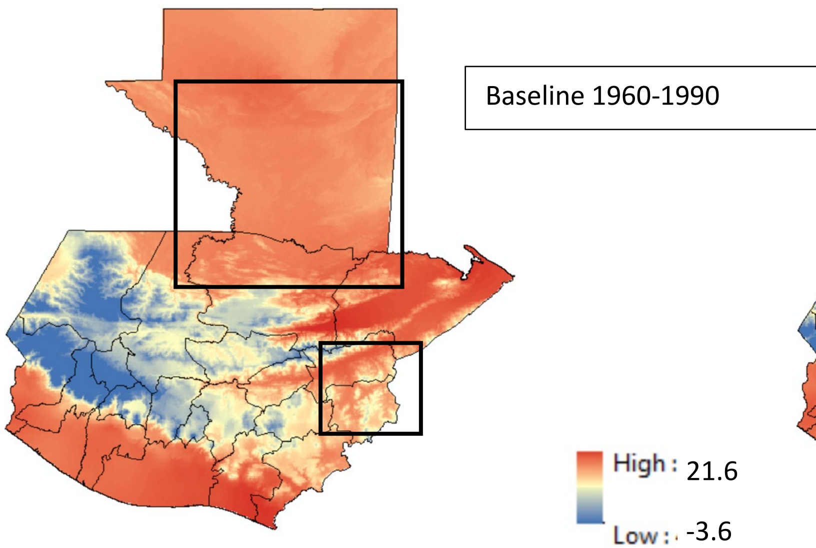


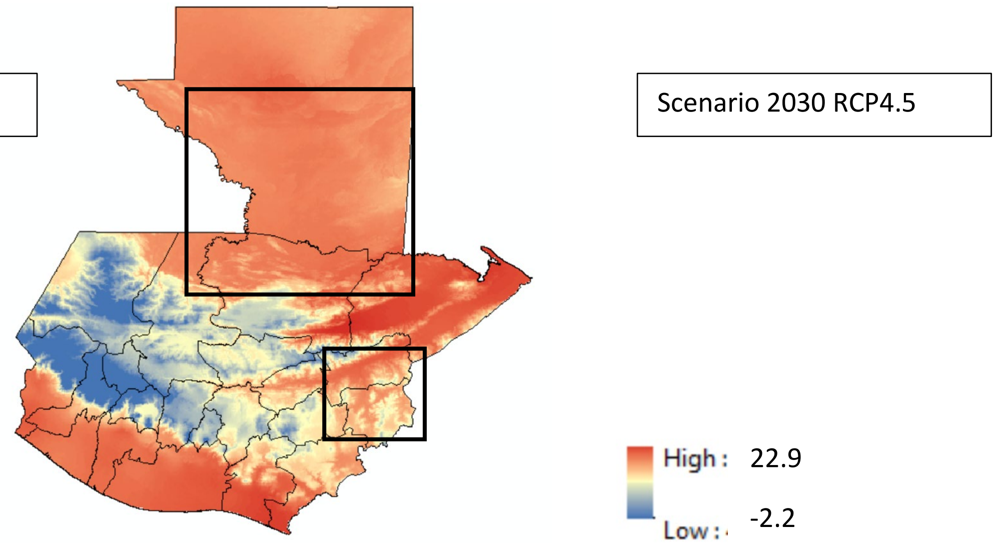
Max Temperature of Warmest Month (° C)

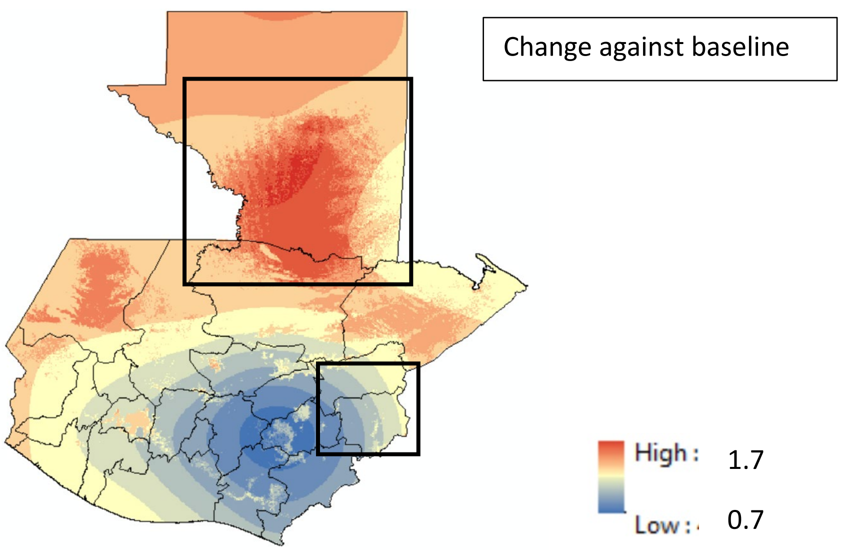
This variable suggests an increase in the maximum temperature for the two intervention areas of the Mayan Lowlands and an increase in the dry corridor area as well of up to 2.8 ° C.

Agricultural Relevance

Temperature increases of up to 2.8 ° C during the warmest month in both intervention areas could translate in increased evapotranspiration and soil moisture lost with an overall negative impact on the crop yield if water offer is not met.







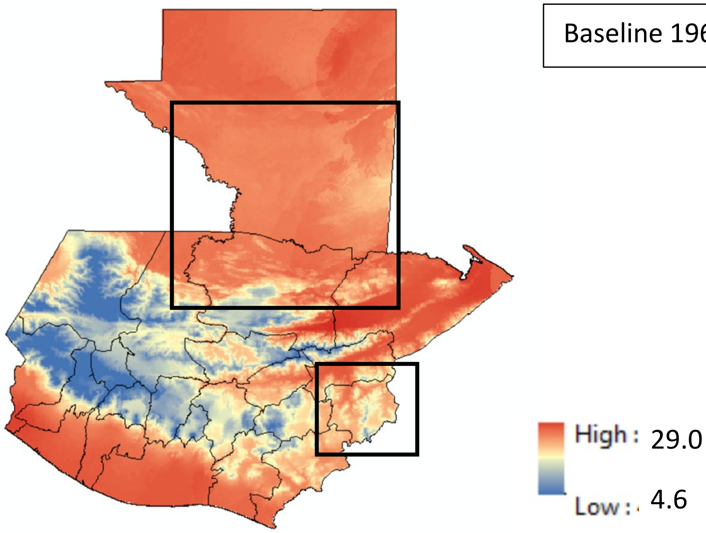
Min Temperature of Coldest Month (° C)

Similarly to Max temperature, this variable suggests an increase in the maximum temperature for the two intervention areas of the Mayan Lowlands and an increase in the dry corridor area as well of up to 1.7 ° C

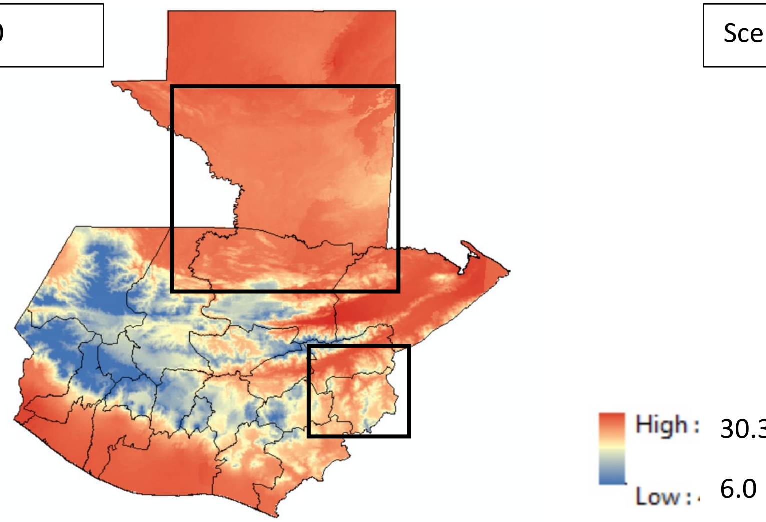
Agricultural Relevance

Temperature increases of up to 1.7 ° C during the coldest month in the Mayan Lowlands could translate in decreased Maize productivity. Similarly, an increase of 0.7 in the Dry Corridor further reduce the soil moisture.

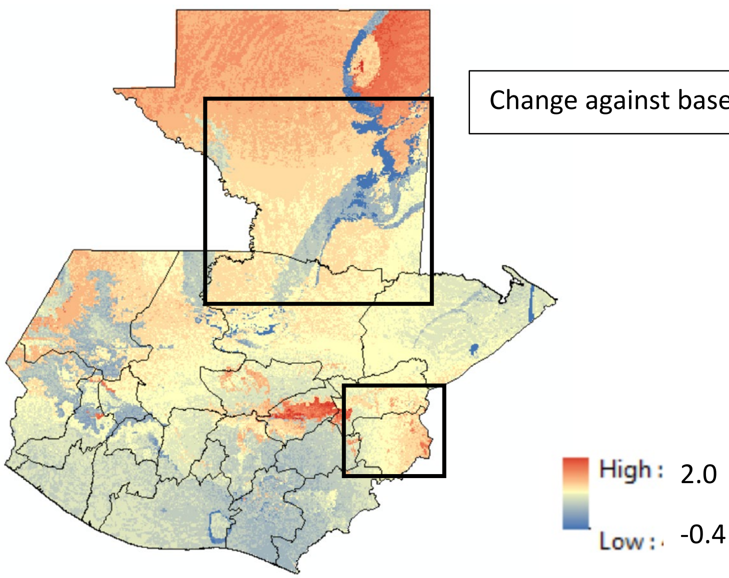
Baseline 1960-1990



Scenario 2030 RCP4.5



Change against baseline

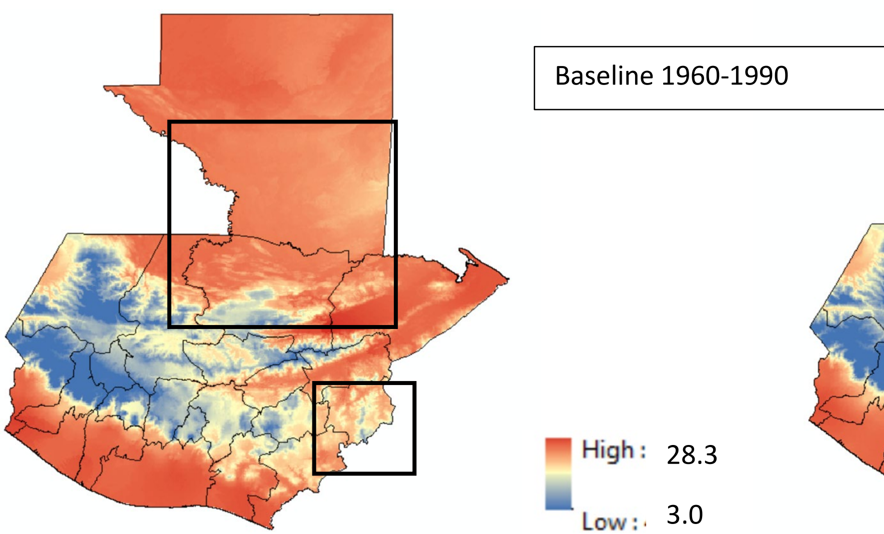


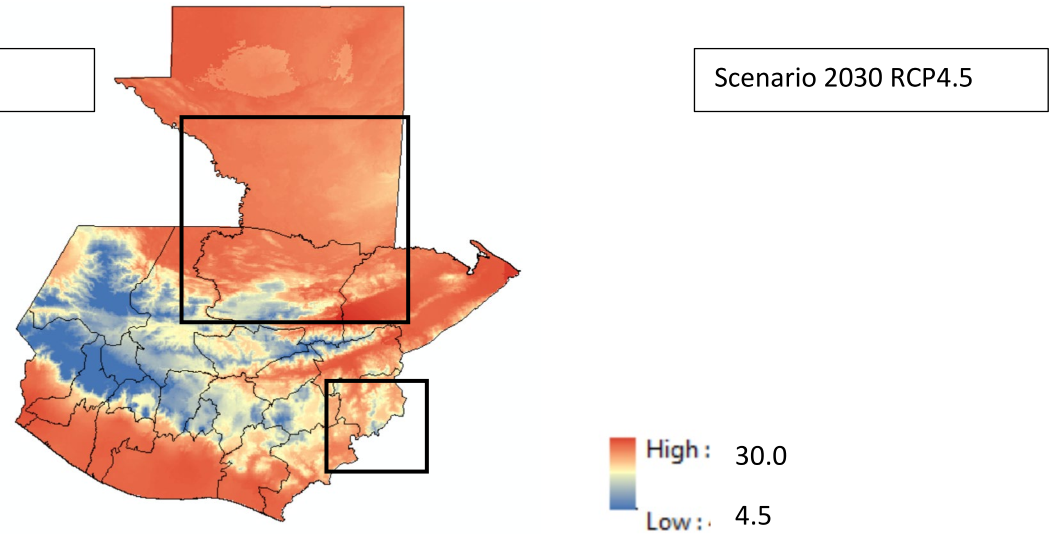
Mean Temperature of Wettest Quarter (° C)

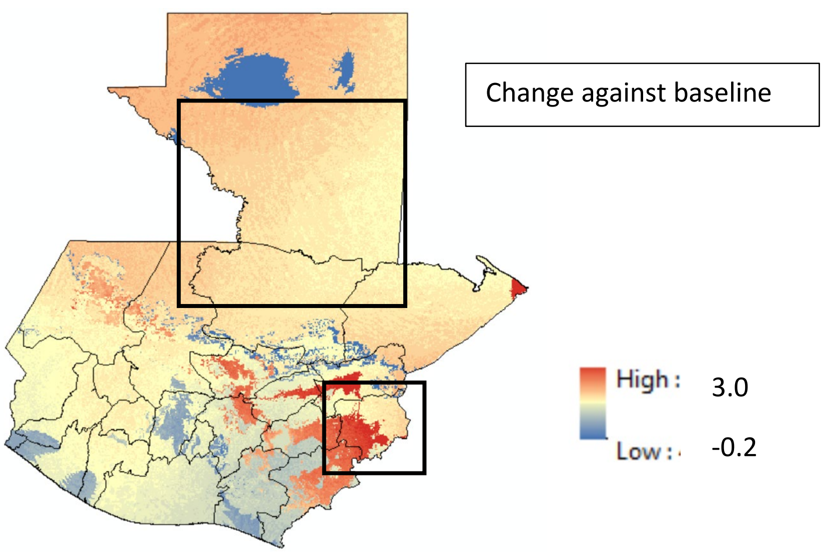
This variable suggests an increase in the maximum temperature for the two intervention areas of the Mayan Lowlands of up to 2 °C and with some mixed results in the center area (near Poptun) and a less intense change for the Dry Corridor area, excepting areas near the Honduran border.

Agricultural Relevance

Temperature increases of up to 2.0 ° C during the wettest season could increase the evaporative demand and promote water loss from the soil to the atmosphere with an overall negative impact on the crops.





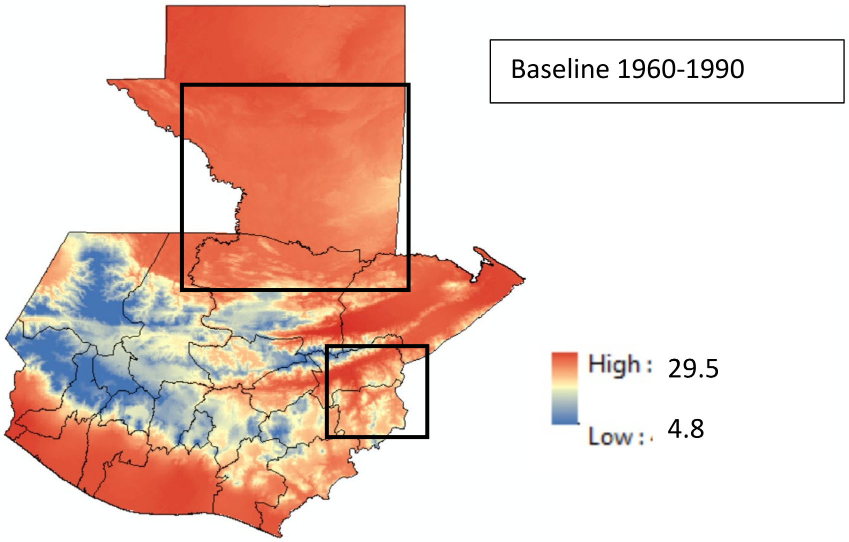


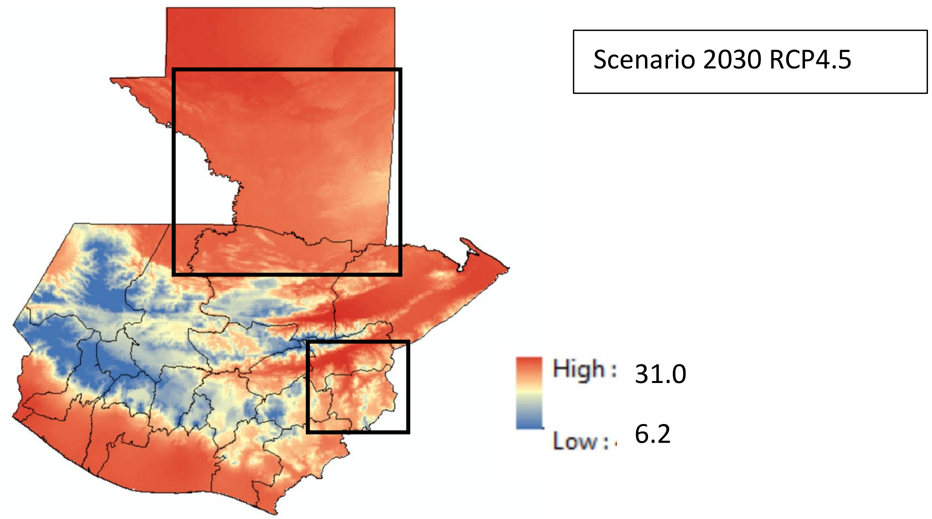
Mean Temperature of Driest Quarter (° C)

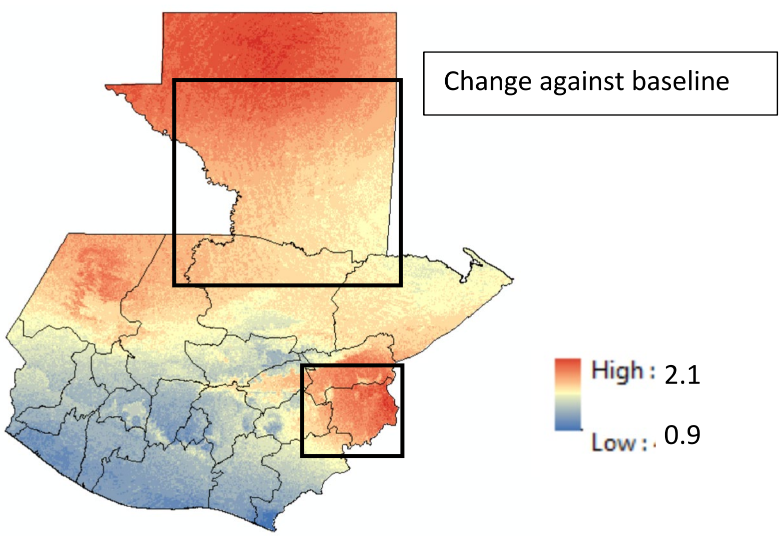
In this case, the mean temperature for the Dry corridor during the driest quarter is expected to increase substantially to up to 3 ° C. Less intense increments are expected for the Mayan Lowlands yet, the upward trend is evident in most of the intervention areas.

Agricultural Relevance

Temperature increases of up to 3.0 ° C during the driest season could accelerate the evaporative demand and promote water loss from the soil to the atmosphere with an overall negative impact on the crops.





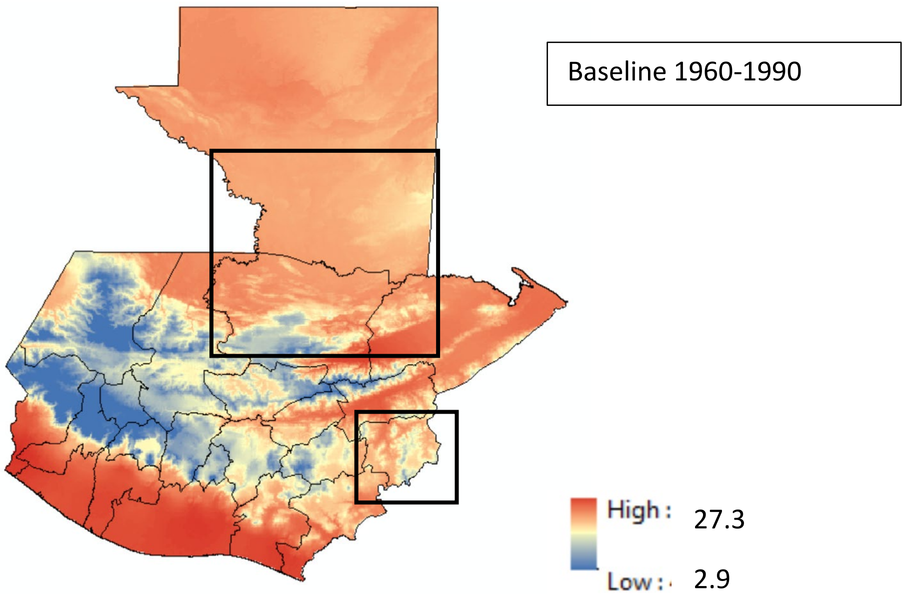


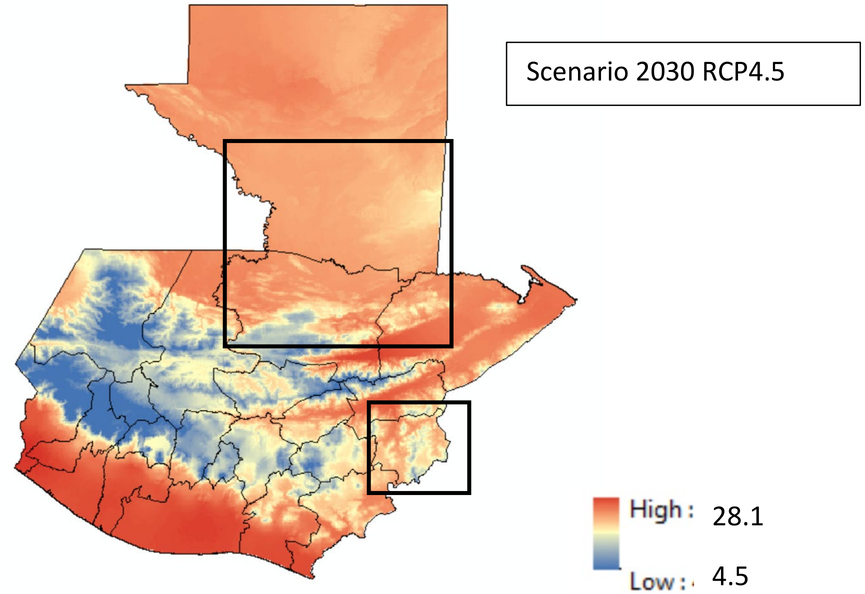
Mean Temperature of the Warmest Quarter (° C)

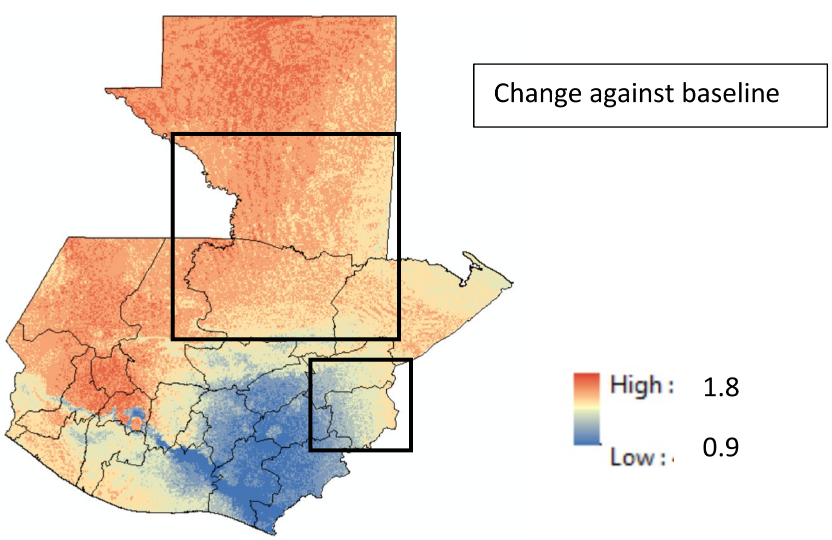
In this case, both the Dry corridor area and the Mayan Lowlands are expected to see increases in temperature of up to 2.1 C

Agricultural Relevance

The temperature increments of up to 2.1 ° C during the warmest season could promote additional stress on staple crops like Maize in the Dry Corridor region of Guatemala. The largest increments are observed for the two intervention areas.





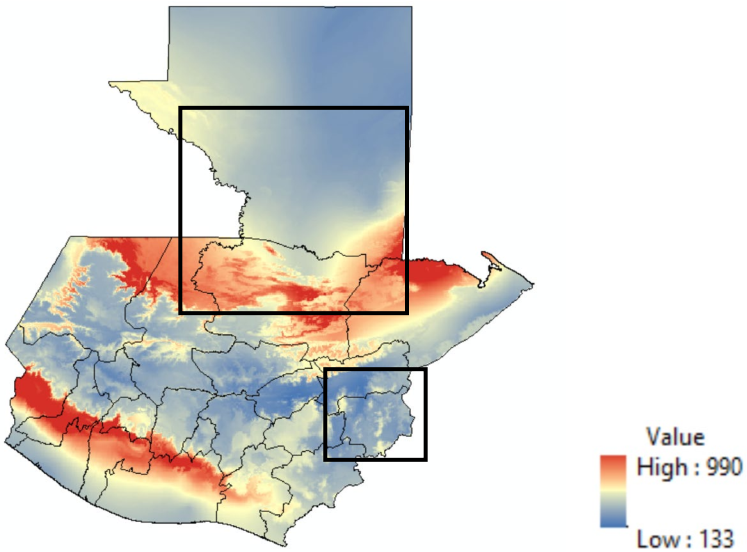


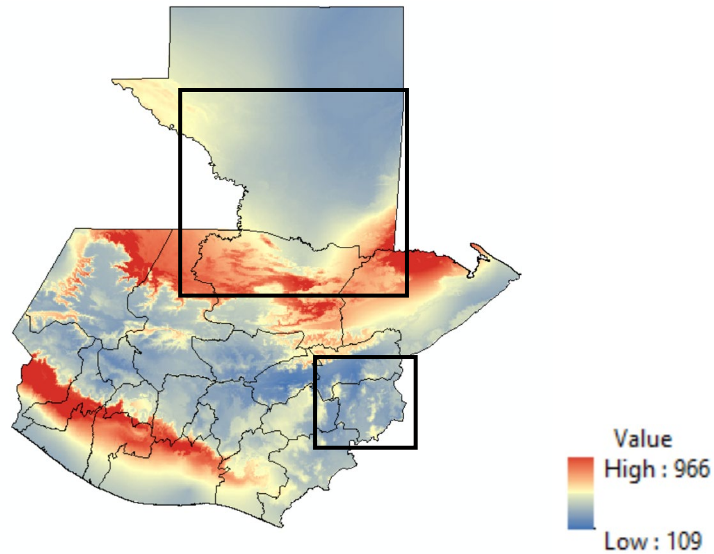
Mean Temperature of Coldest Quarter (° C)

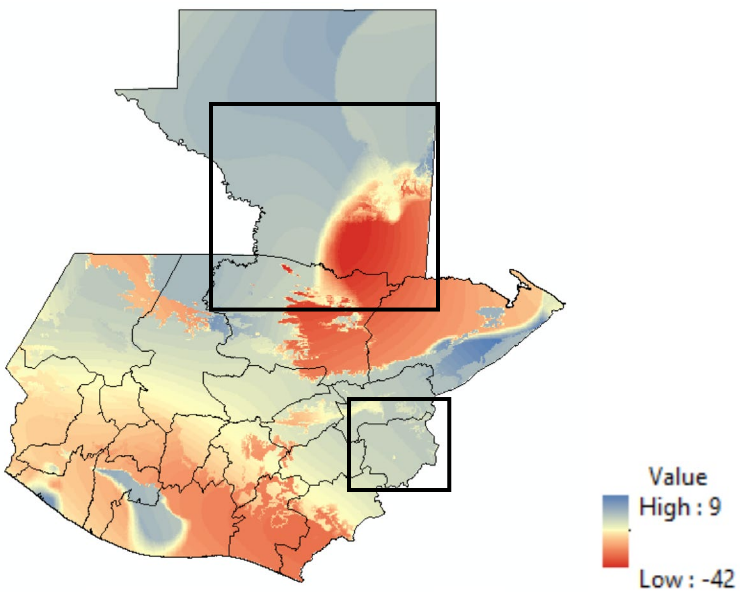
Even during the coldest season in the country, both the Dry corridor area and the Mayan Lowlands are expected to see increases in temperature of up to 1.8 ° C

Agricultural Relevance

The temperature increments of up to 1.8 ° C during the coldest season could promote additional stress on staple crops like Maize in the Mayan Lowlands of Guatemala.





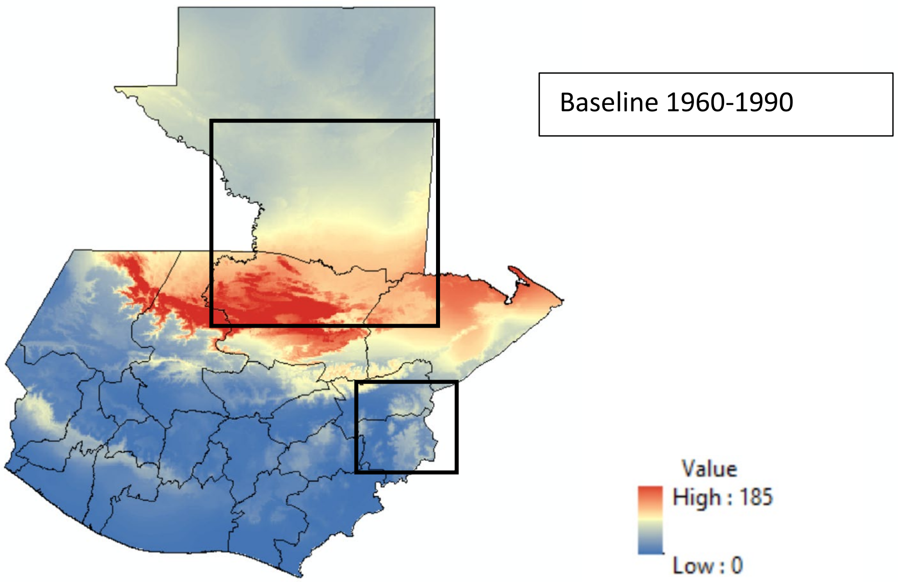


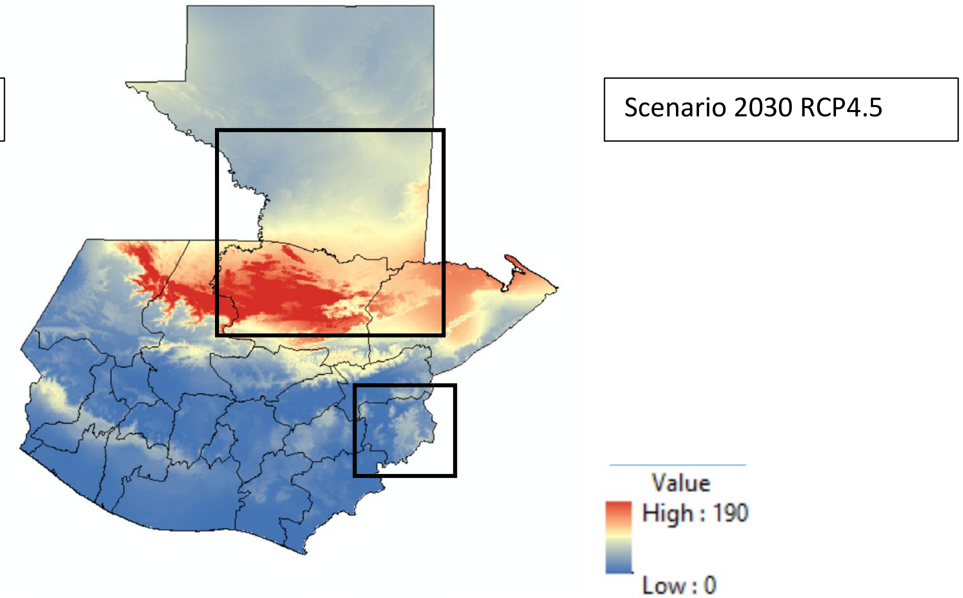
Precipitation of Wettest Month (in mm)

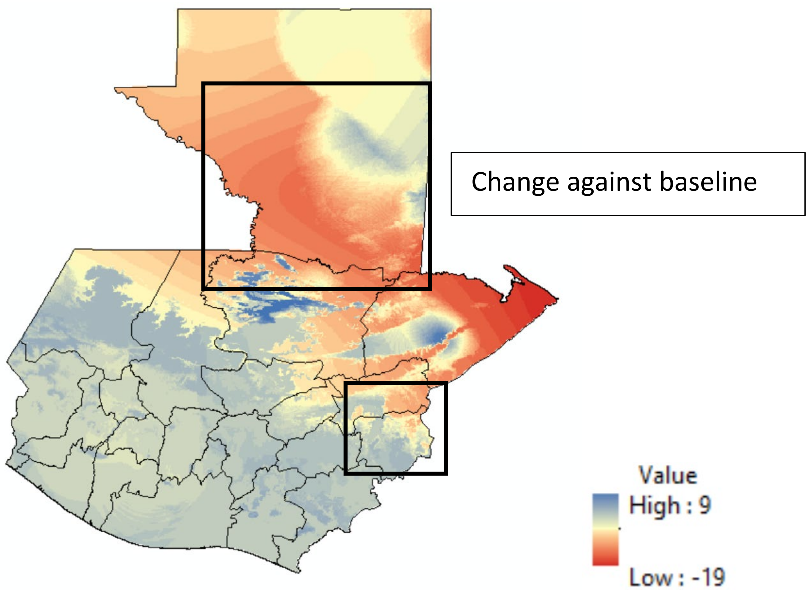
When it comes to precipitation of the wettest month, the Mayan Lowlands are expected to see decreases in precipitation of up to 42 mm. The dry corridor might gain some precipitation in this season.

Agricultural Relevance

The wettest month in the year could see a reduction of up to 42 mm. This is enough rainfall deficit to generate loss in the yield of Maize in the Mayan Lowlands.





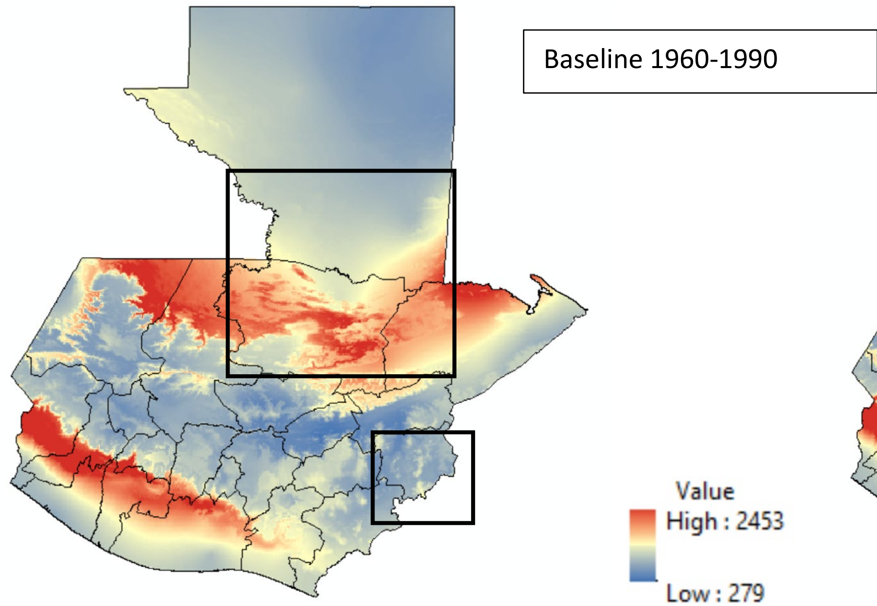


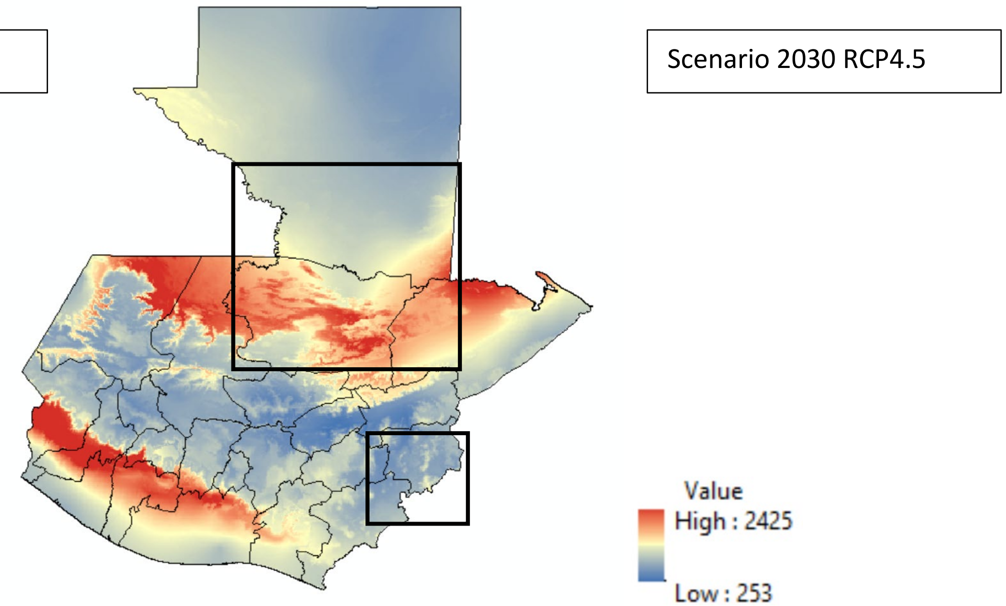
Precipitation of Driest Month (in mm)

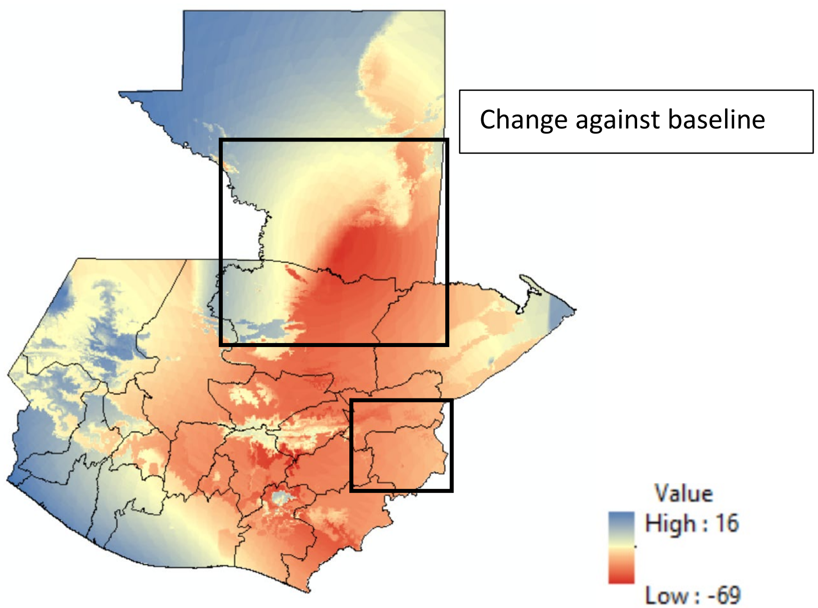
When it comes to precipitation of the driest month, the Mayan Lowlands are expected to see decreases in precipitation of up to 19 mm. The dry corridor has mixed projections for the territory, but the current low rainfall received in the driest month suggest that soil moisture could be loss to the atmosphere further drying the soils.

Agricultural Relevance

Loss of soil humidity in the driest month in regions with near zero rainfall could trigger desertification processes, making it harder for farmers to plant under these soil conditions.







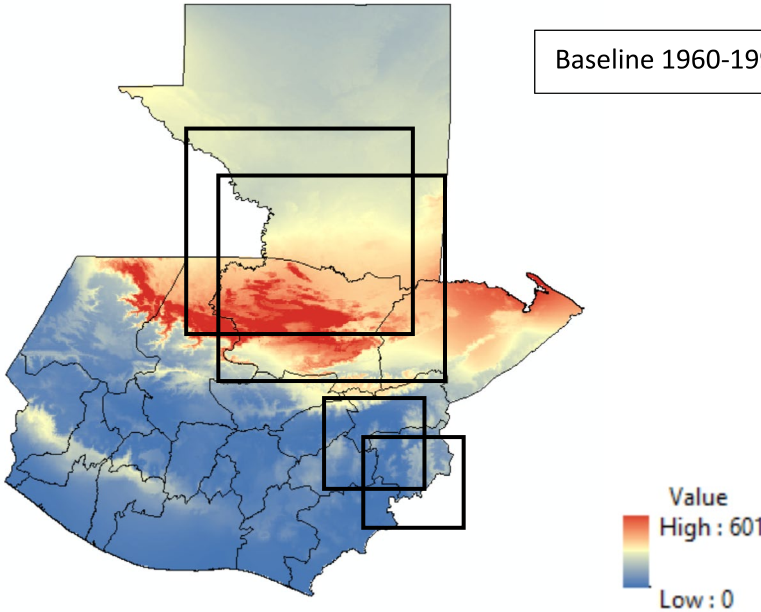
Precipitation of the Wettest Quarter (in mm)

When it comes to precipitation of the wettest quarter (JJA) the two intervention areas could see a decline of up to 69 mm in the season.

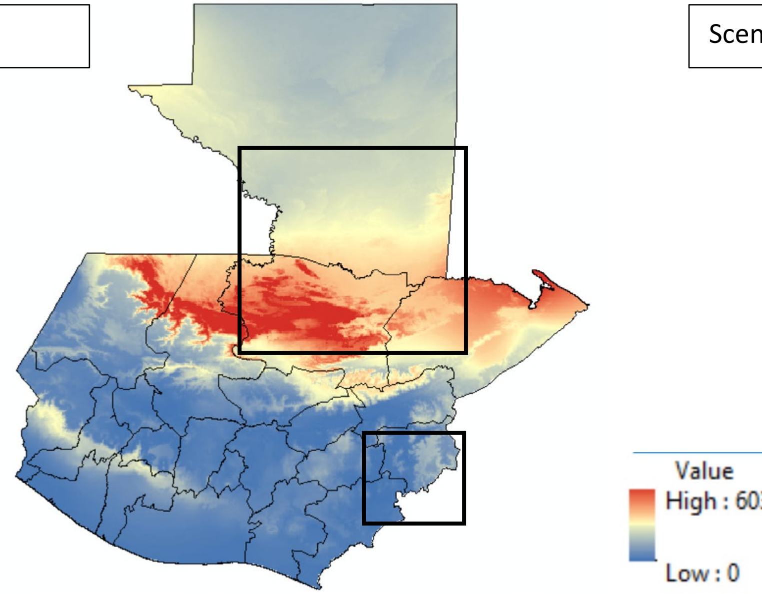
Agricultural Relevance

A reduction of precipitation in the wettest season of June-July-August could be detrimental to agricultural practices due to the tight synchrony between the rainfall onset and the water demand by crops during these months. Both the reproductive and grain-filling stages of Maize the two regions could be affected by this humidity loss. Overall, an reduction in yield is expected to happen.

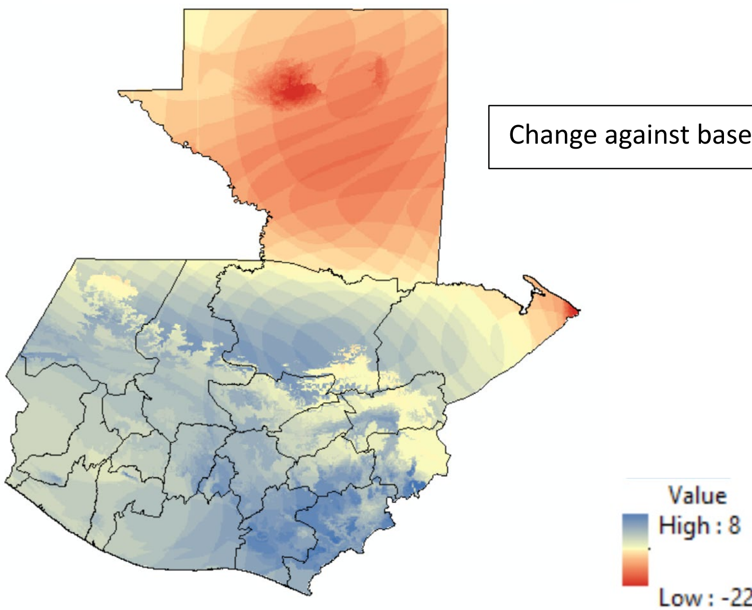
Baseline 1960-1990



Scenario 2030 RCP4.5



Change against baseline

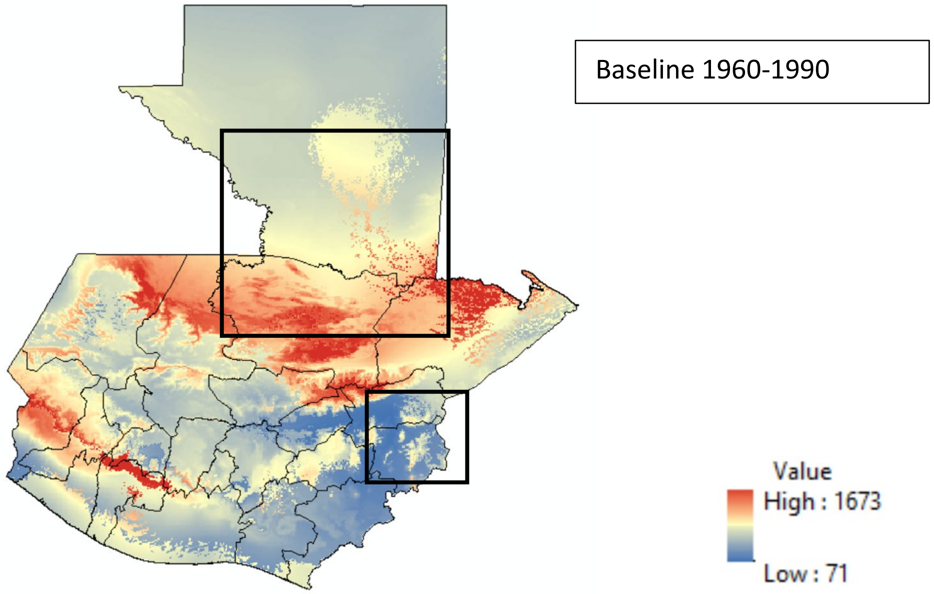


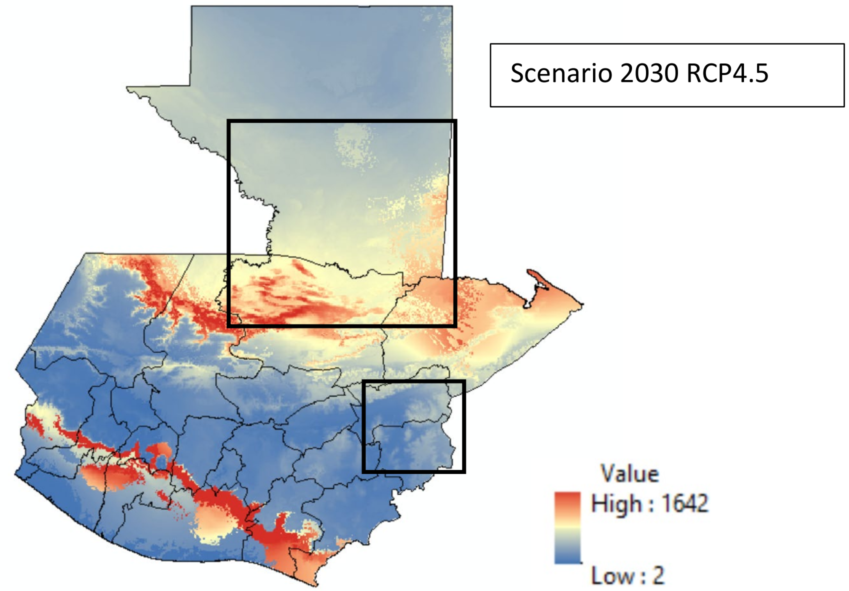
Precipitation of the Driest Quarter (in mm)

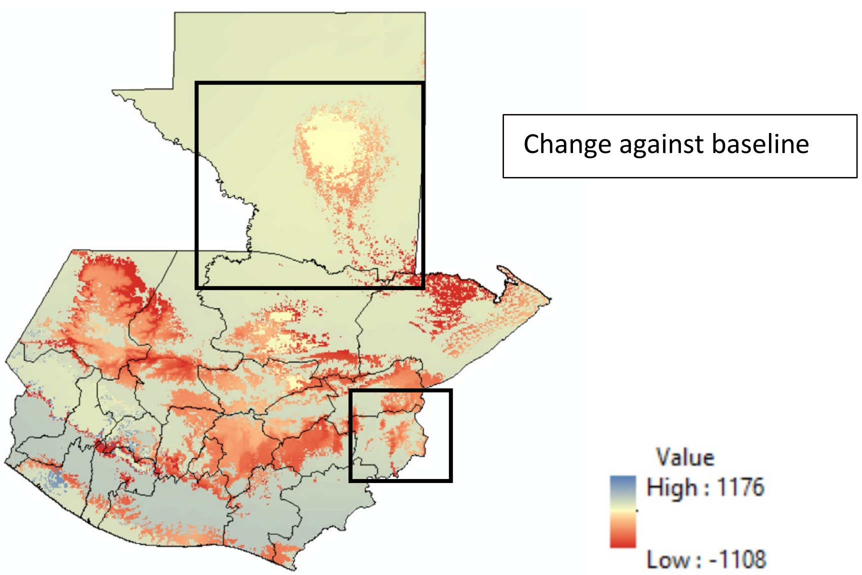
When it comes to precipitation of the Driest quarter the Mayan Lowlands could see a decrease of up to 22 mm. The results for the Dry Corridor area suggest mixed results.

Agricultural Relevance

Similarly to expected reductions in the driest month, precipitation reduction for the driest quarter suggest and overall loss of soil moisture that could affect the sowing process with overall negative impacts on yield.





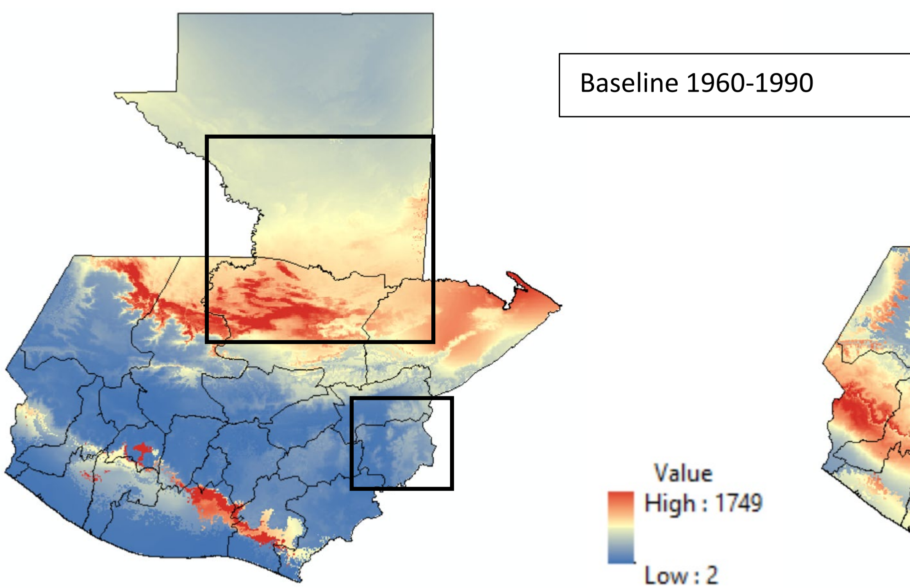


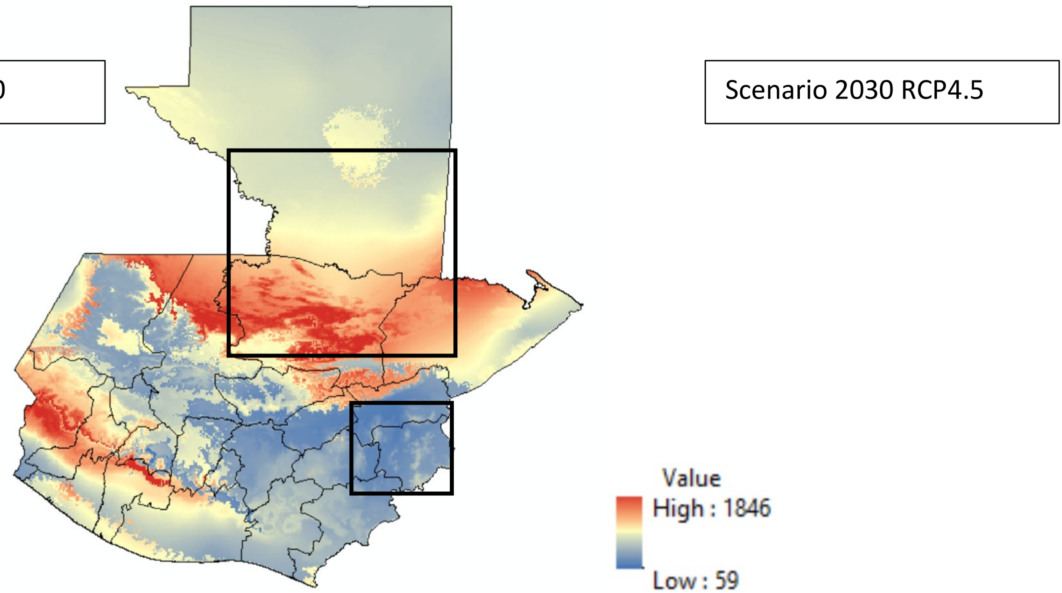
Precipitation of the Warmest Quarter (in mm)

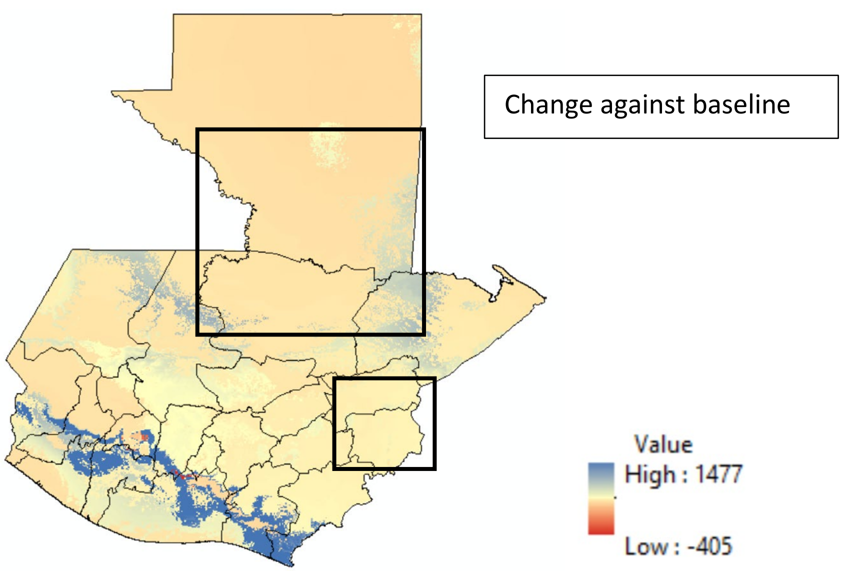
When it comes to precipitation of the Warmest quarter the Mayan Lowlands could see some mild reduction of precipitation, while the Dry Corridor suggests some areas with a substantial decrease in precipitation.

Agricultural Relevance

Although the calculations for the difference between the baseline and projected precipitation of the warmest quarter suggest some substantial increments of rainfall, these only are projected for certain regions in the south slope of the volcanic chain. More important are those substantial negative changes the intervention areas, with direct impacts on critical phenological stages of Maize and Beans in the region.







Precipitation of the Coldest Quarter (in mm)

When it comes to precipitation of the Coldest quarter the Mayan Lowlands and the Dry Corridor could see a mild effect on the precipitation reduction for the season whereas other regions (e.g. the Pacific slope) could see an increment of up to 1477 mm

Agricultural Relevance

Rainfall reduction in the intervention areas is expected with direct effects on soil moisture and hence, negative impacts for sowing of Maize and beans.

C.5. Climate impacts and vulnerability

C.5.1. Historic climate variability impacts in Guatemala

167. According to Emergency Events Database (EMDAT) information of the International Disasters Database (2017), in Guatemala there have been 67 extreme natural events from the 1980s to date, which include droughts, floods, forest fires, storms, landslides and extreme temperatures that have had impacts on the country's human, financial, natural and physical (infrastructure) capital. The records by decade show an increase in the number of extreme events for Guatemala. The occurrence of extreme events increased during 1970s, especially those associated with hydrological changes. Six extreme events were recorded in the 80s, and eight in the nineties. These increased to 25 from 2001 to 2009.

168. During the last seven years, there have been 28 extreme events that resulted in human and economic losses (EM-DAT, 2017). Figure 45. shows the number of extreme events by decades, as well as economic losses, represented in millions of dollars[24], and the number of persons affected by such events.

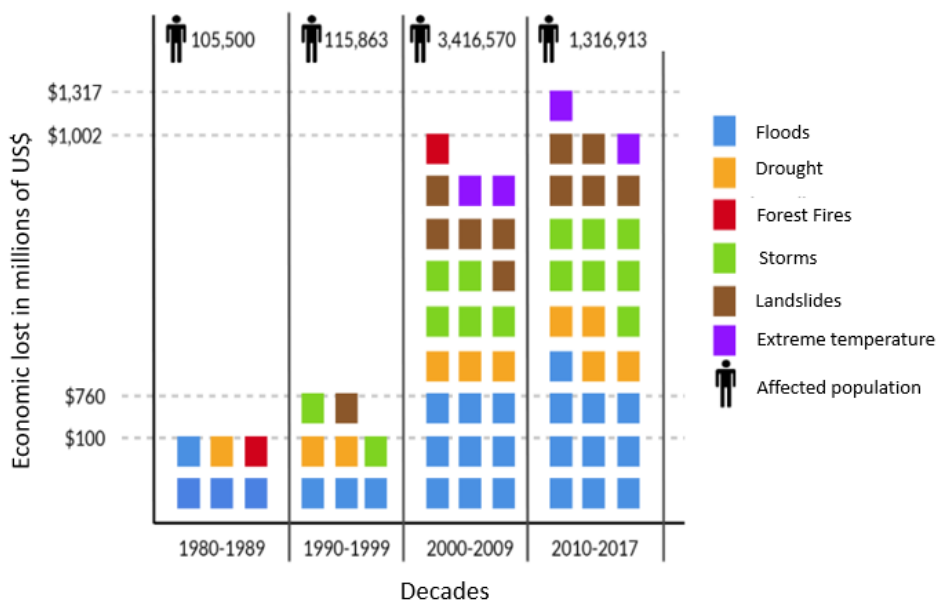


Figure 45. Occurrence of extreme natural events by decade for Guatemala, 1980-2017. Source: developed in-house with EM-DAT 2017 data.

[24] Economic losses do not represent all the events, since the EM-DAT platform does not quantify all the events.

169. According to this information, the occurrence and intensity of extreme events are increasing. Although floods and storms usually draw the media and decision-makers' attention due to their unique nature and intense immediate effects, droughts can cause more damage to the vulnerable population since their effects worsen over time, their area of influence increases and they cannot be easily predicted, which does not make headlines. The impact of a drought on food security affects the young throughout their lives. According to the GEO Guatemala report (MARN, IARNA-URL and UNEP, 2009), 10% of the territory is threatened to a greater or lesser degree by drought events, especially in the "dry corridor", which includes areas in the departments of Baja Verapaz, El Progreso, Zacapa, Jalapa, Chiquimula, Santa Rosa and Jutiapa, some of which will be areas for action under this project.

170. An analysis of the existing information shows that the approximate area of the country that has high and medium susceptibility to drought is 49,430 sq. km (45.4% of the national territory) (MARN, 2007), and according to INE-SEGEPLAN information (2001), more than 1,113,000 people live in areas threatened by desertification (35% of the affected population) (MARN, 2007).

171. The 1994 drought, which had a direct impact on the prolongation of the midsummer drought[25], resulted in losses equivalent to USD 44.5 million. Subsequently, during the 1997-1998 ENOS event, maize harvest losses reached USD 23 million Quetzals. Similarly, economic losses associated with the bean harvest represented USD 4.4 million Quetzals and rice production suffered losses of USD 1.2 million Quetzals. Again, the damage caused by drought in August 2004 shows the threat posed by drought in areas of the dry corridor, as well as the social, economic and institutional conditions that increased vulnerability to such events (MARN, IARNA-URL and UNEP, 2009).

Table 23: Effects of the August 2004 drought.

Department	Affected families	Affected are (ha)	Losses (USD)
Zacapa	4,935	9,469	15,825
Chiquimula	21,156	8,108	28,325
Suchitepéquez	798	3,943	18,758
El Progreso	4,234	5,040	9,759
Jutiapa	1,946	2,296	5,549
Quiché	1,835	2,356	11,160
Total	34,904	31,212	89,376

Source: IARNA-URL, 2012.

172. Mass displacements during extreme weather events have resulted in losses of agricultural and forest soils, loss of trees and crops, silting and debris being washed out to bodies of water, alteration of natural drainage systems and landscape changes. It is estimated that hurricane

[25] In Guatemala, the midsummer drought, known as canicula, is characterized by the reduction or absence of rainfall for a 15-day period and temperature increases in July or August (MARN, 2014). In recent years, however, the midsummer drought has been longer than normal and has resulted in a considerable drop in the amount of monthly precipitation. This phenomenon is known as meteorological drought (Bardales, 2012, cited by MARN, 2014).

Stan alone left 719,800 hectares of soil eroded (ECLAC, 2005), which in turn represents a loss of land productivity.

C.5.2. Impact on the agricultural sector

173. In Guatemala, basic and subsistence crops are greatly affected by extreme weather events such as drought, extreme temperatures, storms or hurricanes, which offer unfavorable conditions for their cycles. Production areas will therefore be displaced and reduced.

174. Since Guatemala is a predominantly agricultural country, the effects of natural disasters on this sector are catastrophic and result in considerable social and economic losses. Conditions that affect national agricultural production are seen during El Niño years. Drought can result in the loss of certain crops; this reduces grain supplies and results in price increases, which inter alia affects food security (Pons, Brincker & Castellanos, 2018).

175. Reduced rainfall during El Niño events in 1972-73, 1976-77, 1982- 83, 1994 and 1997-98 resulted in variations in maize yields. According to a Humanitarian Network report for 2009 (Pons, Brincker & Castellanos, 2018), in 2009 maize and beans, along with sorghum and yucca, suffered losses of more than 50% due to the drought that gripped the country. Similarly, during June and July 2012, there was a considerable drop in rainfall, characterized by INSIVUMEH as a prolonged midsummer drought.

176. As a result of constant monitoring of these rainfall conditions and crop phenological stages, the Ministry of Agriculture, Livestock and Food (MAGA), the Food and Nutritional Security Secretariat (SESAN), the World Food Programme (WFP), the Famine Early Warning Systems Network (FEWS NET) and OXFAM developed a rapid assessment of maize and bean crop losses resulting from a prolonged midsummer drought, determining its impact on the production of basic grains, especially on below-subsistence and subsistence production plots.

Table 24: Basic grain production losses due to the 2012 prolonged midsummer drought.

Department	# of municipalities	Households affected	Area damaged (ha)	Lost area (ha)	Economic losses (USD)
Zacapa	6	6,337	13,612	6,217	2,388,697
Baja Verapaz	7	13,881	11,394	5,555	2,298,947
Jutiapa	17	6,312	10,377	3,282	1,920,711
Chiquimula	9	7,191	5,404	3,246	1,256,053
El Progreso	8	5,782	3,988	2,844	1,216,513
Jalapa	5	5,221	4,508	2,780	1,020,513
Santa Rosa	4	368	724	497	529,211
Huehuetenango	5	6,629	760	496	189,263
Quiché	4	1,551	741	442	175,921
San Marcos	1	25	10	3	1,382
Total	66	53,297	51,518	25,362	10,997,211

Sources: SESAN, MAGA, OXFAM, ACF, WFP, 2013.

177. According to MAGA information (2014), the damage caused by the 2014 prolonged midsummer drought reduced maize productivity by close to 1.8 million quintals and bean productivity by more than 660,000 quintals. The total losses of these two crops due to the midsummer drought amounted to approximately USD 60 million and affected more than 168,000 families.

178. On the other hand, crop losses are also caused by extreme rainfall events such as hurricane Mitch in 1998 and hurricane Stan in 2005. Table 25 shows the impact of both events, which not only directly affected the production of basic grains and the most sensitive rural economies, but also threatened the food security of rural communities whose livelihoods depend on income from their labor from coffee harvesting. Torrential rains from storms or hurricanes during the coffee harvest period when the berries are ready to be harvested have shown to rip the coffee beans from the plants (Pons, Brincker, & Castellanos, 2018).

Table 25: Production and economic losses in the agricultural sector

Event	Total losses in the agricultural sector	Rice production losses	Bean production losses	Maize production losses	Coffee production losses
	Millions of US$	Tons			
Hurricane Mitch	499.4	11,834	2,000	25,277	8,600
Hurricane Stan	77.7	13	2,985	66,209	6,736

Source: Prepared in-house with ECLAC data, 1999 and 2005.

179. Both events resulted in considerable losses of basic crops for domestic consumption, such as rice, beans and maize, and of export products such as coffee. There are also considerable losses in ranchlands, of which close to 50,000 hectares where livestock is raised were affected by Hurricane Mitch; Izabal and Escuintla were the most severely affected departments (ECLAC, 1999). According to the ECLAC report (1999), damage in the livestock sector totaled 3.42 million U.S. dollars, and resulted in export losses of USD 790,000. Hurricane Stan is considered to have been one of the worst disasters ever documented for the country, resulting in the loss of 61,000 hectares of crops, distributed among 15 departments (Mora et al., 2010).

180. The interaction between productive systems and nature, such as pollination, depend on landscape-scale dynamics and climate changes (Hanson et al., 2012). Native forest pollinizers are important for production of the main staples and subsistence crops such as coffee, beans and many other crops, particularly in landscapes dominated by small farmers (Klein et al., 2007). Preserving the forest cover to encourage populations of pollinizers in native forests has shown to improve small farmers' yields by up to 20% in Central America (Ricketts, 2004; Garibaldi et al., 2013).

C.5.2.1. Maize

181. Negative impacts associated with the grain filling period are estimated at the national level, due to the accumulation ranges of higher temperature periods. A reduction in maize yields of between 25 and 50% is thus estimated for 2020 (see Table 23) (Confalonieri et al., 2012).

182. Differentiated local impacts are projected at the departmental level. According to ECLAC (2018) and Schmidt et al. (2012), for 2050, certain departments, such as Totonicapán, will have higher yields, with increases ranging from 9 to 52%. The same authors state that losses of up to 36% will be seen in some lowland departments such as Izabal (see Table 24). The number of departments where yields will be positively or negatively impacted will increase for 2100. In regions such as the western highlands, maize yield increases of up to 19.39% are estimated, whereas losses of up to 39.17% are estimated in departments such as Izabal, Petén and Suchitepéquez under the worst-case scenario (RCP 8.5).

183. It is worth noting that the ECLAC (2018) projections in the tables above used the AR4 Intergovernmental Panel on Climate Change (IPCC) scenarios, whereas Schmidt (2012) uses the of the International Center for Tropical Agriculture (CIAT) scenarios.

C.5.2.2. Beans

184. Bean yield projections under scenarios RCP 6.0 and 8.5 are quite similar to maize projections in that there are differentiated changes: in departments in the western highlands yields will increase, whereas in low land departments there will be losses. For 2020, under the worst-case scenario, six departments would have yield increases, among which Totonicapán would have the highest yields, and another 15 departments would have losses, among which Suchitepéquez would be most severely affected with losses of more than 23% (For details on projected yield changes for 2020 see Tables 26 and 28; changes in yields for 2050 and 2070 can be seen in Tables 27 and 29).

Table 26: Maize yield percentage change projections for 2020 at the departmental level.

	ECLAC 2018		Schmidt et al., 2012	
Departments	B2	A2	With adaptation	Without adaptation
Alta Verapaz	-0.92	-8.99	4.4	-2.6
Baja Verapaz	0.27	-3.80	-2.2	-18.4
Chimaltenango	2.66	-3.24	4.8	-17.2
Chiquimula	-3.75	-11.88	-5.6	-25.8
El Progreso	-1.32	-6.62	9.2	20.5
Escuintla	-6.53	-17.55	-9.2	-27.7
Guatemala	1.18	-3.88	2.4	-17.1
Huehuetenango	1.83	-3.24	13.3	1.7
Izabal	-8.63	-20.73	-3.7	-15.5
Jalapa	0.24	-6.15	1.9	-14.9
Jutiapa	-2.55	-6.86	-4.0	-24
Petén	-6.20	-11.36	-11.2	-32.7
Quetzaltenango	3.92	-2.65	26.3	21.7
Quiché	5.14	-5.20	3.8	-8.7
Retalhuleu	-4.93	-13.28	-13.9	-22.7
Sacatepéquez	1.85	-3.86	6.5	4.5
San Marcos	1.12	-3.71	29.7	23.6
Santa Rosa	-3.26	-6.47	0.3	-7
Sololá	2.49	-2.24	22.8	6.4
Suchitepéquez	-8.10	19.07	-3.0	-13.3
Totonicapán	5.77	1.99	51.6	42.6
Zacapa	-4.17	-9.91	-1.3	-4.5

Source: Adapted from ECLAC, 2018; Schmidt et al., 2012

Table 27: Maize yield percentage change projections for 2050, at the departmental level.

	ECLAC 2018		Schmidt et al., 2012	
Departments	B2	A2	With adaptation	Without adaptation
Alta Verapaz	-4.60	-13.73	4.40	-2.6
Baja Verapaz	2.27	-7.14	-2.20	-17.7
Chimaltenango	2.66	-1.69	4.30	-18.1
Chiquimula	-11.94	-23.69	-5.40	-26.0
El Progreso	-5.93	-13.05	9.30	20.2
Escuintla	-13.09	-28.51	-9.40	-28.1
Guatemala	-0.52	-5.35	-2.70	-17.5
Huehuetenango	2.69	-1.53	13.20	1.4
Izabal	-19.67	-36.47	-3.50	-14.9
Jalapa	-3.23	-10.29	1.80	-13.2
Jutiapa	-7.07	-13.31	-3.40	-22.8
Petén	-14.11	-23.12	-11.40	-33.2
Quetzaltenango	7.31	3.17	26.50	19.9
Quiché	5.95	-2.66	3.90	-9.0
Retalhuleu	-9.90	-20.91	-14.20	-22.6
Sacatepéquez	1.37	-3.42	6.70	0.4
San Marcos	1.53	-2.59	28.90	23.2
Santa Rosa	-7.65	-13.25	0.30	-7.8
Sololá	3.10	-0.31	22.90	6.2
Suchitepéquez	-13.37	-29.78	-1.30	-11.8
Totonicapán	9.49	9.22	51.90	41.7
Zacapa	-11.48	-21.02	-2.80	-6.6

Source: Adapted from ECLAC, 2018; Schmidt et al., 2012

Table 28: Bean yield percentage change projections for 2020 at the departmental level.

Departments	ECLAC 2018		Schmidt et al. 2012
	B2	A2	
Alta Verapaz	8.12	-4.36	-7.0
Baja Verapaz	5.79	-0.19	-7.0
Chimaltenango	19.91	4.34	0.0
Chiquimula	-2.57	-9.79	-8.0
El Progreso	2.10	-3.61	6.0
Escuintla	-7.84	-20.41	-5.0
Guatemala	10.63	-0.24	-3.0
Huehuetenango	21.63	0.00	12.0
Izabal	-9.05	-21.94	-3.0
Jalapa	5.45	-4.90	-1.0
Jutiapa	-2.80	-7.50	-4.0
Petén	-5.47	-5.57	-13.0
Quetzaltenango	131.47	36.76	31.0
Quiché	35.07	-4.17	3.0
Retalhuleu	-3.52	-11.97	-
Sacatepéquez	13.43	1.65	4.0
San Marcos	18.92	3.90	38.0
Santa Rosa	-3.76	-5.58	-1.0
Sololá	23.56	6.97	16.0
Suchitepéquez	-10.80	-23.08	-
Totonicapán	244.97	131.84	23.0
Zacapa	-4.22	-9.15	-8.0

Source: Adapted from ECLAC, 2018; Schmidt et al., 2012

Table 29: Bean yield percentage change projections at the departmental level

Departments	2050		2070	
	B2	A2	B2	A2
Alta Verapaz	8.57	-1.89	12.79	3.11
Baja Verapaz	5.23	-0.19	5.61	0.19
Chimaltenango	22.60	19.01	37.87	37.13
Chiquimula	-5.44	-17.21	-11.47	-25.52
El Progreso	1.16	-6.05	-0.93	-9.55
Escuintla	-13.61	-35.36	-24.56	-52.22
Guatemala	11.23	4.71	16.55	10.87
Huehuetenango	22.52	18.79	42.55	40.43
Izabal	-17.76	-38.02	-32.50	-56.45
Jalapa	6.43	-3.22	8.67	-0.70
Jutiapa	-5.26	-14.78	-10.75	-23.74
Petén	-11.04	-19.24	-23.24	-33.89
Quetzaltenango	147.35	157.06	284.41	308.82
Quiché	40.28	29.17	76.39	71.53
Retalhuleu	-8.10	-21.48	-14.08	-30.99
Sacatepéquez	15.46	10.90	24.84	22.31
San Marcos	18.18	17.07	34.69	32.47
Santa Rosa	-6.91	-15.27	-13.82	-26.42
Sololá	25.48	26.20	47.84	49.76
Suchitepéquez	-16.44	-39.80	-29.27	-57.53
Totonicapán	276.82	338.55	482.96	573.74
Zacapa	-8.07	-18.65	-16.77	-30.04

Source: ECLAC, 2018

C.5.2.3. Coffee

185. According to estimates by Ovalle-Rivera et al. (2015), the areas in the country best suited for coffee growing will be reduced by 2050 by an average of 53% (CIAT, 2012). The slopes to the south of the volcano chain, the north of Zacapa and the east of Chiquimula are the areas that will become least suitable, whereas departments such as Chimaltenango will continue to be suitable for this crop (Baca et al., 2014), since appropriate temperatures for this crop will increase. These temperatures are currently found at altitudes between 400 and 2000 meters over sea level. For 2050, projected temperatures will be found at higher altitudes, approximately 800 to 2500 meters over sea level. This means a net loss of areas suitable for growing coffee (Figure 19.). Projected yield changes in the departments of Guatemala are shown below in Table 27

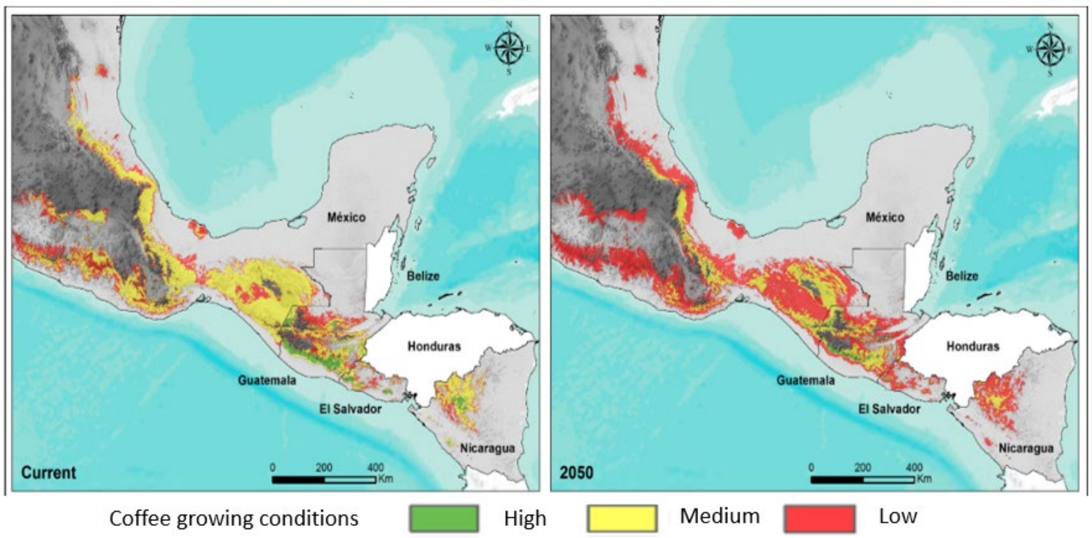


Figure 46. Prediction of climates suitable for Arabica coffee production in Mexico, Guatemala, El Salvador and Nicaragua in 2010 and 2050.
Source: Adapted from Baca, 2013.

C.5.3. Potential impact on water availability

186. Figure 47 represents soil aptitude in areas initially covered with tropical forest vegetation. They will become practically extinct at the end of the century and will change into areas suitable for grasslands. The projected changes in the distribution of natural vegetation at the end of the 21st century may have an impact on local circulation and water resources in the region (Lyra et al., 2017).

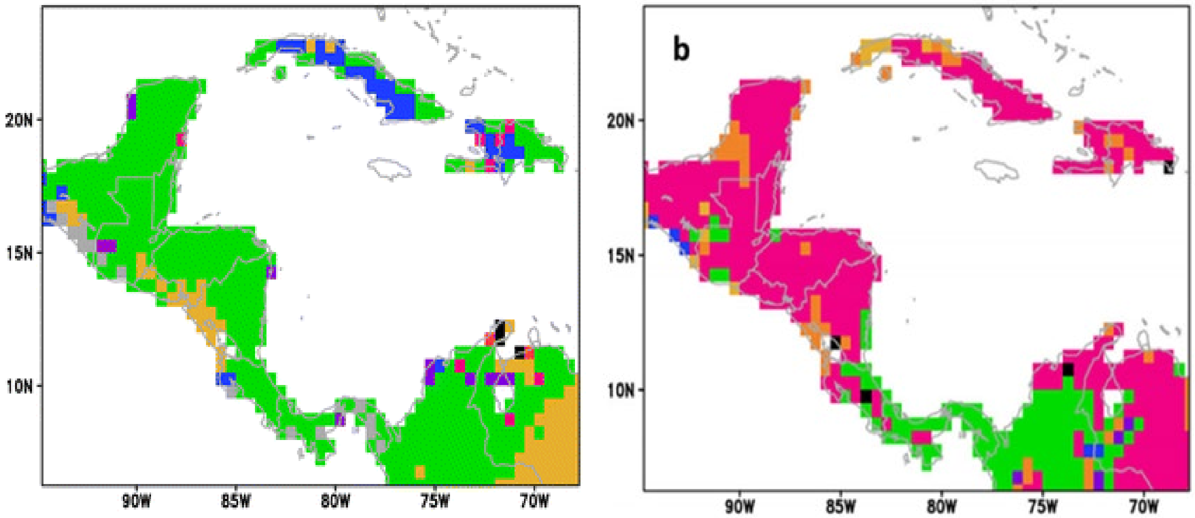


Figure 47. Initial land cover and changes based on RCP8.5 scenario.
Green= Tropical forest at the end of 21 Century for RCP8.5 scenario. Fuchsia = Grasslands.
Source: Lyra, et al., (2017)

Table 30: Coffee yield percentage change projections at the departmental level.

Departments	2030		2050		2070	
	B2	A2	B2	A2	B2	A2
Alta Verapaz	-3.63	-1.45	-4.79	-3.63	-7.11	-9.72
Baja Verapaz	-3.86	0.27	-5.70	-4.51	-9.02	-12.47
Chimaltenango	0.00	2.34	-0.74	1.73	-0.49	0.12
Chiquimula	-9.55	-8.74	-15.08	-17.40	-22.93	-30.87
El Progreso	-5.73	-3.09	-8.71	-9.16	-13.40	-18.67
Escuintla	-9.31	-27.27	-27.60	-43.07	-37.45	-61.26
Guatemala	-1.89	-0.63	-4.62	-3.05	-6.20	-8.61
Huehuetenango	1.54	1.73	0.67	-0.29	1.06	1.25
Izabal	-15.23	-9.12	-17.31	-16.27	-29.33	-33.06
Jalapa	-2.70	-1.24	-6.19	-5.51	-8.32	-12.15
Jutiapa	-9.75	-10.01	-14.49	-17.39	-20.95	-32.02
Petén	-18.93	-13.80	-23.44	-24.30	-48.72	-65.20
Quetzaltenango	2.89	3.81	1.83	3.65	5.18	8.98
Quiché	-7.80	-2.84	-2.37	-2.56	-1.14	-1.99
Retalhuleu	-7.80	-15.60	-17.02	-25.96	-24.11	-38.16
Sacatepéquez	0.44	0.78	-2.11	0.44	-2.33	-2.55
San Marcos	1.17	0.23	-1.87	-2.57	-2.22	-2.80
Santa Rosa	-10.87	-10.97	-15.22	-20.75	-22.43	-35.57
Sololá	0.45	2.63	-0.45	1.09	0.64	2.18
Suchitepéquez	-7.96	-31.22	-27.61	-44.15	-37.94	-61.82
Totonicapán	-5.86	-2.58	-5.04	-1.99	-1.99	1.88
Zacapa	-11.32	-8.65	-15.90	-17.81	-24.94	-32.70

Source: ECLAC, 2018

187. The study suggests that the main reduction of forests in Central America may require more attention and that additional conservation areas should be prioritized to reduce the impacts on biodiversity and water supply. The impacts that are shown have implications for conservation practices and climate change adaptation strategies that should be developed and implemented to improve the resilience of Central American forests to climate change (Lyra et al. 2017).

188. The regions with critical change levels in Guatemala at the short and medium term (2020 and 2050) would be the east-west belts in the center of Petén (Arco de La Libertad), the Northern Transversal Strip and the Motagua, Cuilco and Selegua river valleys, as well as mountainous systems (IARNA, 2011). The same analysis indicates a drastic change in the country's bioclimatic conditions over approximately 90% of its surface, which would reduce the water availability of ecosystems, with implications for them and for biodiversity, as well as for productive systems.

189. Thus, Guatemala might go from being a country with a water surplus to facing major water shortages in the near future; in other words, potential evapotranspiration will be greater than precipitation (IARNA, 2011). According to the 2003 water balance, the total availability of water is 93,338 million cubic meters (GWP, 2017). The diagnosis of the Guatemalan Integrated Water Resource Management Strategy (SEGEPLAN, 2006) reports a total water volume of 97,120 million cubic meters. The country has therefore been historically classified as water stress-free. However, natural events such as El Niño, which represent extreme drought conditions, have serious negative effects on water availability at the local level.

190. In this connection, the volume of water sources for consumption was seen during the 2014 drought; this negatively impacts health and increases the power required for pumping water and drilling new wells, which have negative impacts particularly on the economic sector.

191. Similarly, destruction in water production sectors such as forest areas with natural springs contributed to degradation and imbalance of bodies of water such as water basins, especially on the Pacific slopes. During the 1997-1998 El Niño drought conditions in the country contribute to aggravate the incidence and severity of forest fires, which consumed part of the forests of the department of Petén and other northwestern regions. In Petén, the fires destroyed more than 65,000 hectares of plant and animal life, affecting large parts of the protected areas of the Maya Biosphere Reserve (MBR) (Meerhoff, 2008). According to the Guatemalan Forest Information System (SIFGUA by its Spanish acronym) (2017), a total of 442 forest fires was recorded in 2016, which destroyed approximately 15,000 hectares of forest; and the threat is increasing due to human and economic pressures. There are more than 350 forest fires in the region annually, and the extent of the destruction depends, in many cases, on climate variables such as late onset of the rainy season or extreme high temperatures.

192. Storms and hurricanes also represent a loss of forest cover. For example, it is estimated that 6,200 hectares of riverbank forests were lost during Hurricane Mitch (ECLAC, 1999), which also entails a loss of biodiversity and of certain environmental services such as carbon fixation, soil protection, water cycle regulation, protection of biodiversity and ecosystems.

193. Annual rainfall and changes thereto also affect water availability, for example in the case of the María Linda River basin, which flows into the Chiquimulilla canal. The accumulated annual precipitation for this basin is 1,700.2 mm; however, during the 1997 El Niño event, annual precipitation dropped to 1,592.7 mm (Läderach, 2013). Similar effects can be seen on the basins of the Samalá and Los Esclavos rivers; the latter shows a total deficit of -9.9% for 1997 and a gain of 16% for 1998 compared to the normal values. The most significant drops in precipitation during 1997 were recorded as of July. The volume of this river also fell up to 40.2%, which makes that a dry year. Accumulated rainfall deficits were recorded for the first semester of 1998; however, there was excessive rainfall for the second semester, which also explains the increase in river volume, which makes this a wet year (INSIVUMEH, 2002).

194. Finally, in the Chixoy river basin the effects were different from those on the other basins analyzed. For this river, during both years with El Niño events there were gains in both rainfall and river volume. There was excess precipitation during all of 1997, with the exception of August, when there was a slight shortage. The opposite was seen for 1998, since there was a shortage of rain from January to October and excessive rainfall in November and December, which raised the annual precipitation above the normal level. This change in precipitation was reflected in the river volume (INSIVUMEH, 2002).

195. Extreme events such as these are due to climate variability. However, reduced water availability has been seen during the last few years at the local level due to a gradual change in average weather conditions. There are regions, such as the dry corridor, where one can even speak of a certain degree of aridity. This reduction, when projected to future years, would be even more severe. Thus, for 2100 more than half the water available per capita will have been lost, as seen in Figure 48.

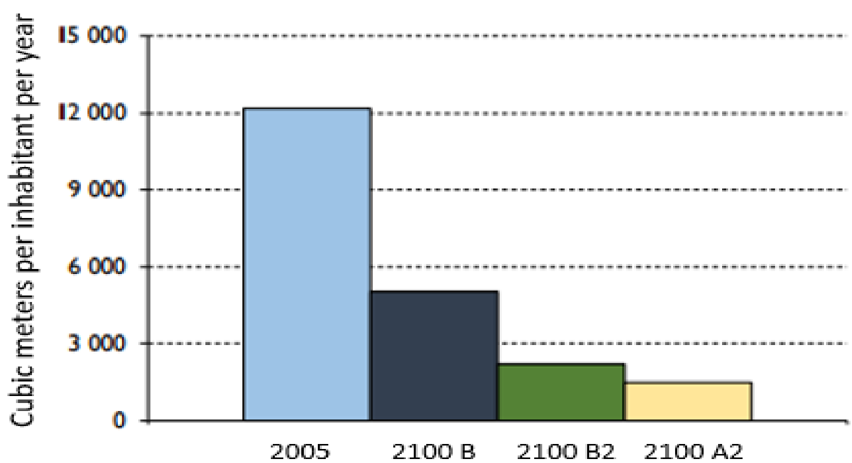


Figure 48. Projected water availability per capita.
Source: ECLAC 2018.

196. This is especially problematic if one considers the growing demand for water in the country. According to Population Reference Bureau estimates (2016), the country's population will increase

to 27.6 million inhabitants by 2050. Consequently, an increase in urban areas and use of the land for production will increase, thus reducing wooded areas and natural water sources. The need for water for agriculture, industry and municipal use will increase exponentially during the next century (Table 31).

Table 31: Total water demand with basic scenarios B2[26] and A2[27], 2000-2100.

Total demand								Variation with respect to 2000			
Scenario	2000	2020	2030	2050	2070	2100	2020	2030	2050	2070	2100
Base	5,141	9,259.90	12,344.8	21,220	32,591.7	90,843.20	80	140	324	651	1,667
B2	5,115	10,872.00	14,53543	26,121.7	46,976.7	1 10 986.6	113	124	411	818	2,070
A2	5,118	10,893.00	14,467.3	25,923.4	46,72.7	1,135,134.60	113	183	406	1313	2,119

Source: ECLAC, 2018

SECTION D. Vision of the Project

197. This section provides a detailed description of the proposed project, on the basis of the issues identified which were introduced in the first part of this section. A description of prioritized areas and beneficiaries follows, describing how they were identified/prioritized, as well as adaptation barriers that the project must bear in mind. Then there is a description of the proposed activities to address these issues and help reduce the impacts of climate change on the prioritized populations.

D.1. The Problem at Hand

198. As stated in the previous section, Guatemala is highly vulnerable to the effects of climate change. Populations living in poverty and extreme poverty are most affected.

199. From 2001 to 2014, the average temperature (1970/2000 being the baseline) increased throughout Guatemala. Temperature projections show a rising trend, with expected increases for the decade of the 2050s between 2.5 and 4.1ºC. (MARN, Segunda Comunicación Nacional Sobre Cambio Climático, 2015) (MARN, Second National Climate Change Communication, 2015).

200. As a consequence of the above, recent regional climate models suggest increased water shortage in the country’s dry regions (East), but they also suggest considerable changes in traditionally humid areas where most of subsistence agriculture is concentrated (including the project area that includes the south of Petén, Alta and Baja Verapaz) (Pons, Brincker, & Castellanos, 2018).

201. Climate change is also expected to affect the water cycle in Guatemala, with scenarios showing an increase in climate variability, as well as increasingly frequent dry and very dry years. Historically, Guatemala has been a low water stress country, but currently approximately 45.4% of the country (49,430 sq. km) shows mid to high susceptibility to drought (MARN, 2007).

[26] Scenario AR4 IPCC equivalent to RCP 6.0
[27] Scenario AR4 IPCC equivalent to RCP 8.5 (Rogelj, Meinshausen and Knutti, 2012).

202. Small farmers' vulnerability to drier conditions is high (particularly to drought and midsummer drought) and the main factor that affects their ability to adapt is that they depend to a large extent on rain-fed agriculture. The population in drought-prone areas includes 13% (1,113,000) of the national population, including 387,000 indigenous people (MARN, 2016).

D.1.1. The Climate Problem for Food Security

203. IN 2014, the World Health Organization (WHO) made projections estimating the number of preschool children with chronic malnutrition at the global level for 2030 and 2050, under two scenarios: one considering climate change and one without considering it. The results showed that for 2030, under the climate change scenario, an increase of 7.5 million preschoolers with chronic malnutrition is expected, in comparison with the scenario without climate change (WHO, cited by INCAP, 2017).

204. The 2014 prolonged midsummer drought affected 22 departments and 208 of Guatemala's municipalities. The maize and bean crops of close to 170,000 families suffered damage. Losses of close to 86,900 tons (1.8 million quintals) of maize and 30,400 tons (661,000 quintals) of beans were recorded. These losses affected approximately 80% and 63% of maize and bean subsistence production, respectively, which resulted in economic losses of USD 61 million. The worst impacts were experienced by below-subsistence and subsistence producers, who cultivate an average area of 0.6 ha, with a median of 0.2 ha, to produce basic grains for self-consumption, mainly of maize (94.1% and beans (46.7%) (SESAN, 2014). It is estimated that around 236,000 families experimented total or partial crop losses, which negatively affected their food security. In the specific case of the project area, this weather event affected 40% of the total area used by subsistence and below-subsistence growers (12,090 ha) and caused losses of USD 11.6 million. For more details, see Table 32).

Table 32: Damage caused by the prolonged drought in 2014 in five departments prioritized by RELIVE Project

Department	Number of Municipalities	Number of Families Affected	Damaged area partially occupied by families at below-subsistence and subsistence socioeconomic levels (ha)	Damaged area totally occupied by families at below-subsistence and subsistence socioeconomic levels	Estimated revenue reduction in USD
Alta Verapaz	1	2,315	283	31	241,909.77
Baja Verapaz	8	12,782	6,482	3,739	5,537,066.94
Chiquimula	11	30,860	14,912	7,971	12.737.649.41
Petén	10	791	790	296	5,211,001.11
Zacapa	6	11,888	849	53	675,070.07
Total	**36**	**58,636**	**23,316**	**12,090**	**11,665,047.89**

Source: Sesan (2014)

205. This shows that agriculture is very sensitive to climate change in the project area (ECLAC, La economía del cambio climático. Technical paper 2018) (SGCCC-CEAB/UVG, 2017). It is also estimated that for 2070, between 40 and 70% of losses due to climate change will affect the agricultural sector, which will result in reduction of the GDP of 3 to 5% (Pons, Brincker, & Castellanos, 2018).

206. Studies have shown that unless farmers adapt their growing practices, agricultural productivity will decrease as a result of exposure to projected climate conditions: temperature increasers, reduced precipitation and increased duration of the dry season (Lyra et al., 2017). The Guatemalan Second National Communication on Climate Change indicates that small farmers' response capacity is very low, since only 16% of the farmers interviewed have taken specific steps to adapt in spite of average losses of 55% of their production of basic grains during drought periods (MARN, 2015).

207. The above threatens the food security of the population in the project area in two ways: the first by affecting family vegetable plots and basic grain production from which families can obtain their food directly, and the second by affecting agro-forestry systems such as coffee and cacao, where productivity drops and hence the income earned by families from these systems, either by selling their products or because they are employed in different production stages, especially in coffee harvesting, since many people migrate to work as day laborers in coffee plantations (this last point is addressed below).

The climate problem faced by coffee growers

208. Projections show that due to climate change, traditional coffee-growing regions might disappear, and new growing areas might appear. For example, projections of the effect of climate change on coffee-growing areas in Guatemala indicate that coffee production will move to places with more favorable climate conditions for the crop, located between 800 and 2,500 meters over sea level. On the contrary, current coffee-growing areas located between 400 and 2,000 meters over sea level will lose most of their productive capacity. Generally speaking, a 19% reduction in the area suitable for growing coffee of the Arabica variety is predicted, which represents around 126,050 ha (excluding protected areas), although increases of areas suitable for its production at elevations between 1,500 and 2,000 meters over sea level are predicted (Ovalle-Rivera, Laderach, Bunn, Obersteiner, & Schroth, 2015).

209. The incidence of the disease caused by the Hemileia vastatrix fungus, known as coffee rust, is one of the worst problems affecting coffee production. This disease has recently experienced a resurgence due to a series of factors. One of them is a reduction in the range of daytime temperatures, considered to be the main cause of the epidemic resurgence of rust in 2011-2012. Measurements conducted in 2012 compared with measurements in previous years in 1,225 plantations in Guatemala (Avelino, 2015) reported changes in the average temperatures expected (both low and high), of +0,9°C-1,2°C. It is estimated that this temperature variability has reduce the latency period of the disease, creating favorable conditions for the development of the epidemic. According to estimates developed in 2013 in project areas, between 31% and 53% of the planted area was affected by rust, whereas the incidence of rust in September 2017 was 9.5% - 17.5% on average, respectively. Based on the above, it is expected that temperature increases in the RELIVE work area will have a direct impact on crop yields.

210. In Project influence area, most growers implement comprehensive measures (including shade management, fertilization and chemical control) for rust control (Chocooj & Morales, 2017), but

without appropriate techniques, which does not make it possible to efficiently reduce the damage caused by the disease. Although a specific model for predicting rust damage does not exist, it is known that changing climate conditions and extreme events associated with climate change favor the incidence and severity of rust in coffee plantations, resulting in production losses (Avelino, 2015).

211. Coffee production losses affect growers who depend directly on coffee, such as coffee plantation owners, and families that migrate from their homes to coffee-growing areas to work on the coffee harvest. For the producers, revenues are reduced by losses, and since their coffee plantations are not diversified, they incur a high financial risk because they depend on a single product. For laborers, as coffee production decreases, families are no longer hired and they lose an important source of revenues, sometimes the only one available.

D.1.2. The Climate Problem Faced by Cacao Producers

212. Most cacao-producing areas in Central America are currently located on the Atlantic slopes, with rainfall of more than 2,000 mm/year (except in El Salvador). At these places, reduced rainfall would not considerably affect cacao yields, since the plant requires about 4-5 mm/day 1,600/1,800 mm/year) to develop and produce (Carr & Lockwood, 2011). However, drier areas would be more conducive to the development of insects that attack cacao, instead of the fungi that attack it with the current humid climate of the Atlantic region of the isthmus. Current physiological models indicate that changes in accumulated rainfall, the pattern of occurrence during the year and temperature changes might explain up to 70% of variations in subsequent harvests (Zuidema, 2005). According to model estimates, the yield of this grain might go down by 15%-35% as a result of less rainfall and higher temperatures.

213. On the other hand, temperatures will increase by 2-3oC in almost all cacao-producing regions in Central America; however, direct effects are not expected on the physiology of the plant because cacao resists high temperatures (Abdulai, 2017). However, temperature increases and changes in the rainfall calendar might increase the incidence and severity of pests and diseases, which might in turn reduce yields. Expert agronomists suggest that losses due to moniliasis, “Mazorca Negra” and eventually the arrival of witches ‘broom in Central America might affect between 30%-60% of regional production (Phillips-Mora, Ortiz, & Aime, 2006).

214. The combined effect of reduced yields and increased damage caused by pests and diseases, exacerbated by climate change, will result in a drastic crop reduction, resulting in significant economic losses for rural families. Assuming and average regional yield of 275 kg/ha/year (i.e. without using new varieties and with traditional crop management) growers might lose between 175-200 kg/ha/year. Based on a median price of U$1.75/kg of cacao, harvest reduction is estimated at US$300-450/ha/year. Under this scenario, appropriate use of shade, new varieties and integral management of the system might be the simplest solution for dealing with temperature increases, on-site water management and facilitating agro-ecological crop (Harvey, 2014) (Tscharntke, 2011). Field research and simulation exercises indicate that a shade level of 55% is “optimal” for harvesting about 585 kg/ha/year of cacao while carbon is sequestered in the

order of 65 Mg/ha-1 (Schroth et al., 2014). However, this shade level must be adjusted to each growing area (Somarriba, 2013).

215. Economic losses due to the combined effect of climate change and pests and diseases might be more severe in Guatemalan cacao growing regions. For example, the results of diagnoses conducted in cacao plantations in Alta Verapaz indicate that they were planted between 1985-1990 and it is estimated that the age of 35% of the planted area is advanced (30 years) and most of the hybrid genotypes are susceptible to moniliasis. Among the varieties grown, considerable differences can be detected in the incidence of moniliasis, some incurring losses of more than 70%. In this context, cacao is more vulnerable to changing climate conditions. The use of new disease-resistant genotypes, integral agronomic crop management and nutrient management are the principal means for making cacao growers more resilient (CATIE, 2018a).

216. According to Leandro-Muñoz et al. (2017), temperature is the most determining factor for the appearance of moniliasis signs and symptoms. Warm temperatures favor the appearance of symptoms and significantly reduces the latency period of this fungus. Other authors state that changes in rainfall dynamics might favor pathogens that are more dependent upon water, such as the fungus that causes “Mazorca Negra”, cancer of the trunk and other vascular diseases. That is why it is very important for value chain actors to be aware of soil use aptitude change trends to be able to design short, medium and long-term mitigation and adaptation strategies that ensure growers’ livelihoods and sustainable cacao production.

D.1.3. The Climate Problem, Water and Forests

217. As already explained in earlier sections, climate change in Guatemala will result in increased temperatures and reduced precipitation, which will turn water into a scarce resource in comparison with the current situation. With regard to precipitation, the volume of rain is expected to go from 61,826.61x106 m3 (which is the average value for the period 1997-2000) to 45,840.15 x106 m3, which means a potential reduction of 26% with respect to water recharge. Changes in water recharge will be mainly due to lower precipitation volumes and increased evapotranspiration.

218. At the departmental level, reduced rainfall between 1997-2000 and the decade of 2070 is of the order of 40% for Petén and 31% for Baja Verapaz. The most significant reductions in recharge are seen in Chiquimula (91%), Baja Verapaz (71%) and Petén (74%). All of them are considered for project implementation. Rainfall will drop in the prioritized municipalities during the aforesaid periods by 1% to 53%. There are reductions in water recharge that range between 3% and 100% (for the municipality of Chiquimula).

219. In a climate change context, where water will become a scarce resource, forests play a fundamental role. Work done by Bruijnzeel (1988) shows that forests allow more water to infiltrate, which not only feeds water tables, but also increases the water available during the dry season. In a study of paired basins, Álvarez (2010) showed that basins with adequate forest cover management can produce up to 25% more water during the dry season than poorly managed ones. This clearly shows the role and importance of natural forests, especially in high parts of the

basins, since their value lies in their function for providing water, particularly during the dry season, since water is a critical factor, especially when strategic aspects that go from productivity (in quality and quantity) to local governance aspects depend on this element.

220. A study of the dynamics of forest cover in Guatemala during 1991, 1996 and 2001 and the 2001 Forest Cover Map (INAB, CONAP, & UVG., 2006) showed that each year between 1991/93 and 2001, the country lost an average of 73,148 ha of forest each year, or an annual deforestation rate of 1.43%. This loss is concentrated in the department of Petén, where an annual average of 47,412 ha disappears. In relative terms, however, Chiquimula is the department that lost more forests during the 10 years under study, at an annual rate of 2.46% with respect to the original forest, whereas Petén ranks third, with a deforestation rate of 1.81%, below Jutiapa with 2.17%.

221. The following information shows the net departmental rate and annual departmental rate of change for the period in the departments of interest, prioritized for the green climate fund.

Table 33: Net change by department and annual departmental rate of change for the indicated period

Department	Net departmental change (ha)	Annual departmental rate of change (%)
Alta Verapaz	-50,290	-1.22
Baja Verapaz	-8,408	-0.64
Chiquimula	-14,388	-2.46
Petén	-331,034	-1.81
Zacapa	-12,188	-1.34

Source: INAB, CONAP, UVG (2006)

222. This information shows that implementation of natural forest management activities (practices and means of adaptation) for conservation and production purposes, especially on water, are strategic for ensuring the permanence of the forest cover in basins where the municipalities of interest are located to reduce the risks due to drought and/or floods.

D.2. Location

223. This section explains the methodology chosen to prioritize and select project areas (municipalities). It includes a description of the process and maps that illustrate this process.

D.2.1. Methodology Used to Prioritize Work Areas

224. The project areas were prioritized based on a methodology, which uses a combination of criteria on climate risk and exposure combined with socio-economic indicators, which characterize the adaptive capacity of the population. The identification of the prioritization criteria was informed by experts' opinion and outcomes from a consultation with the NDA and other key stakeholders. The prioritization was conducted at two levels:

Level 1 – Identification of areas with high climate risk

Level 2 – Identification of municipalities with population with low adaptive capacity

Level 1 – Identification of areas with high climate risk

225. At this level of prioritization, the following variables were used to identify the areas with high climate risk (Figures 26 - 28):

226. A composite index was implemented to determine the specific areas, which was derived based on the conceptual framework suggested by the Intergovernmental Panel on Climate Change (IPCC) under the AR5 climate change adaptation report (IPCC 2013) which suggests that the risk from a climate hazard (such as aridity) can be determined by the intersection of three areas: vulnerability, climate hazards and exposure.

227. Derived from this, the aridity calculations were used as the hazard (climate threat); lack of forest cover as vulnerability; and the percentage of agriculture per municipality as exposed systems (exposure). The reasoning behind the use of an aridity index as an important component for assessing the climate risk of the country's rural communities is that this is a good indicator of the regional climate (Marengo & Bernasconi 2015). Based on the strategic hydrological landscape restoration objectives of this study, we chose to select those areas that have been degraded and therefore have forest restoration potential (areas vulnerable to aridity change). Finally, the risk was determined by the geographical location of subsistence and coffee farming systems. The intersection of these indicators allowed the calculation of risk at the country level to determine priority regions within the country.

228. In this way, calculations were made for the years 2030, 2050 and 2070 under different scenarios of greenhouse gas concentrations. The results suggest that the regions of the northern, southern Petén, western and dry corridor could be affected by the change in aridity in their municipalities and by the amount of subsistence agriculture that depends almost entirely on rainfall. In addition, most of these regions have a high capacity to restore strategic hydrological landscapes. After determining the prioritization of the areas from a technical perspective through the composite index, the results were presented to key stakeholders to identify a final list of prioritized municipalities.

229. Below are the three variables that make up the Risk Index. This index is useful only to determine which rural agricultural communities at the municipality level are most exposed (as a % of the municipal territory dedicated to annual agriculture and/or coffee), in which of them there is restoration potential (as a % of the municipal territory with forest restoration potential) and which of them will experience the greatest climate threat (as a % change in aridity). The variables used are described here:

230. - % of change in aridity: The aridity calculation for the Guatemalan territory was estimated following the methodology described in Section 4. Then, the change between the projected aridity and the aridity calculated for the baseline was calculated. This difference was then transformed into a percentage and finally expressed as a proportion. There are places in the country that become more arid and places that become less arid. This variable was used to estimate the risk index by identifying, which areas most exposed to change in aridity according to projections for RCP 2,6, RCP 4,5 and RCP 8,5 for the years 2030, 2050 and 2070. The prioritized municipalities

have a projected increase of aridity with more than 50% by 2030 from the baseline 1961-1990. With the increase in aridity in these areas, the agricultural production will be affected.

231. - % of the municipal territory dedicated to annual agriculture and/or coffee: For this particular project, it is of interest to select areas where the poorest and most vulnerable population is located, for this reason the areas with medium and large size of agricultural production in the country were excluded from the risk analysis. Therefore, priority was given to those crops that make up the food security of rural families. All annual crops plus coffee (perennial crop) were selected as the crops that are important for food security. The exposure of the municipalities to climate change, which sustain the majority of the agricultural production, also supports the food security of rural families.

232. - % of the territory with forest restoration potential – Guatemala has the highest percentage of degraded land (58.9 percent) in Central America (Magrin et al., 2014), mainly as a result of agricultural intensification and expansion. The National Institute of Forests (INAB) has identified areas with potential for restoration. These areas include the classes of: Agroforestry with annual crops, agroforestry with permanent crops, silvopastoral systems, forest production lands, forest protection lands and protected areas. For this index, the classes of production forest land and protection forest land have been grouped together.

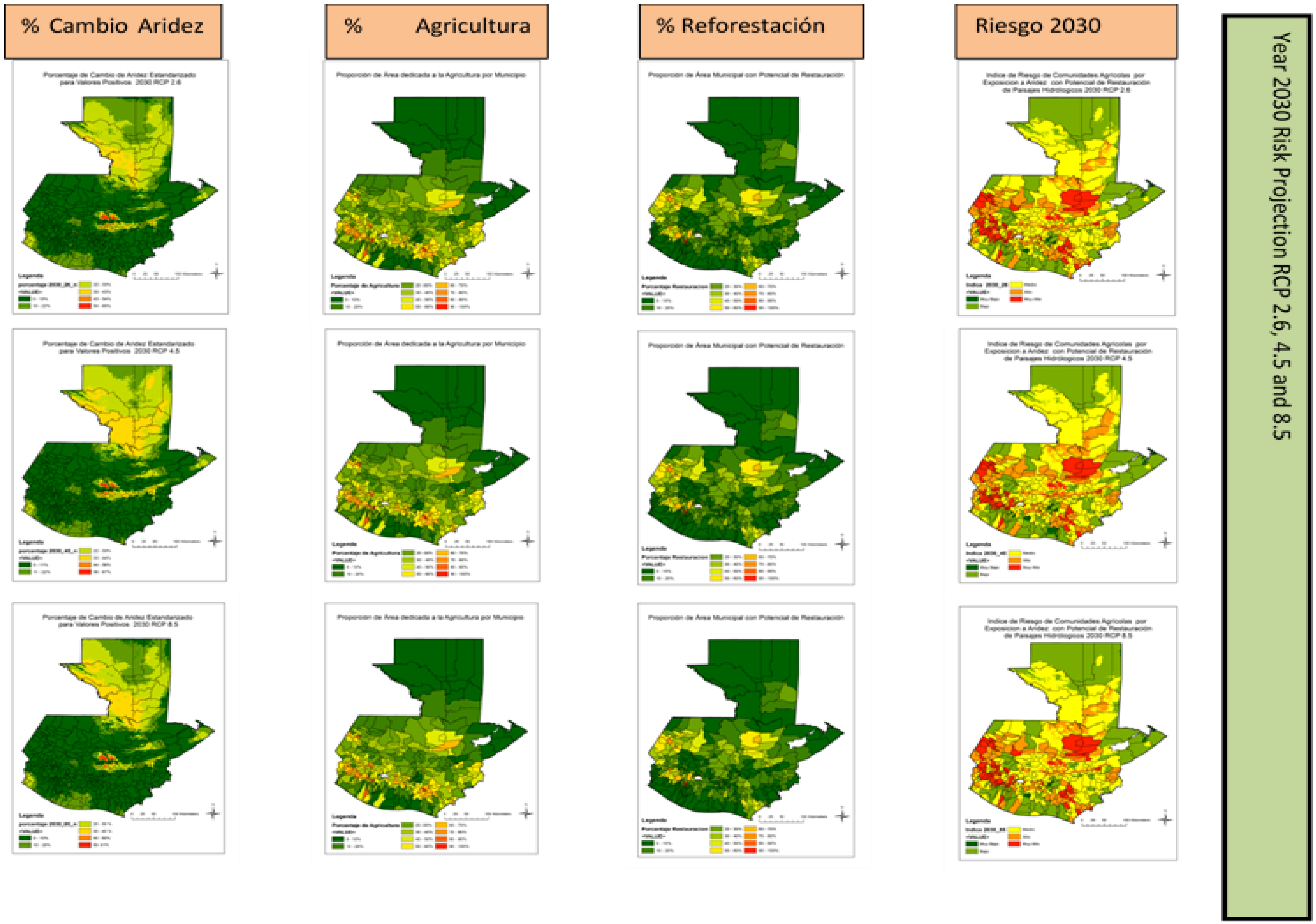


Figure 49. Estimation of the climate risk index for RCP 2.6, 4.5 and 8.5 for 2030.

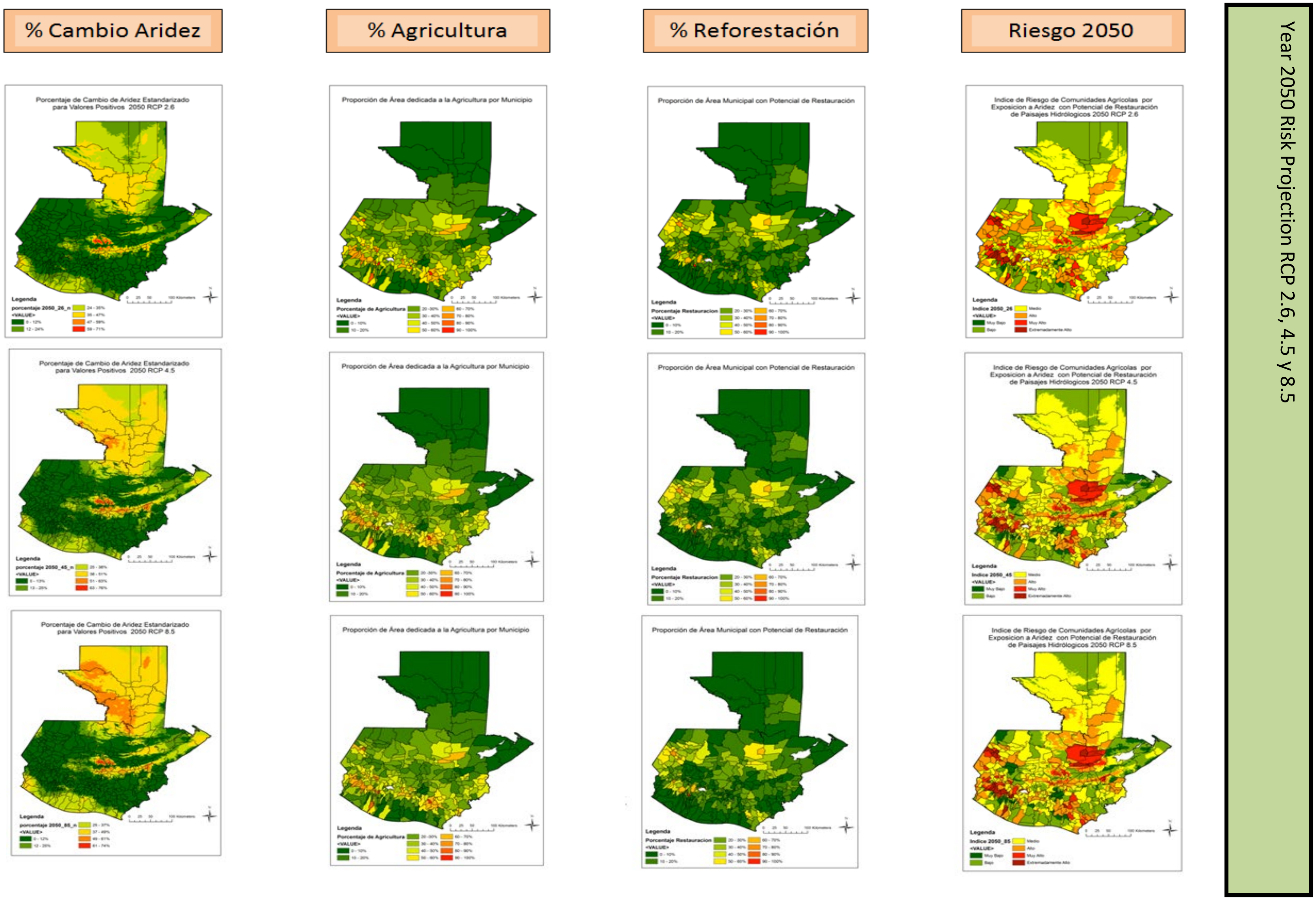


Figure 50. Estimation of the climate risk index for RCP 2.6, 4.5 and 8.5 for 2050.

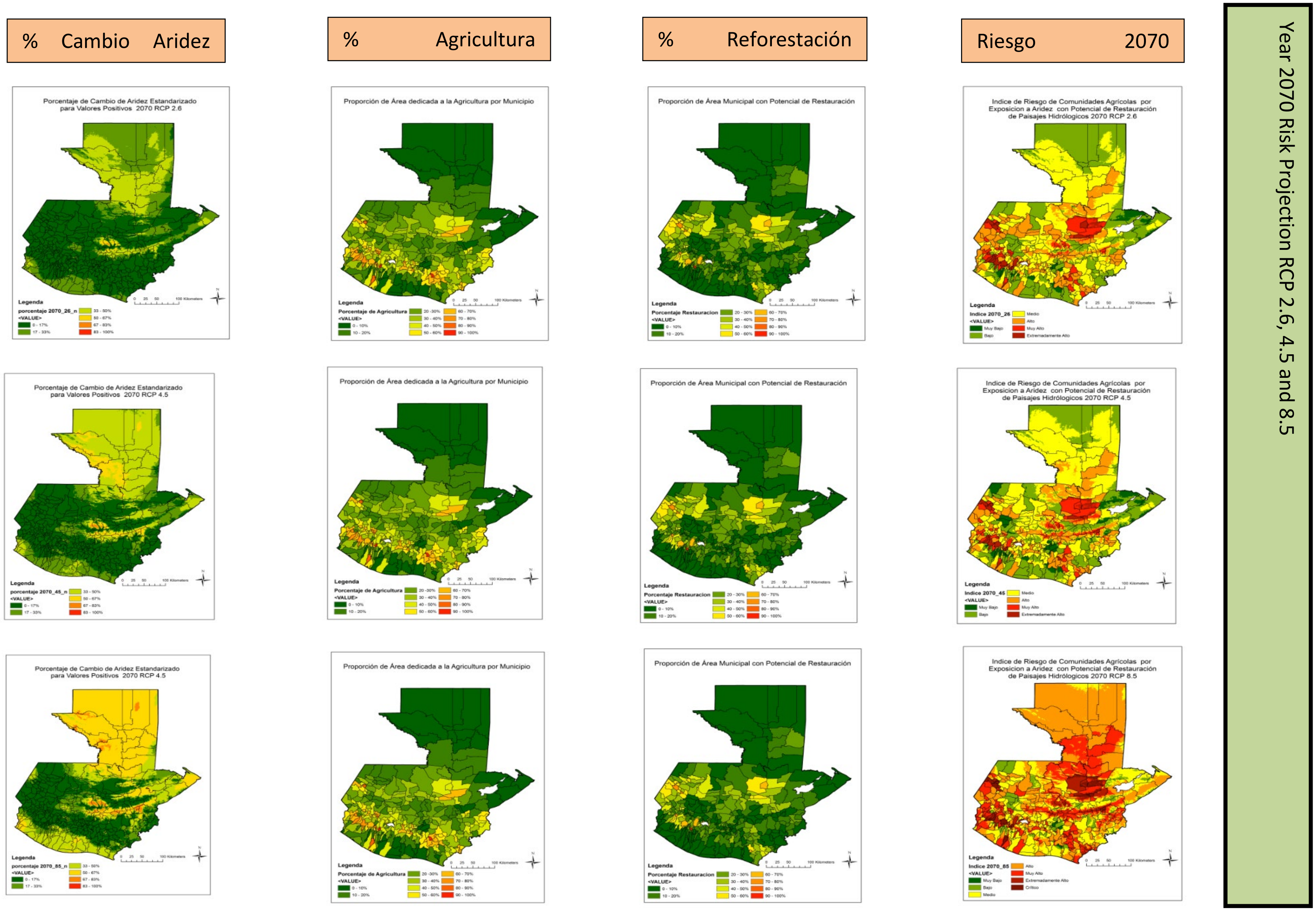


Figure 51. Estimation of the climate risk index for RCP 2.6, 4.5 and 8.5 for 2070.

Level 2 – Identification of municipalities with population with low adaptive capacity

233. At this level of prioritization, the results for the climate risk index for RCP4.5 for 2030 were considered. The regions whose risk was assessed as high and very high, i.e. one and two standard deviations from the mean respectively, were selected. Based on this criterion, municipalities were selected whose territory was exposed to 10% or more of the total area of the territory. As a last step, a filter was carried out to exclude those municipalities in which there is intervention by other projects.

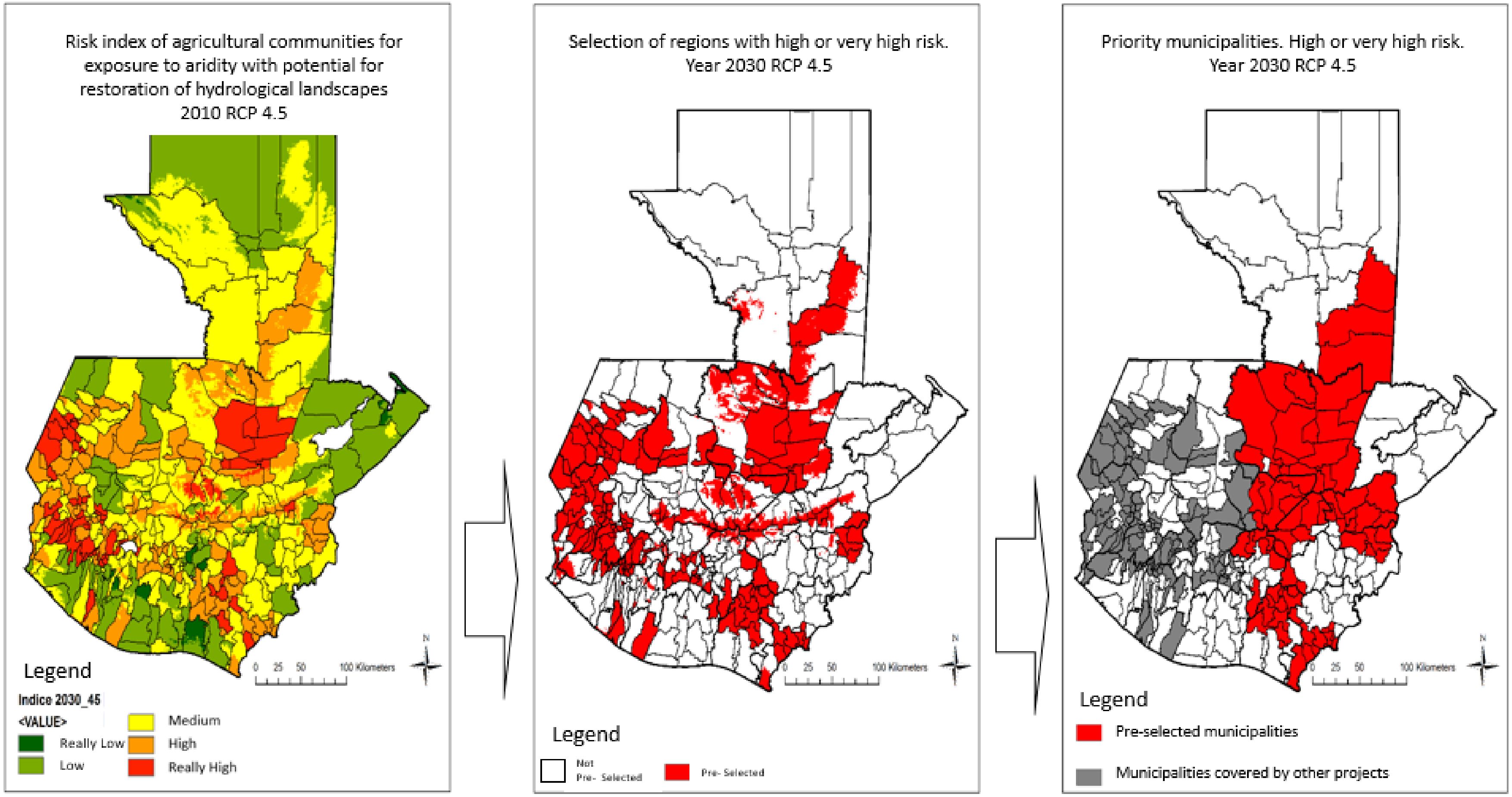


Figure 52. Illustrative sequence showing how the first selection process of municipalities prioritized for the project was conducted.

D.2.2. Prioritized Areas

234. Because the total number of municipalities (and hence the working area) was very large (73 Municipalities), an additional prioritization was based on the populations' vulnerability. The following indicators were used for this purpose: (1) total poverty higher than the national average (more than 61%); (2) extreme poverty higher than the national average (higher than 25%); and (3) that the municipalities are prioritized by the National Chronic Malnutrition Strategy (areas with high and very high chronic malnutrition). After applying the selection methodology (see the previous section), a total of 29 municipalities in the departments of Alta Verapaz, Baja Verapaz, Petén and the eastern departments of Zacapa and Chiquimula were selected. The following table shows the list of municipalities by department and region (see Table 34), as well as their location in the country (see Figure 53).

Table 34: List of prioritized municipalities

No.	Municipality	Department	Region
1	Chisec	Alta Verapaz	Alta Verapaz
2	Panzós	Alta Verapaz	
3	Santa Catalina la Tinta	Alta Verapaz	
4	Tucurú	Alta Verapaz	
5	Cahabón	Alta Verapaz	
6	Cobán	Alta Verapaz	
7	Fray Bartolomé de las Casas	Alta Verapaz	
8	Lanquín	Alta Verapaz	
9	San Cristóbal Verapaz	Alta Verapaz	
10	San Pedro Carchá	Alta Verapaz	
11	Santa Cruz Verapaz	Alta Verapaz	
12	Senahú	Alta Verapaz	
13	Tamahú	Alta Verapaz	
14	Chahal	Alta Verapaz	
15	Raxruhá	Alta Verapaz	
16	San Juan Chamelco	Alta Verapaz	
17	Tactic	Alta Verapaz	
18	Purulhá	Baja Verapaz	Baja Verapaz
19	Rabinal	Baja Verapaz	
20	San Miguel Chicaj	Baja Verapaz	
21	Jocotán	Chiquimula	Oriente
22	Camotán	Chiquimula	
23	Chiquimula	Chiquimula	
24	Olopa	Chiquimula	
25	San Juan la Ermita	Chiquimula	
26	La Unión	Zacapa	
27	San Luis	Petén	Petén
28	Dolores	Petén	
29	Poptún	Petén	

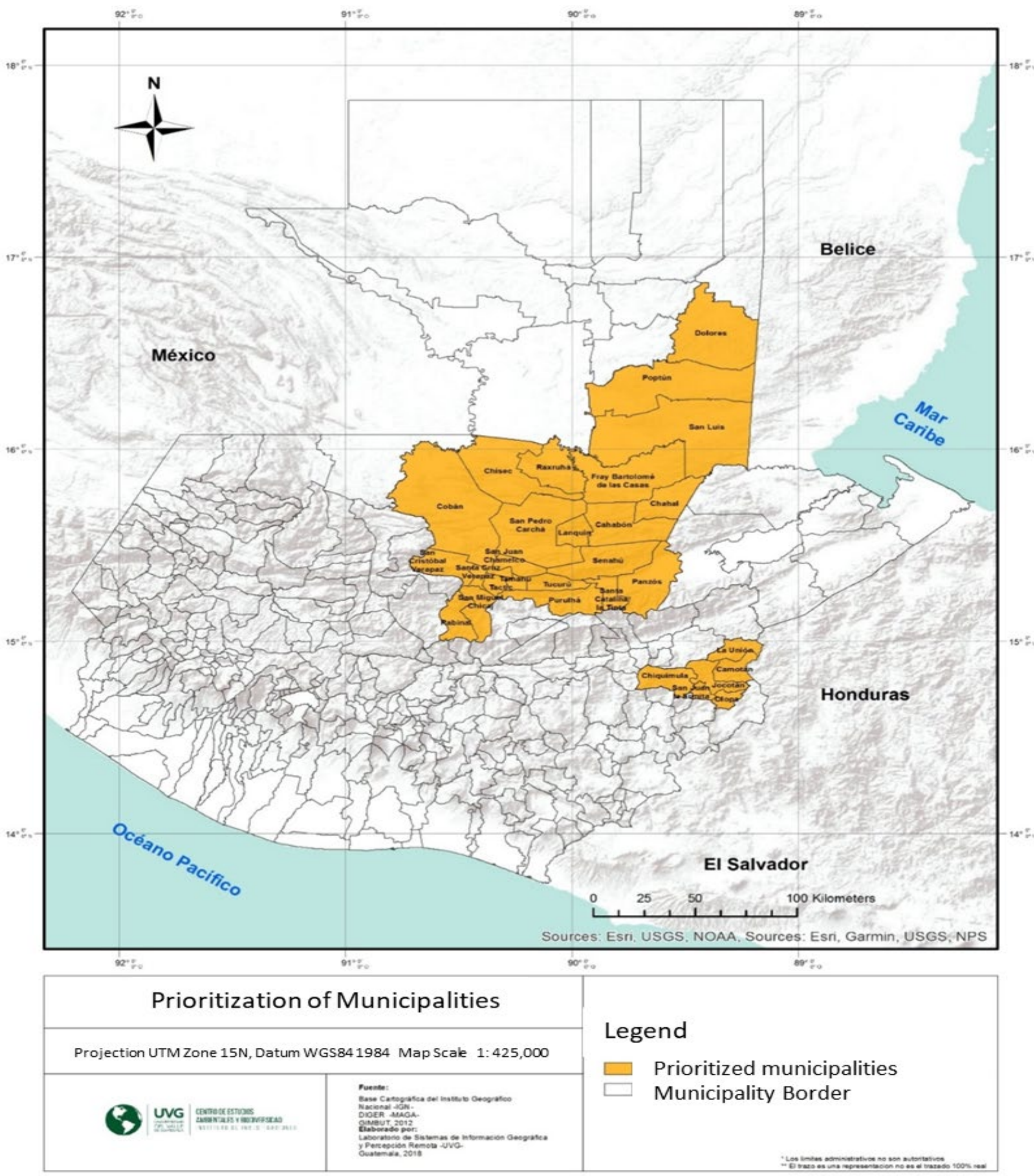


Figure 53. Map showing the location of prioritized municipalities.

235. Given that these 29 municipalities comprehend a vast area, a secondary analysis (based on the results in the landscape identified with the climate vulnerability analysis) was developed to prioritized the specific watershed were project actions will be implemented.

236. The first step in the prioritization process was the selection of the criteria that will be used. For this purpose, a workshop was conducted with watershed management specialists from INAB, MAGA, and MARN. The criteria identified in this activity were:

- Micro-basins with a deficit water balance by 2050, assuming a minimum per capita availability value of 1,700 m3 per year

- Micro-basins where the annual agriculture and coffee represents more than 20% of the land use.
- Micro-basins with deforestation rate higher than the national average (1%).
- Percentage of the area of each micro-basin under the categories of very high and high importance for hydrological catchment and regulation. Watersheds with a percentage of 75% or more will be prioritized.
- Micro-basins located in the municipalities with a population return rate of over 140 per 100 thousand inhabitants (IOM range)

237. Micro-basins in which there is a "Very High" prevalence of chronic malnutrition (greater than 48%).

238. Once the criteria were selected, the micro-watershed prioritization geospatial model was built and applied, and the results were validated by the participants themselves at a workshop organized by FAO Guatemala. It is worth mentioning that this is a preliminary prioritization that has to be corroborated in the field once the project begins.

239. The geospatial model ranked the micro-basins in high and low priority for the implementation of project activities. Based on this, 14 micro-basins were selected. The extensions of basic grains, agroforestry systems, coffee, and cocoa that will be implemented by the project in each one of the micro-basins are presented in Table 35.

Table 35: Area of Implementation of the RELIVE Project in Guatemala per crops, agroforestry systems, forest incentives, coffee and cacao.

No.	Micro-basin	Basic grains (ha)	Agroforestry/forest incentives (ha)	Forest incentives	Coffee (ha)	Cacao (ha)	Total area of implementation (ha)
1	Boloncó	74	938		0	0	1,012
2	Cahabón	835	3,822		330	808	5,617
3	Chixoy o Negro	370	1,254		250	320	2,126
4	Grande de Zacapa	102	115		0	0	167
5	Grande o Jocotán	553	647	282	370	0	1,708
6	Matanzas	53	710		110	40	907
7	Olopa	12	85		60	0	155
8	Polochic	449	2,665		318	110	3,444
9	San José	88	41		0	0	120
10	Santo Tomas	50	28		0	0	70
11	Sarstún	78	1,955		0	270	2,247
12	Shusho	30	20		0	0	50
13	Shutaque	61	45		0	0	99
14	Zapote	84	437		370	0	883
TOTAL		**2,839**	**12,762**	**282**	**1,808**	**1,548**	**19239**

240. The map with prioritized micro-watersheds is presented in Appendix 2.

D.3. Beneficiaries

D.3.1. General Description of the Beneficiaries

241. Project beneficiaries are small maize, bean, coffee, cacao and family vegetable garden farmers. Each of these was described in Section B.1.3.

D.3.2. Estimate of the Number of Beneficiaries

242. The estimate of beneficiaries per activity is based on the number of beneficiaries of adaptation practices related to basic grains, coffee, cocoa, family gardens and forest management.

243. No census provides information regarding the distribution of basic grain farmers by municipality, so it was assumed that 18% of the prioritized farmers live in the working area. This assumption is based on INE (2018) data indicating that this is the percentage of the total Guatemalan population that lives in the departments where the project will be implemented. MAGA (2017) data indicate that 790,671 farmers are prioritized by the 2016-2020 Family Agriculture Program for Strengthening the Peasant Economy (PAFFEC). Of these, 538,854 live in poverty and extreme poverty. The latter are prioritized for this project.

244. Based on the above, in areas prioritized by the RELIVE project there are approximately 141,284 families (583,146 indirect beneficiaries). Due to the fact that it is impossible to reach the entire population prioritized by MAGA, and considering project partners' working capacity; after several meetings of the project formulation team (which includes implementing partner technicians), it was decided that 13% of the growers (19,239 families/115,434 direct beneficiaries with less than 1 ha of land per family) could be supported.

245. MAGA information (2014) indicating that there are 22,503 growers in the project area was used for coffee. After several meetings of the project formulation team and MAGA and FAO crop specialists, it was concluded that the project partners' capacity would make it possible to support 8% of the producers who work in the project area (1,808 families with less than 1 ha of land per family) could be supported.

246. The number of beneficiaries (2,548 cacao growers) were reported in the project area by MAGA (2016). As in previous instances, the project formulation team did an analysis of the project implementation team's capacities with the support of MAGA and FAO technicians and concluded that 61% of the producers in the region (approximately 1,548 families with less than 1 ha of land per family) could be supported.

247. As for the beneficiaries that will receive forest incentives, an analysis of demand in the region was conducted and it was determined together with INAB technicians that based on regional demand and the amounts available for the counterpart, 19,239 hectares could be

supported, of which 18,957 belonged to agroforestry systems, 100 hectares to forests for protecting water sources, and 182 hectares to forest management for production and water (each family possesses a hectare). In this regard, it is worth mentioning that greater weight was given to agroforestry systems for two reasons. The first one is the nature of the project, which focuses on livelihood resilience and not on ecosystems, and the second one that INAB is interested in promoting the modality of agroforestry systems as a goal for the forest incentive program.

248. It is also worth considering that of the 18,957 hectares of agroforestry systems that will receive incentives, 6,195 correspond to farmers already accounted for (2,839 to producers of basic grains and family vegetable plots, 1,808 to coffee growers and 1,548 to cacao growers), meaning that 12,762 belong to new producers.

D.3.3. Linkage of Beneficiaries and Activities in the Project Proposal

249. Activity 1.1.1 will benefit 115,434 direct beneficiaries [28] through the implementation of agro-meteorological monitoring systems for drought, water management and crop pests and prevision of diseases. These beneficiaries are the same included in the agroforestry systems, and the procedure for their estimation was introduced in the last paragraph of the previous section.

250. The beneficiaries of activity 1.1.2 (Install 13 hydro-meteorological monitoring equipment for drought to inform climate resilient agricultural management strategies), are the 115,434 direct beneficiaries and 583,146 indirect beneficiaries that includes beneficiaries of basic grains, cacao, coffee and forest activities (agroforestry systems, forest protection management, and forest management). The procedure to estimate the number of beneficiaries is presented in section C.3.2.

251. Activity 1.1.3 Disseminate climate information and response adaptation measures using locally-relevant delivery mechanisms as virtual platforms, electronic means, telecommunication and visits of the extension workers. This activity will establish three effective delivery mechanisms for the provision of climate that are going to beneficiate the 115,434 direct beneficiaries and 583,146 indirect beneficiaries indicated in activity 1.1.2.

252. Activity 1.1.4 Implement 4 local agro-ecological centers for climate change adaptation for knowledge generation and sharing. This activity will benefit the 115,434 direct beneficiariesand 583,146 indirect beneficiaries indicated in activity 1.1.2.

253. In Activity 1.2.1 (Fund the implementation of the adaptation practices and gender-sensitive technology packages for staple crops, coffee and cocoa with special attention to 37,170 direct beneficiaries (6,195 family farms), that will disseminate the impact to the

[28] The assumption for this estimate is that each family owns 0.885 hectares. Therefore, when the number of hectares calculated in the previous section is multiplied by this figure, the number of families is obtained.

115,434 direct beneficiaries, the 37,170 direct beneficiaries adopting the 8 measures for each agricultural system refers to those that will be implemented by basic grain producers and family vegetable plots (17,034 direct beneficiaries), coffee (10,848 direct beneficiaries) and cacao (9,288 direct beneficiaries). These are the same considered in Activity 1.2.2 (Implement at least 10 trainings to enhance the technical capacity and knowledge of 6,1951 family farms for climate-risk informed planning and implementation of agricultural adaptation measures at farm level). This families are the same ones estimated in activity 1.1.1.

254. Activity 1.2.2 Implement at least 10 trainings to enhance the technical capacity and knowledge of 6,195 family farmers (37,170 direct beneficiaries) for climate-risk informed planning and implementation of agricultural adaptation measures at farm level. These are the same considered in Activity 1.2.2 (Implement at least 10 trainings to enhance the technical capacity and knowledge of 6,195 family farms for climate-risk informed planning and implementation of agricultural adaptation measures at farm level). Activity 1.2.3 Establish 28 women-led, farm-level seed nurseries for resilient crops. Activity 1.2.4 Extension workers provide technical assistance through regular consultation sessions and field visits to 19,239 small farmers families.

255. Beneficiaries of activities 1.3.1 (Promote diversification of productive units in home gardens for 2,500 farm families and install 370 greenhouses micro-tunnel facilities for vegetables and poultry) and 1.3.2 (Organize training for 2,500 farmers on coffee and cocoa, processing and marketing activities). These producers were already accounted in activity 1.2.1.

256. Activities 2.1.1 (Establish or strengthen the capacity of 14 Local Water Committees for climate risk-informed integrated water resource management) and 2.1.2 (Provide technical assistance to Local Water Committees to develop and implement 14 climate risk-informed water management plans at micro-basin level which correspond to the project site), will provide benefits for 20,000 inhabitants of 14 basins in the RELIVE area (approximately 15% of the population). This number of beneficiaries has not been accounted in any of the previous activities.

257. Beneficiaries of activities 2.2.1 (Technical support to 19,239 smallholder farmers (women in particular) to access forest incentives), 2.2.2 (Training of 90 technicians from extension services, forest regents and INAB), 2.2.3 (Restore 13,000 ha through climate resilient management of forest ecosystems and agroforestry), and Activity 2.2.4 (Evaluate forest management plans and certify their compliance to manage and allocate the necessary funds to reforest and manage 13,000 hectares of plantations and agroforestry systems), are the same ones accounted on activity 1.1.2 (Install 20 hydro-meteorological monitoring equipment for drought to inform climate resilient agricultural management strategies).

258. In Activity 2.3.1 (Provide trainings to improve technical capacity of 2,500 local officials and members of community), the 2,500 families trained in efficient water management and use practices, refer to family vegetable plot irrigation system beneficiaries. This group is the same considered in Activity 2.3.2 (Install small and simple farm-level drip irrigation system for using harvested water at 250 ha of farm land, each drip system to irrigate not more of 0.1 Ha).

259. In component 3 the beneficiaries include staff and technical governmental and representatives of private organizations. The number of beneficiaries was estimated by the governmental staff in charge to develop the proposal. In activity 3.1.1, training will be provided to 100 technicians from 28 municipal environmental units and other local government agencies on climate change and climate resilient agricultural solutions. It was estimated that capacity of six technical staff from private organizations and six technical staff from public institutions will be strengthened in each watershed. Given that the project will work in 14 watersheds, a total of 84 stakeholders will be benefited by the project; the project intends to increase this number to 100. Activity 3.1.2 facilitate 4 meetings of 2 water management and climate change thematic roundtables including the participation of MAGA, MARN and other relevant actors.

260. In activity 3.2.1 it was estimated that 30 technical staff per each governmental institution (MARN, MAGA and MARN) will be benefited with training and assistance on the management and dissemination of climate information (making a total of 90 staff members). For activity 3.2.2 it was estimated that six technical staff per watershed will improve their technical capacities. As stated in the previous paragraph the project will work in 14 watersheds, making a total of 84 beneficiaries. The project intents to increase this number to 100.

261. For activity 3.2.3 a total of 20 technical staff (from local organizations per each watershed) will strength their capacities on the use of climate information and planning for agriculture adaptation strategies. As stated on the previous paragraphs the project will work on 14 watersheds, making a total number of 280 beneficiaries. The project intends to increase the number of total beneficiaries to 300. In addition, in activity 3.2.3, the capacity of 80 CADERs29 will be strengthened.

262. The following table presents the number of beneficiaries per activity, grouped by component and output.

[29] Learning Centers for Rural Development (CADER).

Table 36: Beneficiaries by RELIVE project component, output and activity

Component/Output/Activity	Beneficiary Families	Comments
Component 1. Implementing climate resilient agricultural practices and enhancing farmers' livelihoods		
Output 1.1: Climate and agro-weather information improved and tailored to the needs of vulnerable smallholder farmers to inform adaptation measures		
Activity 1.1.1 Organize workshops for extension technicians and farmers regarding the importance of climate information and use in decision-making	6,195 family farms (that will impact on 19,239 Family Farms/115,434 direct beneficiaries)	Includes beneficiaries of basic grains, cacao and coffee.
Activity 1.1.2 Install 13 hydro-meteorological monitoring equipment for drought to inform climate resilient agricultural management strategies.	19,239	Includes beneficiaries of basic grains, cacao, coffee and forest activities (agroforestry systems, forest protection management, and forest management)
Activity 1.1.3 Disseminate climate information and response adaptation measures using locally-relevant delivery mechanisms as virtual platforms, electronic means, telecommunication and visits of the extension workers.	19.239	Includes beneficiaries of basic grains, cacao, coffee and forest activities (agroforestry systems, forest protection management, and forest management)
Activity 1.1.4 Implement 4 local agro-ecological centers for climate change adaptation for knowledge generation and sharing	19.239	Includes beneficiaries of basic grains, cacao, coffee and forest activities (agroforestry systems, forest protection management, and forest management)
Output 1.2: Adaptation measures adopted to foster the resilience of coffee, cocoa and basic grain production systems		
Activity 1.2.1 Fund the implementation of the adaptation practices and gender-sensitive technology packages for staple crops, coffee and cocoa in 6,195 family farms	6,195 family farms (that will impact on 19,239 Family Farms/115,434 direct beneficiaries)	Includes beneficiaries of basic grains, cacao and coffee.
Activity 1.2.2 Implement at least 10 trainings to enhance the technical and organizational capacity and knowledge of 6,195 farmers for climate-risk informed planning and implementation of agricultural adaptation measures at farm level	6,195 family farms (that will impact on 19,239 Family Farms/115,434 direct beneficiaries)	Includes beneficiaries of basic grains, cacao and coffee.
Activity 1.2.3 Establish 28 women-led, farmer-level seed nurseries for resilient crops and community forest nurseries	280	20 female headed households per watershed.
Activity 1.2.4 Extension workers provide technical assistance through regular consultation sessions and field visits to 6,195 small farmers	6,195 family farms (that will impact on 19,239 Family Farms/115,434 direct beneficiaries)	Includes beneficiaries of basic grains, cacao and coffee.
Output 1.3: Promotion of the resilience of livelihoods through productive diversification and market access		
Activity 1.3.1 Promote diversification of productive units in home gardens for 2,500 farm families and install 370 greenhouses micro-tunnel facilities for vegetables and poultry	2,500	Includes coffee beneficiaries.
Activity 1.3.2 Organize training for 2,500 farmers improve technical skills for enhancing coffee and cocoa value chains and to strengthen organizational capacities of producers' associations to access markets	2,500	Includes coffee and cacao beneficiaries.
Component 2. Supporting efficient water management for agriculture to reduce the impact of increased water security		

Component/Output/Activity	Beneficiary Families	Comments
Output 2.1: Community-led Water Management Plans developed and implemented at micro-basin level to promote climate resilience and enhance economic productivity		
Activity 2.1.1 Establish or strengthen the capacity of 14 Local Water Committees for climate risk-informed integrated water resource management and planning instruments related to public policy on climate change	20,000	25% of the population in 14 watersheds.
Activity 2.1.2 Provide technical assistance to Local Water Committees to develop and implement 14 climate risk-informed water management plans at micro-basin level which correspond to the project site.	20,000	25% of the population of 14 watersheds.
Output 2.2: Landscapes are climate resilient and sustain critical ecosystems services for water availability in drought periods		
Activity 2.2.1 Technical support to 19,239 smallholder farmers (women in particular) to access forest incentives	19,239	Includes the beneficiaries in field practices related to basic grains, cacao, coffee, forests and agroforestry systems.
Activity 2.2.2 Training of 90 technicians from extension services, forest regents and INAB	90	INAB technical staff and extension agents.
Activity 2.2.3 Restore 13,000 ha through reforestation and agroforestry	19,239	Includes the beneficiaries of field practices related to basic grains, cacao, coffee, forests and agroforestry systems.
Activity 2.2.4 Evaluate forest management plans and certify their compliance to manage and allocate the necessary funds to reforest and manage 13,000 hectares of plantations and agroforestry systems	19,239	Includes the beneficiaries of field practices related to basic grains, cacao, coffee, forests and agroforestry systems.
Output 2.3: Local water collection and irrigation farm systems implemented to secure water supply for resilient livelihoods		
Activity 2.3.1 Provide trainings to improve technical capacity of 2,500 local officials and members of community organizations on the implementation and maintenance of micro-basin infrastructure	2,500	Includes beneficiaries of basic grains, cacao and coffee.
Activity 2.3.2 Install farm-level drip irrigation system for using harvested water at 250 ha of farm land	2,500	Includes beneficiaries of family gardens.
Component 3. Improved enabling conditions for climate resilient livelihoods		
Output 3.1: Institutional systems strengthened to govern climate resilient initiatives at national and local level		
Activity 3.1.1 Provide training of 100 technicians from 28 municipal environmental units and other local governance agencies on climate adaptation planning and climate resilient agricultural solutions	100	Technical staff from private organizations participating in Local Water Committees.
Activity 3.1.2 Facilitate 4 meetings of 2 water management and climate change thematic roundtables including the participation of MAGA, MARN and other relevant actors to integrate agricultural resilience practices in the national action plan on adaptation to climate change.	100	Technical staff from public institutions participating in Local Water Committees.
Output 3.2: Strengthened knowledge transfer and awareness raising among institutions at national, sub-national and local levels		
Activity 3.2.1 Train and assist 90 staff members from INAB, MAGA and MARN on the management and dissemination of climate information.	90	Technical staff: 30 MARN, 30 MAGA, 30 INAB
Activity 3.2.2, Train 100 at departmental and municipal level and agricultural extension workers and other staff from SNER on climate risk-informed agricultural adaptation strategies.	100	Coordinators and extension services workers.
Activity 3.2.3 Train 300 community promoters on the use of climate information and planning instruments for agriculture adaptation strategies and strengthen the capacity of 80 CADERs	300	Technical staff from local organizations.

D.3.4. Criteria for selecting beneficiaries when implementing the project

263. Project beneficiaries, understood as farmers with whom the project will work directly in prioritized areas (methodology described in the previous section, D.3.3) will be selected according to the following criteria:

264. Basic grains and family gardens: As indicated above, beneficiaries in this group are among PAFFEC beneficiaries, so selection criteria will be based on those defined by this program as described below:

a. They live in extreme poverty[30] and their production is below subsistence (see table 37), which limits their access to financial resources for implementing climate change adaptation measures.

b. **They practice Family Agriculture (FA)**. In accordance with the delimitation established by PAFFEC 2016-2020 of what is and is not FA[31] .

c. **They possess up to 1 ha of available land** for farming activities (own or rented; they can prove it).

d. **They sow maize and/or beans and possess family gardens:** these crops are prioritized for this project. Families must have a family garden established on the family plot, since the project will invest in their diversification and improvement.

e. Household with 4 or more members.

f. Children under 7 with some degree of malnutrition.

g. Availability and interest of all household members.

h. Female headed households will be prioritized.

Table 37: Distribution of agricultural households prioritized by the PAFFEC

Incidence of poverty	Below subsistence	Subsistence	Surplus	Total
Extreme poverty	22,054	82,764	28,109	132,927
Not extreme poverty	63,710	254,608	87,609	405,927
Total prioritized population	**(85,764)**	**(337,372)**	**(115,718)**	**(538,854)**
Not poor	20,071	175,920	55,700	251,691
Total	**105,856**	**513,395**	**171,420**	**790,671**

Source: PAFFEC 2016-2020

[30] Poor: the part of the population that does not reach the minimum income to cover a basket that meets their food and non-food needs. Extreme poor: those who are unable to cover the cost of minimal food consumption.

[31] Limited Access to productive land and capital resources; Predominant use of family labor. The head of the household takes part directly in the productive process; in other words, although there may be some division of labor, the head of the household does not act exclusively as manager, but is one of the workers in the household; agricultural/forestry/fishing aqua cultural activity is the household's main source of income, and may be complemented by other non-agricultural activities performed inside or outside the family unit (services related to rural tourism, environmental benefits, production of crafts, salt agro industries, occasional jobs, etc.).

265. Seed nurseries: the selection criteria are the following:

a. Families living in extreme poverty[32] and their production is below subsistence (see Table 37), which limits their access to financial resources for implementing climate change adaptation measures.

b. **They sow maize and/or beans and possess family gardens:** these crops are prioritized for this project. Families must have a family garden established on the family plot, since the project will invest in their diversification and improvement.

c. Household with 4 or more members.

d. Children under 7 with some degree of malnutrition.

e. Availability and interest of all household members.

f. Female headed households.

266. Coffee: Selection criteria for beneficiaries of practices to improve coffee resilience are the same used for basic grains and family gardens presented above (except for criterion 4), but they must also:

1. **Possess up to 1 ha of available land** for the farming activity (own or rented; they can prove it)

267. They produce coffee using shade.Cacao: the same criteria as for coffee will be used for cacao.

268. Forest incentives: for forest management for protection and provision of water, forest management for production and provision of water and agroforestry systems.

269. The criteria to select small landholders and landowners in the project to implement forest management activities are the ones established in the current legislation on forest incentives33 & 34. These criteria are the following:

- Have Guatemalan nationality;
- Be of legal age;
- Be in free exercise of his or her civil rights;
- Land owner of an area of less than 1 hectare and more than 0.1 hectare;

[32] Poor: the part of the population that does not reach the minimum income to cover a basket that meets their food and non-food needs. Extreme poor: those who are unable to cover the cost of minimal food consumption.

[33] Law on forest incentives for holders of small areas of land suitable for forestry or agroforestry (PINPEP, Decree 51-2010) and its regulations;

[34] Resolution No. JD 04.28.2015. Minutes of the Meeting of the Board of Directors of the National Institute of Forests No. JD.28.2015. dated August 12, 215. Approval of amendments to the regulations of the Law on Forestry Incentives for Holders of Small Extensions of Forest or Agroforestry Vocation Land -PINPEP-. Chapter III. Eligibility requirements and impediments to qualify for the program. Article 20. Eligibility requirements.

- Have proof of title of property or possession;

270. Also, regulations in incentive legislation indicates that the following categories are not eligible on receiving forest incentives:

- Land, where the ownership is the result of an invasion or other form of usurpation of property
- Lands already receiving funds from other financial mechanisms granted by the state;
- Land, which in the past has benefited from INAB forestry incentives;
- Landholders who have been found guilty of violations of forest legislation.
- Lands on which forest cover has been removed without authorization, from the date on which Decree No. 51-2010 of the Congress of the Republic, the Forestry Incentives for Holders of Small Areas of Forestry or Agro-Forestry Land, came into force.

271. Other criteria that will be used to prioritize the beneficiaries are:

- Landholders living in extreme poverty;
- Household with 4 or more members;
- Children under 7 with some degree of malnutrition;
- Availability and interest of all household members;
- Female headed households will be prioritized.

D.4. Stakeholders and decentralization criteria for water management

272. Legitimacy, accountability, competence and financial sustainability are the major general criteria in making decisions regarding the appropriate organization to assume the responsibility of different water resource management functions. Base on this, the main potential actors to assume control of these functions should include:

- Public agencies at different levels of government (central, regional, local, autonomous agencies and public sector enterprises)
- Water users' associations, groups and communities at village level, and advocacy organizations in the voluntary sector.
- Private sector, private individuals.

D.5. Barriers to adaptation

273. The cause of farmers' vulnerability to climate change is, on the one hand, that they depend on rain-fed agriculture for producing crops such as maize and beans, which are sensitive changes in water availability; and on the other hand, production technology that might increase resilience is not used. Reducing small farmers' vulnerability to climate change and increasing their resilience would mean that changes in rainfall patterns and

temperature increases would not result in generalized crop losses. In a climate resilience scenario, farmers would adopt practices that would allow them to adapt to climate change. Farmers might also complement their income so that if some crop losses occur their livelihoods would not be threatened.

274. The second United Nations National Framework Communication on Climate Change (MARN, 2015) summarizes the challenges faced by Guatemala in its fight against climate change as follows:

- **Budget availability:** One of the great problems for promoting effective climate change adaptation in the country (and for development in general) is low public investment. Guatemala is the Latin American country with the lowest tax revenues in the region. In 2015 they only represented 12.4% of the GDP, whereas in the region they represented 22.8% (OCDE; CEPAL; CIAT; BID, 2017). Public investment is very low due to this situation (In the past 25 years Guatemala has been one of the 11 countries with the lowest public spending as a percentage of the GDP at the global level), which results in poverty, malnutrition, and mother and child mortality (especially in rural and indigenous areas), which are very high in Latin America. Climate change is a major concern because not only is public investment in the country one of the lowest in the world, but the issue is not an investment priority, despite its vulnerability to climate change. According to MARN (2016), in fiscal year 2013 1.7% of the total budget was allocated to activities related to climate change-related risk mitigation, adaptation and management activities. Although this amount increased by 2.6% in 2014, it is not enough to face climate change challenges. This is a concern, since the cumulative cost of climate change will increase to the point that in 2100 it will represent between 38 and 64% of the GDP. (Beteta, 2014). The low State budget means that the necessary resources for addressing the effects of variability and climate change and fulfilling NDC commitments, building capacities, adaptation, reducing vulnerability and mitigation are not available (Martínez Tuna, 2017).
- **Need for information for planning:** in addition to climate information, more information is needed on the effects and impacts of climate on society and the local and national economy. One of the biggest problems is the lack of systematized databases that might provide components for planning the activities (MARN, 2015).
- **Technological needs:** Research, technology transfer, technical assistance and rural outreach are needed to transfer climate change technologies to the most vulnerable populations. The priority sectors are subsistence farmers and farmers with small production surpluses (MARN, 2015).

275. When a more detailed analysis is done, however, the following barriers may be identified:

Information barriers

276. **Insufficient accuracy and lack of downscaled climate information for agriculture**- Even when the practices used by growers are based on traditional practices, these have not been improved or adapted to the demands of climate change. For example, in the traditional "Milpa" system, stubble is burned. This is not the most appropriate practice, because it results in the loss of organic matter in the soil, damages the nutrient cycle and increases evaporation of water contained in the soil (USAID, 2017). All of this makes the production of basic grains in conditions of extreme drought and/or greater aridity practically impossible. National institutions such as INSIVUMEH and MAGA have made important efforts in coordinating and complementing information and produce monthly bulletins on crop prices and hydrometeorological information. However, there are still constraints for farmers to effectively use the seasonal forecasts, such as: forecasts arrive too late to inform farmers, lack of information about season onset or length; coarse spatial scale lacks local information. Although a network of hydrometeorological stations is in place in the target micro-basins, they are not enough to generate accurate and downscaled information needed by farmers. Therefore, there is a need to upgrade existing stations and install new ones.

277. **Lack of tailored climate information and inequitable access**- Extension officers have limited knowledge on how to use climate information, which hinders their capacities to make informed decisions regarding resilient agricultural strategies. Additionally, majority of farmers have limited knowledge and unequal access to climate information. Currently, it is delivered on a regional scale through monthly newsletters using format and communication channel that are not adequate for farmer needs and do not exist in local language.

278. **Limited knowledge and capacity of farmers on water resource management and** CC resilient agricultural practices- Actions implemented by national and local authorities, local farmers, and other users impact hydrological regulation and threaten food security especially during drought conditions. Additionally, farmers employ unsustainable practices described earlier and conventional crop varieties, and do not have a reliable and affordable means of accessing resilient alternatives that are compatible with decreasing water availability. Smallholder farmers are often unaware of or do not have access to adequate information and adaptation solutions that will reduce their vulnerability and increase the resilience of their livelihoods.

Technical barriers

279. Limited capacity of extension services to provide tailored technical assistance on climate change- Adapting small-scale production to climate change requires to be accompanied by appropriate extension work that offers adequate and sufficient recommendations to help producers find the most adequate varieties for their plantations, considering aspects related to adaptation capacity and climate variability. The predictability and scalability of the available measures, however, is limited and they do not reach farmers as quickly as needed (van Etten, En impresión). Recommendations for ensuring the adaptation and adequacy of new varieties must go through the conventional validation and extension process, which means that they often reach farmers late. If there is no active feedback from farmers regarding this information, it might not fit their actual needs and is therefore uninteresting for them. Without valid information regarding the adaptation capacity of certain varieties and more efficient transfer of this information, varieties that do not perform as well as the ones usually grown locally might be introduced. This all means that the solutions provided by public and private extension systems (including farmers' associations and cooperatives) for addressing the challenges identified above have limited applicability because they are not suitable for marginal production environments. Extension workers have limited knowledge of the challenges associated with climate change and are thus unable to offer relevant and effective solutions. Current trainings and capacity building of extension services workers by the System for Rural Extension (SNER) do not integrate climate change topics. The extension services face severe financial constraints that limit the ability of staff to travel to rural areas and work with smallholder farmers. The existing Learning Centers for Rural Development (CADER) are lacking the required capacity and access to information on CC to advice farmers.

This situation is aggravated by high turnover at extension offices, which limits the possibilities of building a knowledge and experience base. Extension services also face severe financial restrictions that limit the ability for staff to travel to rural areas and work with small farmers. Section B.1.6. provides more details on agricultural extension services in Guatemala. In addition, agricultural and forestry extension services have a strictly defined mandate that does not clearly extend to addressing climate resilience.

280. **Inadequate water and land-use management planning** – At present there is a lack in planning instruments at national level to guide local water resource and land-use management. The actions implemented by national and local authorities, local farmers and other users do not guarantee water supply, nor do these farmers implement practices to promote water regulation. This often results in unsustainable land and water use in the watersheds. The water cycle in most of the country's water basins has been altered, resulting in considerable water losses from surface runoff during the rainy season and reduced water availability during the dry season. Under climate change conditions, which turn water into a scarce resource, local stakeholders should develop the capacity to manage the landscape to ensure water availability and efficient use of the resource. Production will otherwise be severely affected.

Financial barriers

281. **Relatively high cost of upfront investments-** Small farmers in rural areas in Guatemala experience high poverty levels. It is therefore difficult for them to pay the initial costs of many climate resilience investments (new seed varieties, water storage infrastructure, irrigation systems, etc.). Poverty that forces them to depend on rain-fed agriculture limits the efforts to adopt climate-resistant practices. The presence of commercial banks is limited in the area and they do not regularly lend to these farmers because they consider these high-risk investments.

282. **Refusal of commercial banks to lend for climate resilience-agriculture activities -** Critical resilience activities are not directly revenue generating and they do not generate appropriate collateral for commercial borrowing -At present farmers are highly vulnerable to climate risks and often their yield and quality of crops is conditioned by climate variability and may suffer high loss, making it impossible for farmers to generate any surplus income. As a result, commercial banks consider small farmers to be high risk clients and therefore are unable or unwilling to provide capital required to invest in climate resilience measures.

Social barriers

283. **Language barriers:** Indigenous peoples face linguistic barriers in gaining access to government economic tools that promote natural resource management because all the information, including government institutions' requirements for access to these instruments is in Spanish. It is worth mentioning that this problem is greater for women, and that in Alta Verapaz the problem is even more severe. Two examples include the information requirements to access INAB´s forest incentives such as PINPEP and PROBOSQUE and MAGA trust funds.

284. **Women are disadvantaged regarding access to resources and information-** Rural Guatemala is characterized by high levels of male labor migration. In comparison with men, illiteracy rates and reduced access to credit are high among women who stay behind and continue managing family farms. They only have access to smaller credit lines and usually at higher interest rates than men.[35] A detailed analysis of the gender gaps in Guatemala and in the project area is presented in the Gender Assessment (See Part I of Supplementary material 8).

285. **Other barriers:** long distances and high transportation costs make it difficult for farmers to organize themselves for creating collective solutions. In some cases, insecurity in land tenure might be a barrier for small farmers to invest in long-term adaptation measures. This problem will be addressed in the Funding Proposal.

D.6. Project Design

D.6.1. Project components

286. This section presents the practices that the RELIVE project intends to implement to address the problems that the impacts of climate change is causing and might cause in the near future according to the data and projections presented. The project has been divided

[35] https://elperiodico.com.gt/inversion/2018/01/04/mujeres-obtienen-menos-creditos-y-tasas-mas-altas/

into three components, each of them comprising two or three Products. These contain the practices to be implemented in areas prioritized for the project.

Component 1. Implementing climate resilient agricultural practices and enhancing farmers' livelihoods

287. According to AECID, several studies show that the negative impacts produced on agriculture by climate change mainly affect small producers, who are the most vulnerable due to the greater sensitivity and lower adaptive capacity of their production systems.

288. In this regard, landscape use diversification and improved access to multiple resources increases farmers' capacity for responding to environmental variability and change. Furthermore, the use of agroecological strategies, combined with traditional management systems, represent a sound way to increase agricultural productivity, sustainability and resilience (IFOAM, 2014). That is why making changes in crop management, water gathering systems, improved water distribution, drainage and efficient use, water culture education and dissemination, reforestation with drought-resistant species and using climate information in planning are some examples of viable actions for climate change adaptation (AECID, 2018).

289. The main goal of this component is to reduce the losses of basic grain productivity and production caused by extreme weather events, especially among below-subsistence and subsistence producers. The purpose is to improve producers' resilience through the diversification and the introduction of climatically intelligent sustainable practices at the farm level, as well as actions to strengthen producers' and extension workers' capacities, as well as the development of knowledge networks by using climate information and adopting adaptive management practices to develop climate resilience in agroecological systems of target regions, developing farmers' capacity to access and use climate information that will allow them to make decisions regarding production.

Output 1.1 Climate and agro-weather information improved and tailored to the needs of vulnerable smallholder farmers to inform adaptation measures.

290. Through this product, the project will support farmers in prioritized areas to access information adapted to climate through digital tools, using a technology validation and dissemination system called "Mass Participation Assessment" (MPA) (triadic comparisons of technologies, tricot), which make it possible to track climate trends as they appear on the plots. At the same time, it combines perceptions regarding climate adaptation mechanisms with an integral evaluation of the variety yield from the perspective of the producer (van Etten, in print), since the system is based on the principles of citizen science[36] and on simple

[36]The term Citizen Science is used to define a series of activities that link the general public with scientific research and foster citizens' active contribution to research. During the last two decades, there has been growing civil society participation in the collection, verification, analysis, exchange and dissemination of information for scientific purposes, using information and communication technologies, particularly mobile technologies (European Commission 2014, Finquelievich and Fischnaller 2014).

comparisons of technologies or adaptation measures made up of varieties and cultural practices the farmers can implement themselves, while they communicate their results in simple forms through mobile telephones and other means.

291. Thus, the effectiveness of said technologies or adaptation measures adopted by producers are compared using satellite information, in terms of productivity, costs, tolerance to drought, resistance or tolerance to pests and diseases, vegetative development, times for implementation or production and market acceptance[37].

292. The soundness of information generated by this system has been proved through tests conducted on different types of soils and climate conditions (temperature and precipitation), in Guatemala (dry corridor) with black beans and maize, and in Nicaragua with red bean varieties, where drought resistance and bio fortified varieties are found. Thus, the data generated by producers, georeferenced through the use of GPS, has made it possible to link them with climate information, which proves the thermal stress tolerance of the varieties being tested.

Activity 1.1.1 Organize workshops for extension technicians and farmers regarding the importance of climate information and use in decision-making

293. The project will develop a series of capacity building activities, and all of them will be developed with the training of trainers' model. The first step of this process will be to train the technical personnel of the producer associations working in the project, as well as the extension workers of MAGA and the CADER extension workers (the capacity building process will take place in the agro-ecological centers described in activity 1.1.4). Once they are trained, they will transfer knowledge to small farmers.

294. The experience and the credibility of the above-mentioned actors will facilitate the transfer of knowledge and the implantation of capacity building activities.

295. Prior to the implementation of the training workshops, a diagnosis will be developed to establish the most effective methods for transferring knowledge. In this diagnosis, the training curriculum will also be developed.

296. The training workshops will focus on the use of the information provided by the meteorological monitoring equipment (activity 1.2.2), that will be used to disseminate climate information and response adaptation measures (activity 1.1.3).

[37] Publicly available and free information with coverage of the tropics was used. This ensures that the methods can be applied to other tropical locations/areas/regions. The Climate Hazard Group InfraRed Precipitation with Station (CHIRPS) dataset, which provides daily precipitation estimates with a 0.05-degree resolution based on satellite and weather station data, was used for precipitation (Chen, J. et al. 2004, cited by Van Etten et al., in press). Composite earth surface temperature data for eight MODIS days (MYD11A2) data were used to obtain day and night temperature values for each GPS point during the crop growing period (Van Etten *et al.*, in press).

Activity 1.1.2 Install 13 hydro-meteorological monitoring equipment for drought to inform climate resilient agricultural management strategies.

297. The topographic complexity of the Guatemalan mountains and volcanoes causes significant spatial heterogeneity in average climatic conditions across the country's territory. Annual rainfall in parts of the Northwest Lowlands and the South Coast exceeds 4,000 mm, while in the so-called Dry Corridor the historical annual rainfall is less than 800 mm. These complex conditions are related to various climatic mechanisms and their interaction with the country's topography.

298. At present, the hydro-meteorological equipment managed by the National Institute of Seismology, Volcanology Meteorology and Hydrology (INSIVUMEH) is outdated and does not generate and process high quality data at the required scale to appropriately inform smallholder farmers.

299. In order to develop climate-resilient practices, it is required that the small farmers constantly monitor their crops to know for disease outbreak, and on the other that they have climate information that provides them with an early warning (more information on this is presented in practice 1 described below). Based on this, the project will install a total of 20 WatchDog 2900ET hydrometeorological monitoring equipment, to measure, calculate and record:

- Air temperature
- Relative humidity
- Solar radiation
- Evapotranspiration
- Rainfall
- Wind speed and direction
- Dew Point
- Soil moisture
- Leaf moisture
- Ground temperature

300. The technical specifications of the equipment are:

- Data Storage Capacity, 8800 data intervals, with an interval of 30 minutes. The station has can record data for 183 days before starting to overwrite data.
- Height: 12 inches (30 cm.) with the rain gauge; 10 inches (26 cm.) without the rain gauge
- Width: 8.5 inches (21.5 cm.)

- Depth: 12 inches (30 cm.) with the rain gauge,3.5 inches (8.5 cm.) without the rain gauge
- Weight (with rain gauge and anemometer): 6.4 lb. (2.9 Kg.)
- Power Source: 4 AA batteries
- Battery life: 12 months
- External Ports for Sensors: 5 on the 2900ET model)
- With GPRS satellite system, built-in

301. Due to the proximity of the areas where the project will be implemented (for further details see section C.2.3 of this document), the information provided by the hydro-meteorological monitoring equipment would be used for groups of micro-watersheds. The groups of micro-basins were the equipment that will be installed is the following: 1) Sarstún and Boloncó, 2) Cahabón and Polochic, and 3) Grande and Xuxo. The specific sites for the installation of the equipment will be defined when the project starts.

302. RELIVE project objective is to install hydro-meteorological equipment in the area of the project, which will provide reliable information with very specific variables informing smallholder producers of coffee, cocoa, beans and maize. The project will as well provide capacity building to INSIVUMERH on collecting and processing the climate information.

303. It is important to highlight that an ongoing GCF funded project in Guatemala, implemented by the International Union of Conservation of Nature (IUCN), the FP087 project: *Building livelihood resilience to climate change in the upper basins of Guatemala's highlands, includes* the installation of hydro-meteorological equipment in its project implementation area that will be used by INSIVUMERH. RELIVE, will join efforts with the FP087 in order to strengthen INSIVUMERH capacities.

304. There is no overlap between the two projects (see figure 54), rather they will be well coordinated with the objective to improve the national network of meteorological stations managed by INSIVUMERH. This is one of the strengths of the project to seek to complement other GCF projects outputs in order to improve resilience to climate change at a national level.

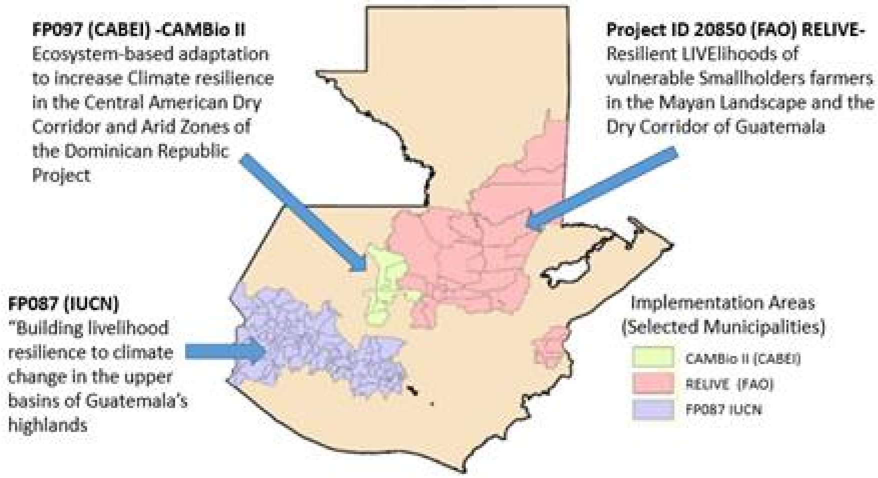


Figure 54: Geographical location of the implementation area of the two GCF approved projects in Guatemala and the RELIVE project

305. INSIVUMERH will benefit from capacity building activities on generating agro-weather information and will continue, as part of their monitoring network, to use and manage the newly installed hydro-meteorological equipment acquired with GCF proceeds from FP087 and RELIVE.

306. GCF will provide the means to the Guatemala Government to be able to produce reliable climate information in line with the standards of the Global Framework for Climate Services.

Activity 1.1.3 Disseminate climate information and response adaptation measures using locally-relevant delivery mechanisms as virtual platforms, electronic means, telecommunication and visits of the extension workers.

307. Practice 1 (below) describes the way climate information will be collected, analyzed and disseminated.

PRACTICE 1. Access to climate information and crop technologies

308. A.1. In the specific case of this project, MPAs will be used with farmers divided into three linked working groups of interest for the prioritized productive items, which are: basic grains (maize and beans), for coffee and cacao. Information generated through Agricultural Stress Index System (ASIS) and MFEWS will be used for basic grains; the ANACAFÉ application Coffee Cloud will be used for coffee; and a specialized tool will be developed for cacao. Climate information and the MPA results will be stored on a freely accessible database and analyzed through knowledge platforms.

Basic grains (maize and beans):

309. In this case, producers will have access to detailed climate information and to a seed portfolio recommended for their climate reality. Climate information will come from global systems ASIS38 and MFEWS39. Access is free and they have an appropriate spatial resolution for representing climate variations at a very low scale. CHIRPS data (at distances of 5 kilometers) will be joined to NDVI (at distances of 250 meters) to produce extremely detailed climate information. Thus, using simulation models, possible climate scenarios (climate forecasts) will be generated for three months into the future, which would allow timely selection by seed producers and farmers of the seed variety to produce and/or use, depending on the climate conditions expected at the time of planting.

310. Information from the farmers and families participating in the project will be recorded during its implementation. The data collected will include the name, the GPS location of the farm and the best way to contact them to provide the information, for example a basic or smart mobile phone, a land line, the farmers' organization he belongs to, or extension agents' visits40. If the farmer has a mobile phone, he may access (i) climate information (three months forecasts of climate variations at a very low scale) and (ii) a recommended seed portfolio for his climate reality. Producers who do not have access to phone service will receive information through the staff of farmers' associations they belong to or through extension agents. Both the staff of farmers' associations and extension agents will receive the information through their participation in the knowledge platform or through a basic or smart phone. The members of farmers' associations and extension agents will transfer this information to farmers during the visits. Text messages, WhatsApp and/or telephone calls will also be used for communication.

Coffee:

311. Some efforts have been made thanks to the collaboration among different actors to create early warning rust and borer beetle monitoring and surveillance systems. These systems also have climate and weather data that give coffee growers information for decision making and implementing timely disease prevention and control measures. It is worth mentioning that joint efforts should be made and a platform complementing the efforts of ANACAFÉ, SATCAFÉ and the MAGA epidemiology department should be created to strengthen the early warning systems that are already operating.

---

[38] The Agricultural Stress Index System (ASIS) was developed by FAO's Global Information and Early Warning System (GIEWS) and the Climate, Energy, and Tenure Division for detecting agricultural areas with a high likelihood of water stress - drought at global, regional and country level. By monitoring vegetation indices across global crop areas during the growing season, ASIS can detect "hotspots" around the globe where crops may be affected by drought. ASIS allows countries to fine-tune parameters of the system based on detailed land use maps and national crop statistics. At the country and local level, ASIS could be used in developing a remote sensing-based index for crop insurance. ASIS is based on 10-day (decadal) satellite data of vegetation and land surface temperature from the METOP-AVHRR sensor at a 1 km resolution.

[39] The Meso-American Famine Early Warning System (MFEWS) supports activities to monitor and assess Central America's food availability and vulnerability to food insecurity as a result of natural disasters, droughts, and other hazards.

[40] FAO field team experience indicates that smart phones might work with young people, with whom an application and WhatsApp groups will be used. But since most growers use basic phones, text messages will also be used.

312. It has been reported that ANACAFÉ, in collaboration with donor agencies, implements the Coffee Cloud system, which operates with weather stations and monitoring of the coffee rust disease. This is based on information farmers obtain from their parcels by sampling and uploading on a smart phone application. The application subsequently indicates a series of practices that should be implemented depending on the degree of infestation. Alerts and recommendations are shared every quarter with farmers by different means (ANACAFÉ web bulletins, radio programs, television programs and text messages); if a high risk of damage caused by diseases exists, a special bulletin is issued and information is disseminated for immediate action to be taken.

313. Since this system is already operating in the country and for project purposes, it will be used in the future; however, an application will be developed for mobile phones, in addition to sending the information generated by the system by text messages and WhatsApp to farmers who do not have access to the information (most of them older farmers), to provide timely information, which is fundamental for the success of the initiative, since preventing actions should be implemented within a period of no more than 72 hours.

314. Thus, the application and the means to send the information will be used to disseminate rust behavior analysis by coffee producing areas and specific recommendations on the activities that should be carried out at the coffee plantation (e.g. preventive or curative control, depending on the incidence and severity and considering climate forecasts, chemical control of rust, shade regulation, fertilization and others), enabling coffee farmers to implement actions/activities on the farm. Moreover, the technical support provided by extension agents, promoters and technicians from coffee producer organizations, will support farmers in following the recommendations shared through early warning systems, ensuring that agroforestry systems are managed in accordance with the climate conditions prevailing in coffee producing areas.

315. Although the system is operating in several regions of the country, not only access to information but also the generation of climate data should be improved (the density of stations in the area of Alta and Baja Verapaz, Chiquimula and Zacapa is very low) and the application should be adjusted to ensure that this climate information is incorporated, analyzed and distributed. The system will be improved with project support to generate climate information in real time, standardize data gathering, generate and disseminate early warnings and analyze the incidence of pests/diseases vs. climate variables, farm typologies, coffee varieties, production areas and biophysical characteristics.

316. Hence the importance of an initiative like this one, since the network of stations can be complemented with project resources and the platform can be extended to reach small farmers who cannot access the information.

Cacao:

317. A system that operates like the one for coffee will be created for cacao. This system will work in the exactly same manner that the coffee system does.

Activity 1.1.4 Implement 4 local agro-ecological centers for climate change adaptation for knowledge generation and sharing

318. Community centers for development will generate resilient technologies and information that will be implemented on the field. GIZ will be responsible for the establishment of 4 local agro-ecological centers for climate change adaptation for knowledge generation and sharing. GIZ will identify in which communities these agro-ecological centers will be established. It will also provide training and materials for the local expert/community member to manage the agro-ecological centers. GIZ has been developing these centers in other parts of the country, and they have already learned lessons that will be used in RELIEVE.

319. The resilient technologies and practices will be tested and validated in the field in each agro-ecological center, then the lessons learned will be identified and transferred to local organizations and small farmers.

320. Each agro-ecological center will have: 1) a capacity building center where key stakeholders will participate in training processes, and 2) experimental field plots where the climate resilient practices will be tested and validated. Resilient practices will be evaluated and related to sustainable water management at micro-basin level, agricultural diversification adapted to climate change, and measures to improve soil and crops quality.

321. As part of the process, constant trainings will be provided to the technical personnel of the producer's associations working in the project, as well as extension workers of MAGA and the CADER extension workers (for further details on the capacity building process see Activity 1.1.1).

322. To ensure the sustainability of the agro-ecological centers, these will be implemented and managed by training a committee that will be responsible for the center. This committee will be integrated by local stakeholders and technical staff of RELIEVE.

323. Agro-ecological centers will be implemented with co-financed resources provided by KOICA, and GIZ will be the partner in charge of Activity 1.1.4.

Output 1.2 Adaptation measures adopted to foster the resilience of coffee, cocoa and basic grain production systems.

324. Factors such as long-term precipitation and median temperature trends, specific disturbances during plant development stages and extreme weather events affect crop production. Therefore, as climate changes, production strategies must change. This means that the use of sustainable and climatically intelligent production techniques should become

the most effective way to counteract yield and productivity gaps in agricultural production caused by environmental effects.

325. This requires measures such as the use of good quality seeds and planting materials of well adapted varieties; using different techniques or methods for growing species and/or varieties in association or with rotation; using integrated pest control methods; conservation agriculture; sustainable soil mechanization; activities for better water management and other actions leading to the greatest possible productivity (FAO, Food and Agriculture Organization of the United Nations, 2018).

326. This Product seeks to promote resilience of agricultural production by implementing innovative packages of practices for crop adaptation to climate change (see section D.6.2 Innovative measures in project activities for more details), focusing on the crops and areas prioritized by the project. Said packages of actions are aimed at: (i) basic grains (maize and beans) and (ii) agroforestry coffee and cacao production systems. Table 38 below shows the gender-sensitive agricultural adaptation packages and practices proposed for each of these crops.

Table 38: Adaptation packages with their activities and expected results.

Gender-sensitive agricultural adaptation packages and activities	Adaptation benefits
Gender-sensitive agricultural adaptation packages for staple crops The package includes the provision and use of drought-resilient varieties of maize and beans. This will maintain or increase the productivity of the crops, even during droughts and prolonged heat waves while contributing to food security. The package promotes the adoption of practices at farm-level to improve soil moisture retention capacity using agroecological approaches (for detailed description of the agroecological practices see section C.6 of the Feasibility Study). It promotes agrobiodiversity in family gardens by planting locally accepted species of fruit trees, timber trees and diversification with varieties of roots (see the list of selected tree varieties in Section C.6, of the feasibility study). This will create microclimate and help ensure stable yields for food security[41].	
Prepare a seeds catalogue at community level and adopt climatically adapted seed varieties in collaboration with farmers and women's groups	- Reduced crop failure in the event of rainfall failure during critical growth periods - Reduced harvest failure in the event of excessive rainfall during harvest
Diversify and adopt agrobiodiversity principles to create a favorable microclimate in the agriculture plot	- Maintenance of microclimate conditions, resulting in reduced loss of soil moisture - Improved infiltration of runoff, recharging soil moisture reserves and contributing to aquifer recharge and stream flow stabilization at landscape level. - Input of soil organic matter, resulting in increased soil moisture retention.
Improve organic matter content and soil moisture retention capacity	- Increases in soil moisture reserves during unseasonal drought periods, associated with increased organic matter content - Reduced evaporative demand from crops - Maintenance of soil cover protects against temperature increases and resulting loss of soil moisture due to evaporation and decomposition of soil organic matter. - Reduction of soil disturbance and maintenance of cover reduces runoff and erosive losses during increasingly intense extreme rainfall events
Post-harvest handling of basic grains	Improved grain storage technology for maize and beans to protect from extreme weather

[41] These measures have been proven to be effective in other projects implemented by FAO such as Prácticas resilientes and Mesoamerica sin hambre.

Gender-sensitive agricultural adaptation packages and activities	Adaptation benefits
	and pests to preserve them for longer periods, thus contributing to food security. The storage technology will be tailored to enhance resilience to CC e.g. proper ventilation to avoid grain damage from excessive heat and moisture, and associated insects.
Gender-sensitive agricultural adaptation packages for coffee and cocoa productive systems The package promotes gradual renewal of coffee and cocoa productive systems with improved varieties. This is expected to result in an overall improvement of coffee production by 76% in 7 years with new varieties compared to business of usual scenario.[42] Additionally, other three species will be introduced for shade to increase resilience of coffee and cocoa planting. See list with proposed species for planting in section C.6 of Feasibility Study).	
Establishment of improved coffee and cocoa hybrids tolerant to rust and drought	Improved drought-resilient variety of coffee and cocoa decreasing the impacts form prolonged droughts, pest, diseases and coffee rust. The proposed varieties have already been used and are well accepted in other countries in the region as well as in other Departments in Guatemala (for more information see section C.6 of the Feasibility Study).

Adaptation and diversification of the structure of shade canopy for greater resilience to climate change	- Maintenance of microclimate conditions, resulting in reduced losses of soil moisture
	- Improved infiltration of runoff, recharging soil moisture reserves and contributing to aquifer recharge and stream flow stabilization at landscape level.
	  - **Coffee:** Density, spatial arrangements and pruning techniques allow for greater aeration in the coffee plantation to counteract temperature increases, and the particular architecture of the coffee plants allows better ventilation into the interior plants, especially in times of heavy rain, so that diseases such as rust cannot thrive.
	  - **Cocoa:** The shade provides protection to cocoa plants from strong winds. Also, the shade contributes to cycling of nutrients, decrease in runoff (in the agroforestry system, runoff is 3% lower in comparison with full sun systems).[43] Finally, the arboreal component helps to create favorable microclimate conditions for the growth of the main crop and is unfavorable for the development of diseases.

Management of the nutrient balance of the coffee agroforestry system	Maintaining soil with the necessary nutrient stocks using compost and organic fertilizers will help plants to be less vulnerable to attack by pests and diseases and more likely to withstand extreme weather events. Climate information will inform farmers on the timing and amount of product application.
Management of coffee pests and diseases with emphasis on rust	Increased resilience of coffee towards pests and diseases by climate informed management practices e.g. the early warning for drought will inform farmers when to take specific measured to decrease the risk of pests and diseases.

Activity 1.2.1. Fund the implementation of the adaptation practices and gender-sensitive technology packages for staple crops, coffee and cocoa in 6,195 family farms.

327. This activity will be implemented through gender-sensitive agricultural adaptation packages, which are a set of practical measures to be implemented in the field for basic grain, coffee and cacao crops that the project will promote. A package of practices for basic

[42] Cerda et al., 2017. Primary and Secondary Yield Losses Caused by Pests and Diseases: Assessment and Modelling in Coffee. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0169133
[43] Cerda, R. D. (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. *Agroforestry Systems*, *88*(6), 957-981. doi:10.1007/s10457-014-9691-8

grains is proposed that will also apply to family vegetable gardens, and another one for coffee and cacao, and will be implemented with the convergence of other project activities such as 1.3.1, 1.3.2, 2.2.1, 2.2.2 2.2.3, 2.3.1 2.3.2, 3.1.1, 3.2.2, 3.2.3.

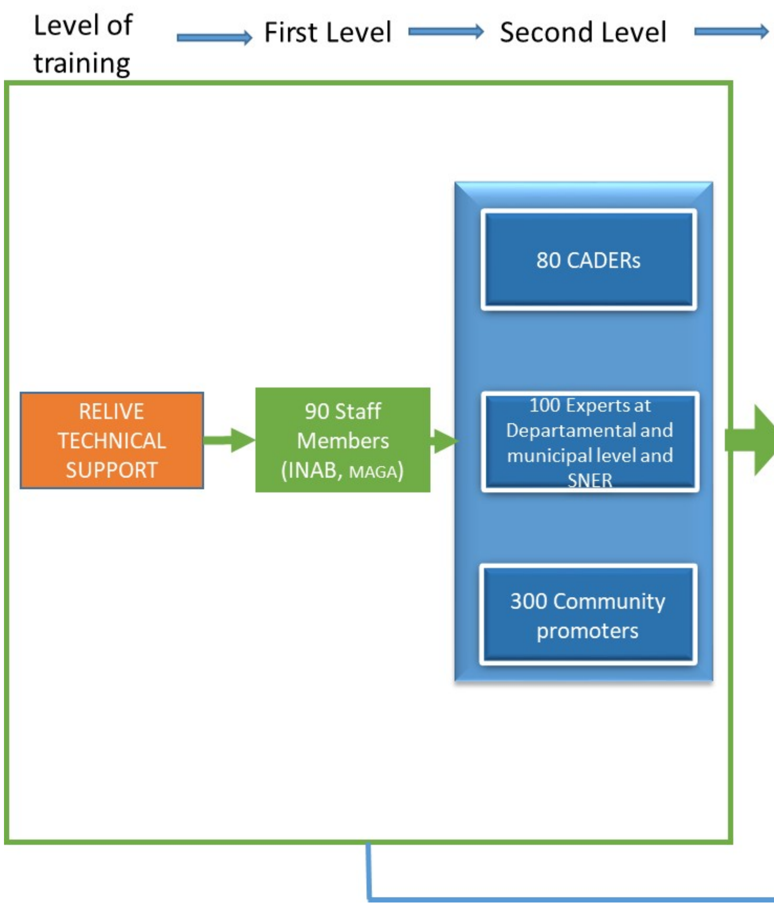
328. To this end, a strategy in 4 different levels will be implemented: at level 1, the project will train MAGA and INAB technicians, who, in turn, will train at level 2 the 100 community promoters, 80 CADERs, and 100 SNER experts. All these experts will provide, at level 3, technical assistance to 6195 family farms distributed in the different micro-basins.

329. These 6195 family farms represent a total of 37,770 direct beneficiaries, who will have direct support from the project to acquire inputs and improve their production systems.

330. At level 4, there will be the remaining 12,762 Family farms, who will only have access to incentives of the PINFOR and PROBOSQUE program and technical advice for the project and will be covered under other activity.

331. The training and technology transfer process will be based on the existing MAGA and INAB platform, which will be reinforced by the project. For this, field schools, demonstration farms, training courses, and a learning-by-doing process will be used. Additionally, field visits by specialist technicians will be implemented so that they can have direct contact with small producers.

332. It is expected that the process will strengthen existing platforms and that it will allow the initiative to be scaled up to a greater number of beneficiaries. Figure 55. Describes the process.



	Third Level: Small family Farms With direct Project investment + Incentives				Fourth Level: Small family Farms with Incentives
Micro-basins	Basic grains (ha)	Coffe e (ha)	Cacao (ha)	Total	Agroforestry/ forest incentives (ha)
Boloncó	74	0	0	74	938
Cahabón	835	330	808	1973	3,822
Chixoy o Negro	370	250	320	940	1,254
Grande de Zacapa	102	0	0	102	115
Grande o Jocotán	553	370	0	923	647
Matanzas	53	110	40	203	710
Olopa	12	60	0	72	85
Polochic	449	318	110	877	2,665
San José	88	0	0	88	41
Santo Tomas	50	0	0	50	28
Sarstún	78	0	270	348	1,955
Shusho	30	0	0	30	20
Shutaque	61	0	0	61	45
Zapote	84	370	0	454	437
Total Family Farms	2,839	1,808	1,548	6195	12,762
Total Small Farmers Direct Beneficiaries	17,034	10,848	9,288	37,170	76,572

Figure 55. Schematic representation of the training and implementation process of the adaptation practices and gender-sensitive technology packages for staple crops, coffee and cocoa.

Adaptation package for basic grains (maize and beans)

333. Basic grain varieties have been selected or improved on the basis of parents with greater capacity for adaptation to climate changes, with high physiological resilience, to deal with the tensions resulting from climate variability and change, including droughts and prolonged midsummer droughts, as well as the plant health problems aggravated by such events. For example, varieties with maturation cycles that make it possible to adjust crop planting schedules appropriately to face unfavorable seasonal conditions have been identified (León & Arroyo, 2011). Said varieties are characterized by having random pollination and their reproduction maintains a relatively uniform plant population when it comes to the distinctive character of each variety. Open pollination is characterized by greater varietal purity and high vigor (SAGARPA, 2016) and (Vallejo D. & Chuela B., 2008).

334. Improved seeds constitute a strategic input that provides benefits to below-subsistence and subsistence farmers, since they have a better chance of selecting the variety that best adapts to their climate conditions, offering them low-cost planting materials that are easy to store for future planting (Clará, 2013). This also improves the rates of return of the capital invested, increases crop productivity for self-consumption and contribute to food security in the country's most vulnerable areas (CENTA, 2017).

PRACTICE 2. Prepare a seeds catalogue at community level and adopt climatically adapted seed varieties in collaboration with farmers and women's groups

335. This practice consists of introducing and using improved, open pollination varieties tolerant to unfavorable climate factors (e.g. high temperatures, droughts, excess rainfall, pests and diseases exacerbated by climate changes).

336. The main purpose of this practice is maintaining or increasing crop productivity, even under unfavorable climate conditions (prolonged droughts and midsummer droughts), considering plant health, nutrition and management, using a sustainability approach with respect to adverse climate and non-climate factors, promoting the supply of improved, open pollination seeds to individual growers or associated groups to increase the availability of planting material at more accessible prices, ensure greater adaptability to each zone and ensure genetic quality (Espinosa, y otros, 2003) and (CIMMMYT, 1999).

337. Additionally, selecting varieties better adapted to climate conditions at the site reduces the likelihood of suffering indirect problems induced by biotic agents such as pests. Preventing or reducing production losses increases productivity and hence net revenues. Reducing the use of inputs to control pests results in reduced production costs, which may increase revenues. The seeds proposed within the portfolio of improved varieties, as an adaptation measure, were selected and evaluated by institutions such as CIMMYT, ICTA and the CATIE, Biodiversity and Zamorano consortium.

338. Table 39 shows the improved seed varieties proposed in the framework of the project.

Table 39: Maize and beans improved varieties that have been released by ICTA in Guatemala and that can be used in practice 2 framework.

Crop	Variety	Yield	Type of pollination	Properties	Provided by
Maize	ICTA* B15^{ACP+Zn}	Average yields of 4.6 ton/ha and maximum yields of 5.5 ton/ha under optimal production conditions	Free pollination	Drought resistant, with high yields, fortified with high protein content and contributing up to 50% more zinc than non-bio fortified maize of the conventional cultivars. Has a higher essential amino acid content, contributes 90% of the proteins in milk, compared with the maize that normally consumes and contributes only 40%.	ICTA, CIMMYT
Beans	ICTA* CHORTI^{ACM}	Average yield 1.9 ton/ha under optimal conditions	Free pollination	Variety bio fortified with iron and zinc. Rust, angular stain, golden mosaic virus tolerant.	CIAT), HarvestPlus and ICTA

Source: developed in-house. ICTA 2018 and consultations with ICTA staff in Guatemala and Zamorano in Honduras.
(*) Varieties recommended for promotion in the framework of this project (ICTA 2018 and due to results obtained by ICTA).

339. The improved maize seed variety recommended for the initial stage of the project is the ICTA B15ACP+ZINC variety, which is a free polarization variety developed in Guatemala by ICTA and CIMMYT, with high protein and zinc content. It is suitable for planting in areas between 0-1200 meters over sea level. The seeds are produced and distributed by ICTA. Average yield 4.6 ton/ha. This variety can yield up to 5.5 ton/ha when cultivated following ICTA recommendations (2018) and personal communication by Agr. Eng. MSc. Héctor Martínez Figueroa, Main Researcher and Maize Program Coordinator. Northern Research Center (CINOR), Agricultural Science and Technology Institute (ICTA).

340. The improved and tested bean seed variety that is recommended for promotion during the initial phase of the project is ICTA CHORTIACM, a free pollination variety fortified with iron and zinc, rust, angular stain and golden mosaic virus tolerant (CATIE, 2018a).

341. It is worth mentioning that these materials are available and sold freely in the country and are not genetically modified materials.

342. Once the farmer has free access to improved seeds that adapt to the climate conditions that will be present at the time of planting, implementation of cultural practices such as: seed treatment, soil fertilization, weed control and pest and disease control, is recommended, with emphasis on the use of organic inputs as sustainable alternatives to fertilization and plant protection, as well as mountain microorganisms (MM) to reduce natural resource pollution through indiscriminate use of synthetic products, facilitating nutrient availability for plants and controlling pathogens that produce crop diseases (Suchini, Taleno, & Soto, 2017).

343. In this practice, a seeds catalogue at community level will be prepared and climatically adapted seed varieties will be adopted in collaboration with farmers and women's groups.

PRACTICE 3. Diversify and adopt agrobiodiversity principles to create a favorable microclimate in the agriculture plot

344. This practice consists of the introduction and establishment of fruit, timber and service trees (including for firewood), plus some species of roots and tubers, all drought resistant, strategically spread through the production parcel, specifically basic grains and family vegetable gardens.

345. The purpose is for trees to give rise to a microclimate with a certain light, temperature and humidity balance suitable for crops, especially during drought and high temperature periods. Additionally, this practice makes it possible to improve the soil by incorporating organic material from fallen leaves and branches from the planted trees, and the leaf litter creates a cover on the surface of the soil that reduces water loss due to evaporation, which provides more water for the crop (Martínez-Rodríguez, Viguera, Donatti, Harvey, & F., 2017).

346. The tree root system and the incorporation of organic matter improve soil structure, favoring humidity retention and nutrient availability and use, reducing the loss of nutrients through leaching; it reduces soil loss through erosion and controls germination and the establishment of species unsuitable for the crop, reducing weed control costs.

347. Additionally, implementing a dispersed tree system can accelerate the enrichment and recovery process of degraded areas or those more exposed to climate elements, conserving environmental services an allowing farmers to earn additional income from increased productivity of their cultivated land and the incorporation of fruit and/or timber species (Martínez-Rodríguez, Viguera, Donatti, Harvey, & F., 2017) y (Mendieta & Rocha, 2007).

348. According to De Souza et al. (2017), in Central America agroforestry practices (dispersed trees, wind breaking barriers, nitrogen fixers and others), combined with annual crops, are considered to be one of the main climatically intelligent development strategies in arid regions affected by high temperatures. Integrated systems provide many products that contribute to food security and increase family revenues.

349. The products and/or services sought in the parcel should be considered when implementing this practice. Depending on this, the following should be taken into account: current and future soil characteristics and climate conditions in the area, as well as availability of the selected varieties, their potential multiple use and available knowledge regarding their management, species advantages and disadvantages. Tree distribution within the farm should not be uniform, trying to establish a more or less random appearance pattern, so that the densities used promote microclimate regulation and other benefits for the other species grown. Vegetative material, for example stakes of species capable of rooting or plants purchased from nurseries in bags may be used (Camacho, 2013).

350. Considering four basic criteria is recommended when selecting species: (i) the characteristics required by the producer (either for timber or fruit production, nitrogen fixation or forage); (ii) availability of information regarding the selected species (ecology, uses and management); (iii) consider the most abundant species used as agroforestry systems in the Central American territory; and (iv) knowing the origin of the species (broad genetic diversity) (de Sousa et al., 2017).

351. Other key aspects for selecting and managing agroforestry systems for annual crop planting are the functional attributes of each species. These are classified in four groups: (i) complete plant attributes; (ii) informed uses; (iii) reproduction; and (iv) tolerance to adverse environmental conditions.

352. Table 40 shows some Central American tree species reported in the kuxur rum basic grain system that have resilience capacity against temperature and precipitation changes.

Table 40: Central American tree species reported in the kuxur rum basic grain system that have resilience capacity against temperature and precipitation changes forecasted under climate change scenarios RCP 4.5 and 8.5 toward 2050

Scientific name	Common name	Annual precipitation requirement (mm/year)	Altitude range it adapts to (mosl)	Average annual temperature range it adapts to	No. of months of drought it resists	pH requirements	Potential uses
Legumes							
Gliricidia sepium	Madre cacao	600-1500	0 a 1200	20-27	4-6	>5	N fixer, firewood and forage
Erythrina berteroana	Pito	1500-3000	30 a 1000	18-26	2-6	Neutral to acid	FN fixer an forage
Timber							
Swietenia macrophylla	Mahogany	1500-4200	0-600 occasionally up to 1500	22-28	0-4	Acid, neutral, slightly alkaline	Timber
Cedrela odorata	Cedar	1200-3000	0-1200	20-32	0-6	5-7	Firewood and timber
Quercus oleoides	*Oak*	*700-3200*	*0-500*	*23-28*	*4-6*	*acid*	Timber
Fruit							
Byrsonima crassifolia	Nance	600-3000	0-1500	21-28	0-7	Neutrral to acid	Firewood and food
Mammea americana	Mamey	1500-4000	0-1000	27-30	0-3	-	Timber and fruit
Persea americana	Aguacate	700-3000	0-2200	22-26	0-6	Acid to neutral	Food

Source: Modified from Barrance et al. (2003), de Sousa et al. (2017) and FAO (2018).

353. Other often-used legume species are Cushin (*Inga* – several species), also a nitrogen fixer that adds fertility to the soil. Timber species such as laurel (*Cordia alliodora*), cedar (*Cedrella odorata*), walnut (*Juglans allanchana*) and oak (*Tabebuia rosea*) may be used for greater shade trees. The latter produce timber of high quality in high demand locally and nationally; one of the species used in the region is avocado (*Persea americana*). The species selected depends on altitude; nance (*Byrsonima crassifolia*) and other citrus trees such as

orange (*Citrus sinensis*), mandarin (*Citrus reticulata*) and lemon (*Mesino limon*), native lemon, lime (*Citrus x limon*).

PRACTICE 4. Improving the organic matter content and soil humidity retention capacity by managing stubble and eliminating the practice of burning.

354. The purpose of incorporating stubble left over from the previous harvest, together with the biomass resulting from tree pruning, roots and tubers is to increase the soil's organic material content, hence increasing its humidity retention capacity, improving its structure and increasing its nutrient content. These conditions help reduce humidity losses, erosion and fertilizer use (FAO, 2017). The residue is cut, chopped and spread on the growing area to keep a permanent soil cover by depositing biomass from the trees and harvest residues (Posada, 2012). In this case, stubble management implies abandoning the traditional practice of burning, which has shown to have damaging results on the soil, especially in terms of humidity retention.

355. Implementing this practice in the field consists of carrying out activities to keep the stubble from the previous harvest on the parcel as cover and placed in rows on the ground where planting is done, as well as the material resulting from pruning the larger trees; the larger material may be used as firewood (Villarreina Acuña, y otros, 2016), which represents the main source of energy for cooking, which reduces the pressure on forests. A study found that trees can contribute 65% of the firewood consumed by households, contributing to the family economy by saving US$115 annually and to gender equality in families since, by providing firewood, women and children do not have to go looking for firewood and can engage in other activities (Posada, 2012).

356. This practice reduces tillage, avoiding moving the soil during the harvest period, during the harvest period and during establishment of the next crop; fallen leaves help conserve soil nutrients by producing soil cover. Additionally, other strategies are incorporated to manage crop nutrition, such as replacing nutrients extracted during harvest by applying fertilizers. The most important chemical elements for good basic grain nutrition are N, P, K, Ca, Mg, and Zn.

357. Implementing this practice allows the farmer to obtain better yields from the main crop, as well as from other products such as fruits, firewood and timber. In terms of climate change adaptation, stubble from the previous crop along with the residue of pruning increase the soil's humidity retention capacity; reduce soil evapotranspiration, contributing to water infiltration; add nutrients, reducing the need for fertilizers; and improve soil structure, favoring its conservation; they also allow more sustainable production, contributing to farmers' food security. Soil cover also helps reduce weed growth, reducing the use of herbicides (FAO, 2017) and (Posada, 2012).

358. The following activities are recommended for implementing this practice: preparation for planting: to ensure that stubble from the previous season is properly used and does not interfere with planting, it must be chopped and distributed on the ground; delineation of

contour lines: a large percentage of farms where basic grains are produced are located on slopes with gradients of 12-15% or more. On sloping fields, crops should be planted along contour lines and stubble should be placed following such contours; when planting, localized application of fertilizers should be applied to the soil to increase improved seed yields; the first application should be made 10 – 20 days after planting (applying 197 kg/ha de 15-15-15 is recommended); a second application 40 – 45 days after planting is recommended (131,42 kg/ha of urea or 262,8 kg/ha of ammonium sulfate (ICTA, 2015) (Posada, 2012). Organic fertilizers such as poultry manure are recommended. The amounts of synthetic or organic fertilizers and the frequency of application to the soil will depend on soil conditions and crop requirements (Villarreina Acuña, y otros, 2016). Adjusting the amount of fertilizer based on a chemical analysis of the soil is also advised.

PRACTICE 5. Post-harvest management to prevent maize production losses

359. Post-harvest management is the process that starts after grains are harvested with drying, selection and cleaning prior to storage, to ensure that they can be conserved for a longer period and are available for consumption. This practice includes cleaning, selection, drying and storing the grains to reduce the risk of appearance of undesired elements that may increase losses of grains such as maize and beans for consumption or planting.

360. The purpose of this practice is to prevent post-harvest losses during storage of basic grains, which are estimated to range between 6% and 40% in Guatemala depending on the area analyzed (IICA, 2013) and (Mendoza, y otros, 2017). Said losses are also due, mainly, to factors such as rodent, pest and fungus damage. The practice also seeks to contribute to family food security by ensuring basic grain availability throughout the year, reducing food purchase and thus increasing families' capacity to save, preserving grains for sale on the local market when production surpluses are available and, finally, conserving seeds for future planting.

361. When farmers are able to process, dry and store their basic grain harvests, they might be better able to withstand the effects of extreme weather events. Storing basic grains in metal silos prevents possible grain quantity and quality losses due to rotting or pest, insect and rodent attacks, among others. It also reduces losses due to inappropriate post-harvest management and increases food availability for a longer period of time and more safely, thus contributing to the family's food security and reducing the risk of diseases due to consumption of damaged grains. It thus contributes to family economies by reducing food purchases during periods of scarcity.

362. Metal silos should be acquired to implement post-harvest basic grain management. These must be placed out of the rain and sun to prevent sudden

Box 2. Methods for determining grain humidity.

There are several ways of determining grain humidity, including the use of electronic devices or hygrometers. An experienced farmer can tell if the grain is dry enough to store. The method varies in each region and depends on the type of grain. However, the two methods used are: (i) pressing the seed with the thumbnail to test its hardness (dry grains are difficult to press) and (ii) breaking the grain with the teeth to make sure it is hard (dry) enough to store.

temperature and humidity changes. They should not be placed near the ground.

- **Harvesting and drying**: Maize may be harvested when 90 to 95% of the grains located at the tip of the ear have the “black coat” on plants with greener leaves. Bean harvest should start when a large part of the leaves have fallen and pods have changed from green to yellow and have started to dry out. Grain humidity should be reduced to up to 12% for maize and beans prior to storage (Box 2).

- **Cleaning and storage**: Maize ears and grains should be carefully inspected and those affected by fungi and insects should be discarded. Grain inspection and selection is a key step in ensuring safe storage. Good conservation of the grain in the silo depends on it. The silo should also be cleaned to remove microbiological agents hazardous to health that may be present (such as animal excrement, dead animals, etc.), which in turn reduces the need for insecticides. The silo should be hermetically closed to reduce the likelihood that it might be affected by insects or fungi.

363. The silo should be inspected from time to time, at least once a month, to determine temperature and humidity and whether it has been affected by a pest. The use of CO2 may be useful in suffocating any insect that might be hidden among the grains.

364. This activity will be partially funded by GCF. The farmers will provide local materials and work to build the post-harvest center where the metal silo will be placed and the GCF will provide financial resources for the silos.

PRACTICE 6. Using rain water to improve below-subsistence and subsistence families' productive systems by implementing rain water harvesting and efficient irrigation technologies at the farm level.

365. Details on this practice are shown in Output 2.3, Practice 26.

Gender-sensitive agricultural adaptation package for coffee and cacao

Increasing coffee growers' resilience

366. Agroforestry systems (AFSs) are soil use forms where agricultural crops are managed jointly with trees. In comparison with intensive monocultures, AFSs are considered to be more sustainable and resilient (Laderach, y otros, 2011).

367. The proposed adaptation measure consists of making interventions with innovations in the existing coffee plantations for renewal (redesign) of their structure and management for small growers (with areas under 3 ha) located in the departments of Alta Verapaz, Baja Verapaz, Chiquimula and Zacapa. The measure includes a set of five practices based on coffee planters' traditional knowledge. However, they also include innovations that seek to adapt the existing coffee plantations to the climate conditions forecasted for the region, which increases the likelihood that growers might adopt the proposed innovations.

368. The adaptation measure will be more successful when all the practices are combined. The innovation starts by getting coffee growers to implement the practices as a whole and not individually, as they have done traditionally.

PRACTICE 7. Establishment of improved, rust and drought-resistant coffee hybrids tolerant to rust and drought

369. This practice will promote replacement of old coffee plants[44] that are more susceptible to rust (due to climate change), with improved hybrid coffee plants. Coffee plantations would be renewed by completely cutting one out of every four or five furrows each year; for example, in a four-year renovation scheme, furrows are numbered from one to four. All the number one furrows are pruned the first year, number three furrows are pruned the second year, furrows number two the third year, and furrows number four the fourth year. Using this system, growers will always obtain a harvest and renovation costs are spread out over those four or five years. A better result is obtained with the five-year system in coffee plantations growing in highlands (> 1,200 m over sea level), whereas the four-year scheme has worked better in coffee plantations located in lowlands.

370. The genetic material to be used in the renovation/establishment program includes hybrids such as the one developed by ANACAFÉ, named ANACAFÉ-14[45], which is a natural cross between the Pacamara and Catimor varieties, discovered by Mr. Francisco Manchamé in Camotán, Chiquimula. The variety possesses valuable characteristics, such as rust resistance, drought tolerance, excellent vegetative vigor, high productivity and good quality at elevations greater than 1300 meters over sea level. It is low in height, with abundant ramifications and its fruits are elliptical and larger than the standard (Región VII-ANACAFE, 2015).

371. Coffee plantation renewal and establishment programs will also promote F1 hybrids developed by research centers such as CIRAD, ICAFE and CATIE, including the Centroamericano[46], Milenio[47] and Casiopea hybrids, which also have rust resistant characteristics, produce 58% more than conventional varieties under agroforestry systems and start reducing after 18 months. Establishing hybrids F1 and ANACAFÉ-14 at densities of 4,000 plants/ha is recommended, but up to 5,000 plants/ha may be planted. It is worth mentioning that these materials are freely available for sale in the country and are not genetically modified materials.

[44] It is estimated that around 25% of the area where coffee is grown in Guatemala is old (> 25 years) and needs to be renovated. In Project areas, this need for renovating is estimated at around 15,000 ha (estimate base don ANACAFE information).

[45]**ANACAFE-14** is a compact, high-yield variety that responds well at altitudes of more than 1,200 meters over sea level and between 700 and 900 meters over sea level at latitudes 5–15°N and 5–15°S. They have a good cup potential in highlands. This variety is rust-resistant and drought-tolerant. It is susceptible to nematodes and cherry anthracnosis. This variety starts producing after two years; the fruits are large and late-maturing.

[46]**Centroamericano (L13 A44)** is a compact, high-yield variety that responds well at altitudes of more than 1,200 meters over sea level and between 700 and 900 meters over sea level at latitudes 5–15°N and 5–15°S. They have a good cup potential in highlands. This variety is rust- resistant and drought-tolerant. It is susceptible to nematodes and cherry anthracnosis. This variety starts producing after two years; the fruits are large and late-maturing.

[47]**Milenio (L12 A28)** is the product of crossing the-Sarchimor T5296 x a Rume-Sudan variety, a brother of Centroamericano (L13 A44). It has shown good adaptation and productivity at altitudes between 800 and more than 1,200 meters over sea level. Under similar agroenvironmental conditions, its cup quality is similar or better than the Caturra and Catuaí varieties.

PRACTICE 8. Adaptation and diversification of the shade canopy structure-architecture with leguminous arboreal, fruit and timber plants with greater resiliency to the climate conditions forecasted for the region.

372. This practice will include a shade canopy diagnosis and design methodology (Somarriba E. , Estimación visual de la sombra en cacaotales y cafetales, 2002). The diagnosis will include three types of analysis: (a) agroforestry; (b) social and (c) biophysical. The latter will consider the possible impact of climate changes on canopy species.

373. Redesign of producing coffee plantations would later be improved. The selected shade species should perform three functions to address climate change: (i) produce tangible assets for families (coffee in quantity and quality, fruits and timber) for sale and/or self-consumption; (ii) crop and soil protection against temperature increases and precipitation variations; (iii) carbon sequestration to help mitigate climate change.

374. The need for shade varies throughout the different coffee plant development stages; therefore, to provide the shade required by a coffee plant, temporary shade must be established to protect the coffee plants during the first years of the growing cycle. The following species are proposed for use as temporary shade: pigeon peas (Cajanus cajan), crotalaria (Crotalaria sp.) and canavalia (Canavalia sp.), which, in addition to providing shade, also fix nitrogen. Temporary shade is established immediately after the coffee is planted. At the beginning of the rainy season, this shade must be eliminated wholly or in part to accelerate coffee plant growth. Temporary or semi-permanent shade should be fast growing to provide the necessary shade while permanent shade develops. The most frequently-used temporary shade species are: musaceas (bananas, plantains) and castor bean (Ricinus comunis). This temporary shade should be eliminated when permanent shade provides light in the amount and quality required by coffee. Semi-permanent or temporary shade tree density should not exceed 256 individuals/ha. Some temporary shade species are nitrogen fixing legumes; therefore, they contribute to soil fertility (Somarriba, Valdivia, Vasquez, & & Galloway, 2001b).

Table 41: Percentage of shade recommended for coffee depending on the age of the plantation.

YEAR	PERCENTAGE (%)
Year 1	70
Year 2	60
Year 3	50
Year 4	50
Year 5	40
Year 6	40
Year 7	40
Year 8	30 – 40
Beginning in Year 9	30- 35

Source: Somarriba (2002)

Table 42: Species proposed as temporary or semi-permanent shade for shade canopy diversification.

Species	Proposed Density	Use
Crotalaria	3 seeds per hole x 1 m along rows	Temporary shade
Pigeon peas	3 seeds per hole x 1 m long rows	Temporary shade
Castor bean	4 x 6 m	Temporary shade
Banana	6 x 6 m planted along rows	Temporary shade
Plantain	6 x 6 m planted along rows	Temporary shade

375. Finally, permanent shade may include trees of the Leguminosae family, such as *Ingas* (*Inga edulis*, I. *vera, I. paterno*), gravilea (*Grevillea robusta*), timber species such as laurel (*Cordia alliodora*), cedar (*Cedrella odorata*), walnut (*Juglans allanchana*) and oak (*Tabebuia* spp). Fruit tree species to be considered are orange (*Citrus sinensis*) and avocado (*Persea americana*). It is worth to mention that small farmers have been working with the tree species proposed, so they cannot be considered as exotic.

376. Shade species should provide adequate cover for regulating the microclimate (favorable for coffee and unfavorable for diseases such as rust), as well as to protect the soil from excessive evapotranspiration; provide other regulation services, such as better nutrient recycling (leguminous trees with deep roots) and carbon sequestration to help mitigate climate change. In this practice, innovation will focus on using the necessary tools and bibliographic information needed to select new shade species that adapt to climate change.

377. Depending on the dimensions of the shade tree, density should be between 60-100 trees/ha. The following table shows the species and densities proposed for permanent shade in Guatemala.

Table 43: Species and densities proposed as permanent shade for coffee shade canopy diversification in Guatemala.

Species	**# of trees/ha**	**Use**
***Inga* spp**	15	Service
Black timber	15	Service
Avocado	10	Fruit
Orange	10	Fruit
Mango	10	Fruit
Laurel	10-12	Timber
Cedar	10-12	Timber
Walnut	10-12	Timber

Source: personal communication, suggestions by CATIE coffee experts

378. Two basic rules must be followed when establishing permanent coffee shade: (1) plant trees at a distance 1.5 times the width of the adult treetop; and (2) adjust distances by

multiples of coffee bush planting distances to prevent shade tree from growing in the crop furrows (Beer, Muschler, Kass, & Somarriba, 1998) and (Somarriba, Beer, & & Muschler, 2001a).

379. The sketch below (Figure 56) shows the coffee renewal proposal. Coffee plantations would be redesigned to have a system similar to the one illustrated, with orderly shade that would uniformly cover the entire plantation. This represents a flexible model for helping extension agents and coffee growers improve their plantations. Coffee plants would be gradually repopulated or replaced, as would shade trees; thus, redesign might involve eliminating some trees already on the plantation, especially those that offer no product or service. The model is flexible, because the grower may decide which of the proposed species might be fruit, timber or service trees.

380. It can be seen that fruit trees would be located at the edges of the parcel, since these are generally low and lush trees that might generate too much shade in the plantation and favor fungal diseases; having them at the edges prevents this from happening. Leguminous (service) trees are kept inside so they contribute organic matter to the system when pruned. Timber species are also inside the parcel, since they provide light shade and do not harm the crop.

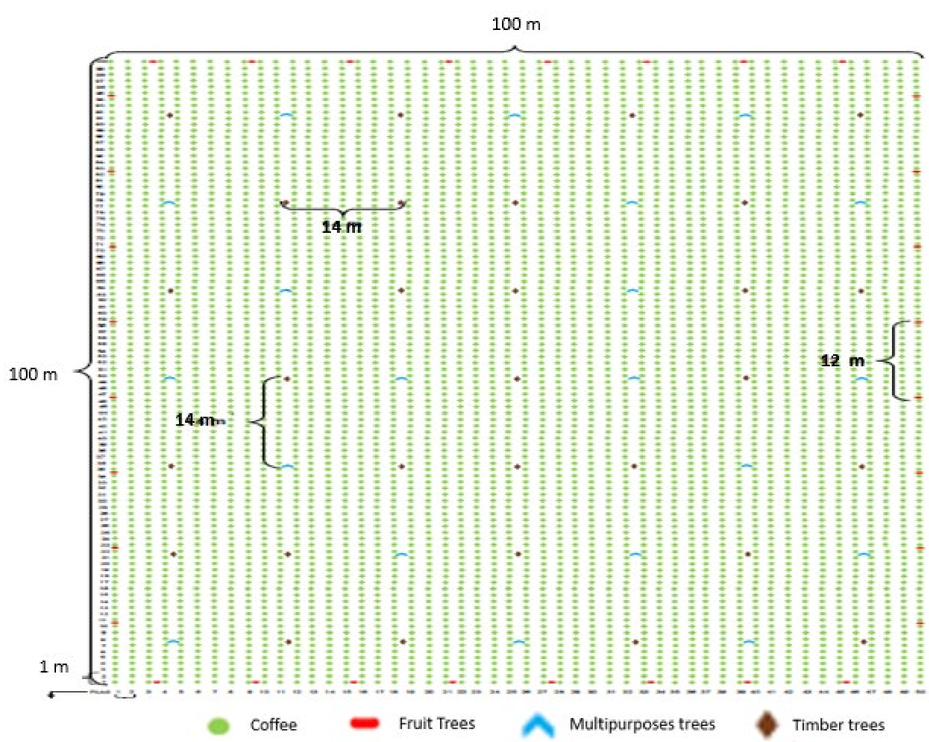


Figure 56. Sketch of the Coffee plantation redesign (renewal) proposal

381. For example, atlases and online platforms that support making decisions regarding trees and plants that may be associated with crops will be used to select shade species, bearing in

mind climate change forecasts, for example: www.worldagroforestry.org/atlas-central-america, www.landscapeportal.org/.

382. The system is first redesigned based on family objectives to implement this practice. Sources of plants for the system are determined next and the establishment schedule is planned. The plants of the main crop should be planted at the beginning of the rainy season, and temporary and permanent shade plants should be planned at least six months before the main crop to prevent "patches" of the plantation without shade. The system should be maintained with fertilization, pruning for shaping and maintenance and yearly control of pests and diseases; the shade canopy should be regulated every year beginning with the fourth year. Timely harvesting of the main crop every 15 days, and harvesting of fruit and other canopy trees to take advantage of all the products for sale or consumption.

383. To implement the practice, it should be decided whether the new materials will be part of a renovation program of low-productivity coffee plantations and/or whether they will be established in new areas of the farms. Independently from the decision, care should be taken first to make sure that the superior materials come from certified nurseries that guarantee the identity of the material. Provisional shad should be established six months before the coffee plants are planted. When coffee plantations are renovated, the new plantation should follow a two to four-year cycle renovation scheme (depending on the size of the plantation and the grower's resources). Hybrids will start producing two years after they are established. These new hybrids/varieties are low in height, compact, with large fruits (CATIE, 2018a); they must be fertilized, tissue should be managed by pruning and pest and disease control every year. Canopy shade should be regulated as of the second year.

- **Land preparation:** cleaning, hole digging and planting of cuttings should be performed during the rainy season.
- **Temporary shade establishment**: pigeon peas, crotalaria or canavalia will be established as provisional shade; musaceas may also be used for shade. Three crotalaria and pigeon pea seeds are deposited directly in the hole at distances of one meter along the planting row. Musaceas would be planted between coffee rows at distances of 3 to 6 m between plants.
- **Coffee bush densities:** Coffee plants would be established at distances depending on land conditions. 2 m between furrows by 1 m between plants is recommended to manage densities of 4,000 plants/ha.
- **Practice management:** comprehensive management of the agroforestry system, which includes fertilization at appropriate levels, should be practiced for hybrids to thrive and yield the expected benefits. These materials are highly productive and thus demand high nutrition. Weed control, shade, tissue management and pest and disease control should also be practiced in accordance with environmental conditions and crop/system needs.

384. Coffee seedlings or vegetative material for the ANACAFÉ-14 variety, which is reproduced by seeds, will be obtained from farms verified by ANACAFÉ. Seed purchases should be planned a year before the start of the plantation through contact with ANACAFÉ or lot owners.

385. F1 hybrids that reach project action areas and farms will be obtained from the CATIE biotechnology laboratory and certified nurseries in Guatemala. If vegetative material is imported, the process takes approximately two months. These materials will subsequently be reproduced by rooting of juvenile branches on hybrid mother plants. The rooting process includes the following stages: (1) obtaining juvenile mother plants produced in a laboratory by somatic embryogenesis; (2) preparing cuttings; (3) rooting tunnels; and (4) acclimatization.

386. Nursery and seedling propagation techniques (infrastructures, care, management) will be transferred to growers/technical teams of coffee organizations/regions for seedling production through seeds or rooting to ensure that plant production capacity is finally established in the communities.

387. Yield losses for varieties susceptible to rust (Caturra variety) may reach up to 26% (Cerda et al., 2017). Losses might hopefully be reduced as much as possible, production might remain stable and yields might increase by up to 50% with the introduction of rust-resistant hybrids F1 and ANACAFÉ-14 and integral system management in comparison with traditional varieties; in other words, production would improve by 76% with the new varieties in comparison with traditional varieties susceptible to diseases and climate change by minimizing losses by 26% and increasing yields by 50%.

388. The yields expected for the Milenio and Centroamericano hybrids under organic management and *Erythrina poeppigiana* shade range between 2.89 tons of gold coffee/ha and 1.70 tons of gold coffee/ha, respectively. These yields are much higher in comparison with Caturra. The expected yields of the ANACAFÉ-14 variety range between 1.66 and 2.02 tons of gold coffee. These yields are up to 50% higher than the productivity recorded for current varieties in Guatemala (estimated at 1.05 tons of gold coffee/ha).

PRACTICE 9. Adaptation of coffee plant spatial arrangement and architecture to climate change effects forecasted for the region.

389. In this practice innovation consists of building a suitable architecture of coffee rows and plants for the plants under the expected climate change conditions. For example, densities, spatial arrangements (rows) and pruning systems and techniques should allow greater coffee plantation aeration to offset temperature increases, and the specific architecture of coffee plants should allow better ventilation inside the plants, especially during very rainy periods, to prevent diseases such as rust from thriving, since lower relative humidity and greater sunlight penetration limit development of the disease and improve the use of products that are sprayed on the foliage (Virginio-Filho & Astorga, 2015). Additionally, timely pruning keeps plant productivity and vigor consistent at the same time as it

facilitates harvesting and plant health control. Pruning may be done by plant or individual, by lanes, over cycles of varying duration (three, four, five or more years); by patches and lots.

390. This practice will consist of making innovations in the arrangement and architecture of coffee plants. Each grower will analyze the coffee densities he can technically manage on his parcel and the type of pruning to be done, based on the characteristics of the hybrids to be introduced (4000 to 5000 plants/ha) and the renovation scheme to be implemented, which depends on each grower's socioeconomic conditions. Renovation of 25% of the coffee plant population each year is proposed. Old or low-producing plants will first be eliminated. Shade trees that should be eliminated due to their age or lack of productivity will also be cut, reducing damage to coffee plants when felling shade trees. Temporary shade (banana or plantain) trees will be planted in areas of the plantation where coffee plants are exposed to direct sunlight.

391. The practice will be implemented as follows: improved hybrids/varieties will be established first in accordance with site conditions and general recommendations on coffee plantation establishment. Hybrid plants will gradually replace old plants. Managing these hybrids with single-stem pruning is recommended (WCR 2016), but two or three main stems may be favored.

PRACTICE 10. Coffee nutrition (fertilization) management in the agroforestry system.

392. Improving soil quality is an essential aspect of climate change adaptation. A change in growers' mindsets should be promoted, who believe that the system will thrive by itself if the soil's chemical, biological and physical fertility are maintained over time. The biological and physical part of the soil is strongly supported by shade canopy trees. As for chemical fertility, innovation will be promoted in the use of more environmentally-friendly fertilizers, for example blue soil Bayfolan or Yara Mila Hydran and micronutrient blends (ulexite + zinc sulfate + copper sulfate + manganese sulfate).

393. Coffee variety innovations (disease resistance) and canopy diversification necessarily require good nutrient management based on parcel soil analyses and tissue management (pruning) to determine the plantation's needs. This practice will not only promote inputs permitted for sustainable production, but allow farmers to make their own compost based on coffee by-products (pulp), cattle manure, harvest residues and organic residues available on farms, among other materials. Organic fertilizer is very important for correcting soil acidity. Application times will be modified according to projected climate conditions and crop and site needs. For instance, the first fertilization will take place when the first few rains are normalized; the subsequent applications will take place during the coffee cherry filling and maturation period.

394. Coffee plantation nutrition should be based on soil analyses to ensure that the plants are receiving the appropriate nutrients and doses to sustain production and keep tissues healthy.

395. This practice consists of applying organic (Bokashi, compost, vermicompost) or inorganic fertilizers twice or three times a year and pruning coffee plants and shade trees to return nutrients to the soil. The amount of these inputs should be based on chemical soil analyses. They should be applied at key moments such as: after maintenance pruning, when most of the fruits start developing and prior to peak harvesting periods. Compost-type organic fertilizer application and two applications of fertilizers approved by sustainable production certification schemes are recommended. Lime should also be applied when soil acidity is very high, to improve fertilizer use by the plants. Application of a foliar fertilizer to coffee plants is also advisable, inter alia to improve leaf development and tolerance to fungal attacks.

396. The following inputs and materials are required to fertilize a hectare of coffee during the productive period: organic fertilizer (at least during planting), fertilizer approved in certification schemes (12 45 kg bags), foliar fertilizer (3 liters or 3 kg depending on the type used), fallen leaves and pruned branches (Villarreina Acuña, y otros, 2016).

397. **Important:** the amount of synthetic or organic fertilizer needed by both the soil and the foliage depend on soil conditions and crop requirements. Among organic fertilizers, the one family use the most might be coffee pulp (Villarreina Acuña, y otros, 2016).

398. **Frequency of application:** depends on the area. Crops are pruned after the harvest; trees are pruned depending on their phenology; organic fertilizers depend on the materials used (for example, coffee pulp in March); edaphic fertilizers are applied during the rainy season and foliar fertilizers depend on plant phenology and the environment (Villarreina Acuña, y otros, 2016).

PRACTICE 11. Coffee pest and disease management, particularly rust, according to climate projections and anomalies for the region, such as increased temperature and more severe droughts.

399. In this practice, growers will use techniques known to them, such as pruning for plant health or product spraying. In this case the innovation consists of the time when products should be applied and the type of products used. Climate information will be used to reconsider when products should be applied by spraying. This climate information and generation of warnings on pest and diseases will be managed through ANACAFÉ, which has developed an early warning system (EWS) that includes relevant pest and disease prevention information (field actions), in addition to providing information on climate variables (extended forecasts of environmental conditions). This information is shared with growers through SMS text messages.

Increasing cacao farm resilience through renewal/establishment of agroforestry systems, with system diversification and structure innovations and agronomic-agroforestry management adapted to climate conditions and risks projected for the region.

400. Strategies that help reduce long-term climate change vulnerability are necessary for the future of agriculture. These types of strategies include modernization of practices/actions for adopting and using new technologies/crops, as well as traditional forms of production that offer great; potential for adapting to changing conditions. The adaptation measure proposed seeks to improve small cacao growers' resilience to extreme events and climate variability.

401. To improve cacao adaptation to changing climate conditions, this package includes combined implementation of five climatically intelligent practices based on agroforestry plantation management. These practices include introducing improved varieties (of "Trinidadian" cacao clones selected by the CATIE genetic improvement program) characterized by being productive, resistant to moniliasis and Mazorca Negra; old cacao plantation redesign and renovation, promoting greater tree density (from 800 plants/ha to up to 1,280 plants/ha); designing or redesigning shade canopy species, including species that offer tangible benefits to farmers´ families and will also be chosen for their suitability for new climate conditions; innovating changes in cacao plantation nutrition, since most small farmers do not fertilize, in harmony with the new cacao and shade canopy plant densities based on soil analyses; innovations in pest and disease management similar to those applied to coffee under this project.

PRACTICE 12. Establishment of productive cacao clones resistant to the main diseases (moniliasis and Mazorca Negra) and with good quality grains.

402. The most vulnerable cacao trees to climate change due to geographic location, age and varietal sensitivity to diseases that will be exacerbated by temperature and humidity alterations. The new varieties/clones proposed have a wide range of agro environmental adaptation, are more productive and tolerant to cacao diseases projected for the project influence area. The six clones that will be established are: CATIE R148, CATIE R449, CATIE R6[50,] ICS-95[51], CC-137[52,] PMCT-58[53] (Table 41). The average productivity of these clones as a whole is up to 1,400 kg/ha/year. At age 11, the incidence of moniliasis was between 5-26% and the incidence of mazorca negra varied between 0-7%. Plantations will include a mix of

---

[48]**CATIE-R1** was developed by CATIE by crossing UF-273 T1 X CATIE-1.000. The trees are small, with moderate foliage and semi-erect branches. Good production and tolerance to mazorca negra and moniliasis.

[49]**CATIE-R4** was developed by CATIE by crossing UF-273 T1 X PA-169. The trees are medium sized, with dense foliage and semi-erect branches. Good production and tolerance to mazorca negra and moniliasis.

[50]**CATIE-R6** was developed by CATIE by crossing UF-273 T1 X PA-169. The trees are medium sized, with dense foliage and semi-erect branches. Good production and tolerance to mazorca negra and moniliasis.

[51]**ICS-95** was developed by Imperial College, Trinidad. Unknown hybrid of Trinitarian x Criollo. Trees are the largest of the six clones, lush and robust. Open branches with lots of foliage that rapidly closes the space between rows. Average production and tolerance to mazorca negra.

[52]**CC-137** was developed by CATIE from open pollination of UF-12. Large, lush and robust trees. Open branches that tend to unite more between rows. Good production and tolerance to mazorca negra.

[53]**PMCT- 58:** was developed by CATIE. Trinidadian hybrid of unknown parentage. Medium-sized trees, although with lots of variation among them; treetops with open branches. Average production and tolerance to mazorca negra.

the six clones selected and will be established at densities of 1,111 trees/ha. All the clones have a high degree of inter-compatibility, which leads to the assumption that fertilization problems will not arise in the field as long as the materials are planted mixed at random or in alternate rows.

403. Including these clones will increase local-traditional productivity of the grain (estimated at 275 kg/ha/year) at least threefold.

Table 44: Production and incidence of diseases in six clones selected by CATIE. Available averages for the first 7 and 11 years and for the last 5 years

Clone	Average production 7 years			Average production 11 years			Average for last 5 years		
	Production (kg/ha/year)	% moniliasis	% mazorca negra	Production (kg/ha/ year)	% moniliasis	% mazorca negra	Production (kg/ha/ year)	% moniliasis	% mazorca negra
CATIE-R6	1,018	5	0	1,485	5	0	2,363	4	0
CATIE-R4	977	7	1	1,336	9	1	2,070	12	1
CC-137	854	24	2	990	32	1	1,321	43	0
CATIE-R1	745	10	8	1,066	12	7	1,674	15	6
PMCT-58	703	20	5	789	26	4	1,036	35	2
ICS-95	516	21	7	636	26	6	926	32	4

It is estimated that around 450 ha in the project area of influence will be renewed. The renewal strategy is every other row per year and every other tree in the row that is kept is eliminated.

404. Clone production for distribution among farmers will be done by establishing communal or centralized nurseries that will produce grafted plants. Budwoods for the nursery grafting process will be obtained from local clonal gardens that were part of the network of clonal gardens of the CATIE Central American Cacao Project, growers' cooperative (e.g. ASECAN, APROCA and Cooperativa Tuneca), technical training institutes (Fray Domingo de Vico Institute) and the San Carlos de Guatemala University School of Agronomy experimental station (FAUSAC). Installing additional clonal gardens to meet the need for grafted plants in project areas of influence is also being considered.

405. Technicians and leading growers will be trained and will work full-time at the nurseries. Knowledge and abilities will be strengthened to choose budwoods with viable buds and use grafting techniques. Hiring expert technical grafters is contemplated to teach grafting tips, improve the process and number of grafts per day. The activities for implementing this practice are: repopulation or replacement of old cacao trees; distancing the plants and plantation management.

PRACTICE 13. Shade canopy structure-architecture adaptation and diversification with plants and trees (legumes, fruit and timber trees) appropriate for the climate conditions forecasted for the region.

406. The shade canopy diagnosis and design methodology will be used in this practice (Somarriba E. , 2002). The diagnosis will include three types of analysis: agroforestry, social and biophysical. The possible impact of climate change on canopy species on the latter will be considered. Tools such as the Atlas of Aptitude of Key Agroforestry Species under Future Climates in Central America (de Sousa, y otros, 2017), which contains information on plant species widely used in agroforestry systems in Central America, will also be used.

407. Shade species selected to improve existing cacao plantations should contribute to the resilience of the agroforestry system against changing climate conditions. The desired characteristics include: (i) species that offer cacao farmers´ families benefits such as fruit (*Persea americana, Citrus spp*.), timber (*Cedrela odorata, Juglans olanchana*), firewood (Inga spp., Gliricidia sepium), medicine (for example cinnamon (*Cinnamomum zeylanicum*), castor bean (*Ricinus comunis*), for self-consumption and/or for income generation; (ii) provide protection to the main crop and soil from changing climate conditions and extreme events (buffer); (iii) finally, the arboreal component helps create favorable microclimate conditions for the main crop and unfavorable for diseases.

408. Species to be promoted for permanent shade are classified as: fruit trees, nitrogen fixers or service and timber trees. Plant distribution and planting distance within the cacao plantation varies depending on the type of tree and the shade the treetop casts. The recommended shade for cacao plants is shown on Table 45. The idea is to mix different types of trees to obtain uniform shade throughout the area under the agroforestry system. Table 43 shows data on types of treetops, the shade they provide and the planting distance for some trees used to accompany cacao. Figure 57 is the sketch (model) of a cacao plantation and the guidance growers might follow in redesigning their cacao plantations.

Table 45: Shade percentage recommended for cacao trees depending on the age of the plantation

YEAR	PERCENTAGE (%)
Year 1	70
Year 2	60
Year 3	50
Year 4	50
Year 5	40
Year 6	40
Year 7	40
Year 8	30 – 40
A s of year 9	30- 35

Source: Somarriba (2002)

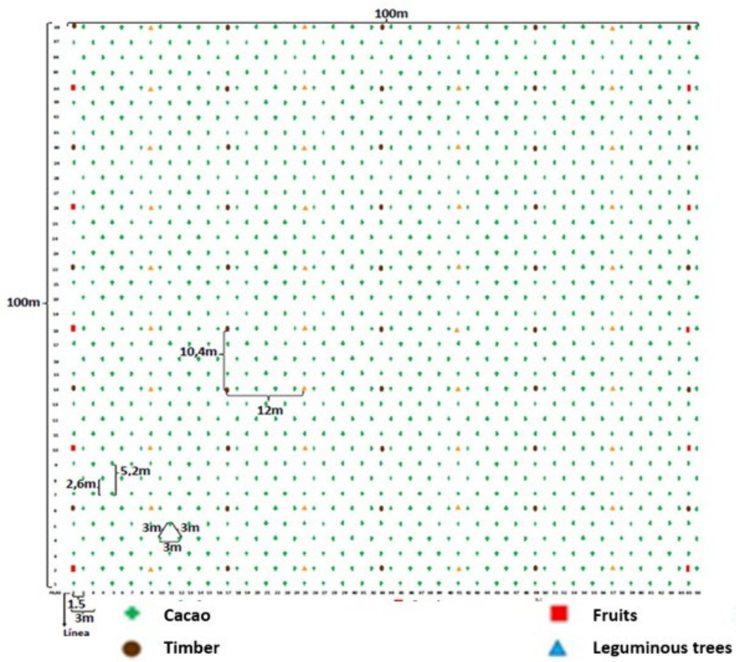


Figure 57. Sketch of the cacao plantation redesign (renewal) proposal

409. This is a sketch of the proposal for renewal of cacao plantations, with orderly shade that uniformly covers the entire plantation. This represents a flexible model to guide extension agents and cacao growers to improve their plantations. Cacao plants and shade trees would be gradually repopulated or replaced. Thus, the design may mean eliminating some trees already in the plantation, especially those that do not offer a product or service. The model is flexible because the grower can decide which of the proposed species might be fruit bearing, timber or service trees. Note that fruit trees are located at the edges of the parcel, since these are generally low and leafy and might generate excessive shade inside the plantation and favor fungal diseases; placing them on the edges prevents this from happening. In contrast, leguminous (service) trees are kept inside so that when they are pruned, they contribute organic matter to the system. Timber trees are also inside the parcel, since they provide light shade and do not harm the crop.

Table 46: Examples of some shade species, type of treetop, shade level and distances used in agroforestry systems with cacao

Species	Type of treetop	Shade level	Distance (m)
Cordia alliodora	Closed	Low	12 x 12 m/10 x 10 m
Tabebuia rosea	Closed	Intermediate	18 x 18 m
Gliricidia sepium	Closed	Low	12 x 12 m/10 x 10 m
***Inga* spp.**	Open	Abundant	20 x 20 m
***Erythrina* spp**	Open	Abundant	18 x 18 m/18 x 18 m
Avocado	Closed	Abundant	12 x 12m
Citrus trees	Closed	Abundant	12 x 12 m

Source: http://cacaomovil.com/guia/5/contenido/arboles-acompanantes/

410. The system is first redesigned based on family objectives to implement this practice. Sources of plants for the system are determined next and the establishment schedule is planned. The plants of the main crop should be planted at the beginning of the rainy season, and temporary and permanent shade plants should be planned at least six months before the main crop to prevent "patches" of the plantation without shade. During the first two to three years, temporary shade plants will remain at high densities (similar to those of the main crop) and then eliminated gradually until the main crop clearly dominates. Planting distance of cacao trees and of the chosen shade species is important and recommendations for plantation management should be followed, as stated above.

PRACTICE 14. Adaptation of cacao tree architecture to prevent the effects of climate change using new shaping and maintenance pruning criteria.

411. In this practice producers will learn techniques for giving the new cacao clones the ideal shape and size (height). These techniques (pruning to shape and maintain) create a tree architecture that is appropriate for the new climate conditions and favors aeration in case temperatures rise, plantation visibility and management. Regional experience with clones suggest managing plants with 3 or more main branches, at a distance of about 60 cm (to prevent contamination of the cacao fruits by diseases, such as mazorca negra, which surge with unexpected rainfall events and the pathogen settles in the soil), and a plant height of 2.5 to 3 meters, which will make it easy to harvest the fruits and prune fruits infected with moniliasis.

412. The proposed modifications of cacao tree architecture and new shade designs will also favor good cacao fruit production and prevent a high fruit load. A high fruit load will lead to plant fatigue leading traditionally to biannual production (high production one-year, low production the next, etc.). Thus, regulating the fruit load is another innovation that will be taught to farmers.

413. To implement this practice, the first action is establishing cacao clones through grafting or rooted twigs following the arrangements and distances selected by farmers. Pruning may be done at any time to shape the trees, but preferable at the beginning of the rainy season (CATIE, 2018a). Other cacao pruning types are:

- ***Development or maintenance pruning*:** Done eight months after planting. It consists of identifying and pruning those branches that tend to become elongated or lean toward the ground, identifying and eliminating crossing branches and suckers' that may deviate from the pattern and reduce competition for light and nutrients.
- ***Pruning during the production stage:*** This involves cutting branches and twigs that impair the development of flowers and ears, cutting branches that overlap neighboring treetops and cutting vertical growth branches at the top of the plant, to achieve a maximum height of 2.5-3 m that facilitates harvesting, removal of diseases fruits and branches (CATIE, 2018a).
- ***Phytosanitary pruning:*** Consists of eliminating the parts of the plant attacked by pests and diseases. This activity may be carried out jointly with other cultivation tasks such as shade regulation and harvesting.

414. General plantation management recommendations should also be taken into consideration.

415. A summary of the main cacao agronomical work included in spatial arrangement and plant architecture management and height is presented below (Table 47).

Table 47: Recommended agronomic cacao management practices

Practice	*When it is done*	*How it is done*
Shade regulation	At the end of the height of the harvest	Regulating the shade level (between 30-50%) by pruning and thinning associated shade trees.
Maintenance pruning	At the end of the height of the harvest	Cutting malformed, very low or crossed cacao branches to allow light in, improve ventilation and reduce humidity in the site.
Sucker removal	Simultaneously with harvests	Cutting suckers while still young using pruning shears.
Drainage management	During the dry season.	Building and keeping drains clean to prevent puddling.
Weeding	At least 4 times a year.	Cutting weeds, particularly long-leafed and tall ones. Also controlling weeds at the end of cacao plantations.

Source: Phillips-Mora & Cerda (2011)

PRACTICE 15. Management of nutrition (fertilization) needs of the agroforestry system with cacao

416. Nutrition management in agroforestry systems is essential for maintaining cacao farm productivity. The arboreal component is a major source for preserving soil fertility and facilitating nutrient absorption into the system. However, inorganic fertilization is important for achieving the expected productivity levels of the superior genetic material used and to ensure that cacao plants resist pests and diseases. The use of fertilizers approved in certification schemes (sustainability indicator and good agricultural practices) will be promoted in this practice.

417. Organic and foliar fertilizers may be used. Compost or poultry manure may be produced on the farm, using materials available on the farms and neighboring communities. The innovation consists of using soil analyses and climate variation patterns to determine the actual cacao plantation amendment needs.

418. This practice means integrating different strategies to improve and preserve the nutrition of the cacao plantation: 1. Preserve soil nutrients (through fallen leaves, soil cover, etc.); 2. Improve recycling (by pruning trees and the crop); and 3. Replace nutrients that are used by the crop (by applying organic and inorganic fertilizers). Cocoa plantation nutrition may therefore be complemented with other practices such as planting green fertilizers, preparing and using organic fertilizers, planting service trees, plant cover, soil analysis and others. The most important chemical elements during the cacao production stage are potassium, nitrogen, calcium, phosphorus, manganese and sulfur.

Table 48. Examples of organic fertilizer doses and frequency of application (compost, decomposed poultry manure) depending on cacao plantation vigor and phenology

Green plants with abundant flowers/fruits	1 kilo (2,2 lb.)	Repeat on the third year
Green but droopy plants with yellow, red or brown spots. Few flowers/fruits.	2 kilos (4,4 lb.)	Repeat on the second year
Plants with few leaves, flowers but few fruits	3 kilos (6,6 lb.)	Repeat every year

Source: *http://cacaomovil.com/guia/4/contenido/opciones-para-mejorar/*

PRACTICE 16. Cacao pest and disease management in accordance with climate projections and anomalies for the region.

419. Pathogen outbreaks or pest infestations are closely linked to temperature and precipitation conditions Moniliasis and mazorca negra may cause crop losses of 45-60%. The incidence of both diseases is greater in cacao plantations with shade trees that are grouped together and poorly managed (CATIE, 2018a). In this practice, comprehensive management

420. An important characteristic of the set of practices in this measure is that they would also improve cacao plant resilience to diseases that are a threat for the region, such as the "witches' broom" disease, which causes major losses in South American countries and has unfortunately reached Panama and Jamaica. There is a risk that this disease that is new for Central America might spread due to different factors.

421. Developing this practice requires knowledge of the historic distribution of rainfall and development of crop phenological stages throughout the year. Climate projections for the area should also be consulted. Proper coffee and cacao plantation pest and disease management should prioritize prevention (Phillips-Mora & Cerda, 2011).

Promotion and development of diversified family gardens adapted to climate conditions and risks forecasted for the 29 prioritized municipalities.

422. A family garden is a space, usually small, where rural families grow different types of plants, particularly vegetables, fruits, medicinal plants, edible herbs and timber trees, and also raise poultry and other minor species to provide food for the family and sometimes to improve family income (Villanueva C. , 2014). The family garden is usually in the backyard54 or close to the dwelling, since the family provides the labor for maintaining it, and this makes the necessary cultural practices more efficient.

[54]El patio es definido por (Taleno & Villanueva., 2016) como: "el espacio geográfico ubicado cerca o alrededor de la vivienda, en el cual ocurren interacciones productivas y sociales de la familia. Es un espacio esencial para el empoderamiento de las mujeres y el desarrollo y bienestar de la familia en aspectos económicos, nutricionales, de salud y socioculturales". The backyard is defined (Taleno & Villanueva., 2016) as "the geographic space near or around the dwelling where family productive and social interactions take place. It is an essential space for women's empowerment and family development and well-being in economic, nutritional, health and sociocultural aspects".

423. Family gardens are an important production system for generally ensuring rural families' food and nutritional security, but especially that of producers included in the below-subsistence and subsistence socioeconomic levels (Ruiz, R.P., & Gutiérrez., 2018).

424. In Central America, Southeast Asia and Sri Lanka, family garden production takes place on a broad range of altitude levels and ecosystems, and is characterized by very efficient use of space. It is a structure made up of multiple layers that make it possible to take optimal advantage of the available sunlight for plant growth and at the same time minimize weed growth and preserve soil fertility. The diversity of the species planted in the garden ensures the availability of varied products throughout the year (FAO; PMA., S/f).

425. Adapting small-scale production in family gardens to forecasted climate changes requires introduction of new cultural practices. Therefore, this measure is characterized by sustainable intensification of family gardens through diversification of vegetables, bowers or vines, fruit trees, roots and tubers, as well as poultry and other minor animal species adaptable to the climate changes forecasted for the region. The following conditions should be met: (i) different crop cycle; (ii) different growth habits; (iii) unrelated taxonomic groups (Cifuentes 2011). At the same time, decision making with regard to the type of varieties and practices to implement should be linked to climate information. This will help diversify the most vulnerable rural families' diet.

426. The purpose of this adaptation measure is to reduce productivity and production losses in subsistence and below-subsistence growers' family gardens. Resilience will be improved by implementing farm-level management actions and capacity building and knowledge networks outside the farm.

PRACTICE 17. Sustainable production diversification and intensification in sustainable vegetable gardens, including vines, roots and tubers.

427. This practice seeks to intensify and diversify sustainable food production for family consumption, increasing species diversity (or functional diversity) and optimizing crop management in family gardens to ensure that the family has enough healthy and nutritive food to cover its energy, nutrient and vitamin requirements. The available and missing nutrients will be determined based on the family backyard inventory and dietary requirements recommended by the WHO (http://www.who.int/es/news-room/fact-sheets/detail/healthy-diet). This information will be crucial in deciding which crops and minor animal species should be incorporated into the garden and backyard. Climate information will also be used to confirm the species and agro environmental management practices to be used.

Box 2. Species that might be promoted in family gardens in Guatemala

- **Vegetables:** includes with edible fruits or seeds, including tomatoes (*Solanum lycopersicum*), squash (*Cucurbita máxima)*, pumpkin (*Cucurbita* spp.), Green beans (*Phaseolus vulgaris*), fava beans (*Phaseolus* spp.), peas (*Pisum sativum*); leaves such as lettuce (*Lactuca sativa*), spinach (*Spinacea oleracea*), basil (*Ocimun basilicum*), mustard (*Brassica* spp.); celery stalks or flowers (*Apium graveolens*), cauliflower (*Brassica oleracea*, var. *botrytis*) and broccoli (*Brassica oleraea*, var. *italica*) (Suchini et al. 2017).
- **Vines:** the most popular species in Central America include passion fruit (*Passiflora edulis var. fl*) and (*Passiflora quadrangularis*), chayote (*Sechium edule*) and chaya (*Cnidoscolus* aconitifolius) (Villareina et al. 2016) as well as loroco (*Fernaldia pundurata*).
- **Tubers and roots.** Includes roots or underground stems of edible plants that are the main products for consumption. The main tubers for self-consumption in Central America include: yucca (*Manihot esculenta*), coco yam (*Xanthosoma sagittifolium*), taro (*Colocasia esculenta*), sweet potato (*Ipomoea* batata) and yam (*Dioscorea spp*). Tubers may produce in a broad variety of climates due to their tolerance to drought, heavy rains and pests (Villareina et al 2016, Suchini et al 2017).

428. Box 2 shows a list of possible vegetable, vine, root and tuber species to be produced in family gardens in Guatemala to strengthen below-subsistence and subsistence families' food and nutritional security.

429. Generally speaking, the actions to be implemented considering the type of crop and its specifications are: appropriate location; soil preparation; seed and seedbed selection; crop planting and management.

PRACTICE 18. Agrobiodiversity diversification and creation of a favorable microclimate in the garden.

430. This practice consists of incorporating strategically distributed trees among the different farm units/productive systems, and specifically those devoted to basic grains and family gardens. The goal is for trees to provide a microclimate with the right balance of light, temperature and humidity for the crops, especially during periods of drought and high temperatures. Additionally, trees are crucial landscape regeneration elements, natural biodiversity processes and ecosystem service protection (Carreño, 2015). Some trials have shown that using trees that provide partial shade and let enough sun reach the ground can increase growth of some leguminous species such as pito (*Erythrina berteroana*), or madre cacao (*Gliricidia sepium*). This gives excellent crop yields, since the roots of these species re inhabited by bacteria, especially of the Rhizobium genus, that establish symbiosis with the plant, forming nodes where atmospheric nitrogen is fixed (Jiménez & Sepúlveda, 2015) and (Rodríguez, Barrueco, García, & Subramaniam, 1984).

431. For more details, see PRACTICE 3: Agro diversity diversification and creation of a favorable microclimate in the parcel.

PRACTICE 19. Backyard poultry production based on homemade feeds

432. Backyard poultry production has two main goals: (i) providing protein for below-subsistence and subsistence families' diets; and (ii) being a source of cash from the sale of eggs and animals (Villanueva, y otros, 2015). Given the resilience shown by small species such as poultry to extreme weather events, in comparison with large species (for example bovines), poultry production is a practice that might help improve rural families' adaptive capacity. Backyard poultry production is common in the Central American region, for example in the Tripoint (Trifinio) and the central area of Nicaragua, where about 80% of rural families have backyard poultry (CATIE, 2013). However, it cannot always be implemented by the most vulnerable families to climate change, nor is it implemented following practices that make it more effective and resilient. This is due to a large extent to initial costs (purchase of animals, establishment of the infrastructure to protect poultry, hen houses and purchasing food) and that the practices families implement do not incorporate climate risks to which they are exposed.

433. Feeding backyard poultry is one of the most important factors for good production and quality. The food given to the birds should meet their nutritional needs, be of quality and provided in the right amounts for proper development of the animals. The food used to feed poultry may be produced in the farm, which reduces costs and is an additional tool that contributes to families' adaptation to climate change. Quality food provides water, protein, carbohydrates, fat, vitamins and minerals to the birds.

434. Backyard poultry production can be classified in three types of systems: extensive, semi-intensive and intensive). The extensive type is the most common system. The production system recommended for families in the region is semi-intensive, since its implementation

and management entail average costs and it offers high-quality average yields (Table 49) However, the system to be implemented depends on the family's goal and the resources available to it.

Table 49: Types of backyard poultry production systems and implementation costs

Characteristic	Type of system		
	Extensive	Semi-extensive	**Extensive**
Infrastructure investment cost	Low	Infrastructure investment cost	Low
Demand for labor	Low	Demand for labor	Low
Cost of food	Low	Cost of food	Low
Potential for use of forage plants	High	Potential for use of forage plants	High
Risk of loss to predators or theft	High	Risk of loss to predators or theft	High
Prophylactic program	No	Prophylactic program	No
Egg production (number of eggs/bird/year)	60-65*	Egg production (number of eggs/bird/year)	60-65*
Meat production	Low	Meat production	Low
Production quality	High	Production quality	High
Use of native species	Yes	Use of native species	Yes
Potential productivity increase	High	Potential productivity increase	High
Bird growth rate	Low	Average	High

** Production with native species, ** Production with improved races.*

435. The facilities and equipment required for backyard poultry production and management depend on the type of system desired. Generally speaking, a rest area should be built for the birds (hen house), an area where the birds can spend the day (grazing area), drinking and feeding troughs, perches, nests and brooders (optional).

436. This practice is based mainly on efficient preparation of bird feed, following homemade recipes for making feed, using resources available on the farm. The most frequently used ingredients are maize, sorghum, dehydrated leaves (guácimo, yucca, pigeon peas), beans (soy, mungo, cowpea, jack beans), eggshells and salt. To prepare the feed, grains such as maize, sorghum and beans are grilled and ground. This can be done using a traditional maize-grinding machine. Plant leaves must be dried in the shade (dehydration process). Once dry, they are ground with the grains and eggshells. Once all the material is ground, it is thoroughly mixed and other ingredients (salt, lime or ash) are added, depending on the formula used (Table 50). The portions birds will eat in the next 24 hours should be prepared each day, although the feed may be in good condition for up to five days if storage conditions are adequate (a cool place) (Villarreina Acuña, y otros, 2016). The birds should be fed at least once a day, in the morning or afternoon.

Table 50: Homemade bird feed recipes for feeding backyard poultry

Ingredient	Diet 1	Diet 2
Maize or sorghum	71,43	66.6
Soy	10.72	13.33
Guácimo leaves	8.93	0
Mother of cacao leaves	7.14	0
Guácimo seeds	0	13.33
Eggshells	1.11	5
Lime	0.46	0
Mineral salt	0.21	0.87
Common salt	0	0.87
Total	100	100

The values for each diet are for preparing 100 lb. or 100 kg of feed.

437. The amount of inputs will depend on the number of animals to be fed and the desired amount of feed (Table 51).

Table 51: Daily feed requirement for backyard poultry

Growth stage (weeks)	Consumption (g/animal/day)	Protein (%)	Metabolizable energy (kcal/kg of dry matter)
Laying hens			
Beginning (0-6)	0.045	17	2,800
Development (7-12)	0.065	15	2,800
Prior to laying (13-18)	0.085	14	2,850
Laying (>18)	0.130	16	2,850
Broiler chickens			
Beginning (1-2)	0.06	22-25	3,025
Development (3-5)	0.200	21-23	3,150
Fattening (6-8)	0.228	19-23	3,200

NOTE: Five birds can be fed with a pound of feed in one day, or a 3-ounce ration for each.

PRACTICE 20. Use of rain water to improve the resilience of below-subsistence and subsistence families' productive systems by implementing efficient rain water harvesting and irrigation technologies at the family garden level.

438. Details of this practice are shown in Output 2.3.

Activity 1.2.2. Implement at least 10 trainings to enhance the technical and organizational capacity and knowledge of 6,195 farmers for climate-risk informed planning and implementation of agricultural adaptation measures at farm level.

439. This activity is linked to Component 1 and PRACTICE 1, which will improve access to climate information and agricultural technologies, and to Component 3, especially PRACTICE 30, which seeks to strengthen local planning to include climate change adaptation actions; PRACTICE 31, which seeks to strengthen capacities for access to climate information as the basis for adaptation planning; and PRACTICE 32, that aims to strengthen rural extension to

improve local capacities for implementation of adaptation and resilience measures. That is why training will be provided, in coordination with actions that will be developed in the aforementioned practices, to strengthen farmers' technical capacity for implementing adaptation measures.

440. Capacity building activities will be implemented through the training of trainers' model explained in activity 1.1.1. The measures at farm level that are going to be transferred are the ones explained on practices 2 to 20 described above.

Activity 1.2.3. Establish 28 women-led, farmer-level seed nurseries for resilient crops and community forest nurseries

441. As explained in the practices described in Activity 1.2.1, improving basic crop, coffee and cacao production system resilience, seed and nursery management will be addressed to guarantee the resistance and quality of species/seedlings used in the above-described productive systems (maize, beans, and family gardens,), women in the communities where these nurseries are established will be encouraged to direct and manage them to allow the women to earn their own income directly.

442. Families in the project area do not have and adequate process of selection and storage of seeds. This situation has a negative impact on the germination of the seeds, and this is having a direct effect on their food security.

443. Seed nurseries for resilient crops led by women will allow not only participatory plant breeding, but also the establishment of a place to protect genetic materials. This activity will also promote sustainable use and conservation of genetic diversity, and yield improvement of crop that will support food security.

444. The first step in this activity will be a series of visits to the area of the project "Improving the livelihoods of small farmers in the departments of Totonicapán, Quiché, Alta and Baja Verapaz", where FAO successfully implemented an experience that benefited 22,116 small farmers in 16 municipalities. On these visits, technicians from small producer organizations, MAGA extensionists and CADER promoters will be trained in the proper implementation, management and administration of seed nurseries. As explained in the activity 1.2.2, the methodology used will be the training of trainers. The idea is that after the training visits, the trainers will be able to reproduce the knowledge in the communities.

445. The training process will include a series of practices in the field and technical support that will allow: 1) select the genetic material that will ensure higher yields and resilience to climate change, and 2) the implementation of a series of post-harvest actions (packaging, labeling, and store) that will ensure the quality and viability of the seeds.

446. To implement seed nurseries, families will work in an organized manner in each community, building storage facilities of five meters wide and long by two and a half meters high, or using existing locations in the communities (these spaces will have to meet minimal requirements for adequate seed storage). The internal infrastructure for storage (shelves

1.8 meters high by five meters long and 0.5 meters deep) will be built with local materials, and will consist of wooden shelves. The containers used to store the seed will be plastic, with a capacity storage between five and ten liters. Below are two pictures that illustrate how the storage facilities and storage structures may look like.

447. The criteria for selecting the farmers that will implement seed nurseries for resilient crops are presented in section C.3.4. (Criteria for selecting beneficiaries when implementing the project).

Activity 1.2.4 Extension workers provide technical assistance through regular consultation sessions and field visits to 6,195 small farmers

448. Although farmers already have a lot of knowledge about their environment and their farming system, extension agents can bring them other knowledge and information which they do not have. For example, knowledge about how climate variations can damage their crops, or influence an increase of pest and diseases and how control them.

449. The application of such knowledge often means that the farmer has to acquire new skills of various kinds: for example, technical skills to implement unfamiliar resilient practices, organizational skills to manage a group project, the skill to assess the economic aspects of technical advice given, or farm management skills for keeping records and allocating the use of farm practices, resources and equipment.

450. The transfer of knowledge and skills to farmers and their families is an important extension activity, that extension agents from MAGA (in collaboration with extension

workers of the project and from the associations involved in the project) will promote within the beneficiaries of RELIVE (Activities 1.1.1, 1.1.2, 1.13 and 1.14).

451. As well as knowledge, information and technical advice, farmers also need some form of organization, both to represent their interests and to give them a means for taking collective action. Extension workers from MAGA will support organizations of local farmers and individual smallholder farmer in the use of climate information, the implementation of adaptation practices and technology packages for staple crops, coffee and cocoa, the promotion of diversification of productive units in home gardens (Activities 1.2.2, 1.2.3, 1.2.4, 1.3.1, and 1.3.2).

452. To achieve the transfer of knowledge and technical advice, MAGA extension workers will provide technical assistance through regular consultation sessions and field visits to smallholder farmers.

Output 1.3 Promotion of the resilience of livelihoods through productive diversification and market access

453. The worst consequences of climate change may affect food security and livelihoods of the population that depends on agriculture in vulnerable countries (FAO, 2013). As mentioned in Section C.1 when describing the climate problem, the livelihoods of populations living in poverty and extreme poverty who depend on nature for their subsistence are highly threatened by rainfall and temperature variations. A climate change scenario forecasts an increase of 7.5 million preschoolers with chronic malnutrition in comparison with a scenario without climate change (INCAP, 2017). Basic grains, coffee and cacao production is affected by prolonged midsummer droughts or excessive rain, water shortages and/or high temperatures, which sets out favorable conditions for pests and diseases (for more details see SECTION C).

454. On the other hand, adding value to a product or service should translate into more jobs, more investment and better use of natural resources; on the other hand, adding value increases the likelihood of food consumption, by placing them at consumers' disposal in areas where they would normally be unavailable, overcoming seasonality and perishability problems. Adding value along a chain often results in imbalances that benefit actors who are closer to the consumer, and not to small growers, for example. Retaining value at the origin, inclusive businesses and businesses at the base of the pyramid are some new approaches that may improve this situation. Retention at the origin is framed within the territorial approach to rural development, by implementing strategies to retain value in the area where the product is generated. This provides better paid employment, more equitable distribution of benefits, among others; but to establish these models, it must exist solid and efficient associative mechanisms, active participation by various actors that provide training, technical assistance and properly guided policies (IICA, 2014).

455. Based on the above, this Product proposes practices to support small producers in strengthening their organization and associative relations, their capacity to introduce their products into the market and adding value to retain it at the origin, thus improving their income as a way of increasing their resilience.

Activity 1.3.1. Promote diversification of productive units in home gardens for 2,500 farm families and install 370 greenhouses micro-tunnel facilities for vegetables and poultry.

456. Details regarding this activity are described in some of the practices of Product 1.2, especially PRACTICE 3, PRACTICE 5, PRACTICE 17 and PRACTICE 18.

457. In addition to the above-mentioned practices, the productive units of small subsistence producers will diversify the installation of micro-tunnels (with vegetables and other crops used locally in family gardens). This technology will also reduce the incidence of pests and diseases while promoting an efficient use of rainwater to be harvested (for more details see practice 26 described latter in this document).

Activity 1.3.2. Organize training for 2,500 farmers to improve technical skills for enhancing coffee and cocoa value chains and to strengthen organizational capacities of producers' associations to access markets.

458. Improving the value of agricultural products and strengthening organizational structures to link them with the market provides opportunities of improving farmers' income and also improves their capacity for addressing and adapting to the negative impacts of climate change. The practices described below will be implemented for that purpose.

PRACTICE 21. Strengthening the resilience of small farmers' livelihoods by adding value to cacao production.

459. This practice complements the actions developed to increase cacao farm resilience through agroforestry system renewal/ establishment, since it will generate income for small farmers, making their livelihoods more resilient, aside from making the aforementioned action sustainable. This is justified by the fact that currently, they are not organized to sell the product and do not have the necessary financial resources to add value to their production, giving them very low income from this activity. The value of cacao may be tripled merely by selling the cacao dry instead of wet. At the same time, their economic conditions limit their response to events caused by climate change.

460. The activities developed as part of this practice are:

- **Organization of producers:** Small farmer´s organization and association will be promoted considering the proximity of their productive units; they will be strengthened by creating companies.
- **Training for adding value to cacao:** As for coffee, training modules will be organized for community farmers and specialized technicians will be hired for the farmer´s organizations, as well as for community promoters and MAGA extension agents. The content of the training is:

    - Organizational strengthening
    - Business development and management
    - Marketing and productive chains

- **Technical assistance:** local promoters and agricultural extension agents will provide technical assistance; six agricultural technicians will be hired by the project., and a technician will also be hired to strengthen organizations. He will strengthen the administrative, accounting and fiscal aspects of the organizations that will be created as part of the project. This technician will also be responsible for developing the traceability system for the cacao reduced in the field and the history of primary and secondary processing.
- **Building productive infrastructure to provide added value:** This activity refers to building cacao processing facilities, which includes collection centers, fermentation area, solar dryers and offices.
- **Generation of added value:** cacao from productive areas will be received at the processing facilities, where it will be fermented and dried. Next it will go to the cleaning area, where impurities and defective grains will be eliminated, and finally stored in warehouses.
- **Market access:** Market access based on the differentiated characteristics of the national product will be promoted.

PRACTICE 22. Strengthening the resilience of small growers' livelihoods by adding value to coffee production.

461. This practice is crucial for the sustainability of actions, to increase coffee farmers´ resilience by establishing or renewing agroforestry systems, along with system diversification and structure innovations and agroforestry management, adapted to expected climate conditions and risks in the region.

462. As in the case of cacao, small coffee farmers are not organized for selling their production and do not have the necessary financial and technical resources for processing their coffee and giving it added value. Therefore, they have to sell it to intermediaries, which makes their profit margins very low and at the same time does not allow them to escape subsistence and below-subsistence conditions that increase their vulnerability to climate change.

463. The activities that will be developed for this practice are:

- **Organization of farmers:** small-scale coffee farmers´ organization and association will be strengthened and promoted considering the proximity of their productive units; they will be stretchered by creating two companies, one in the Verapaces and one in the Zacapa and Chiquimula area.

- **Training for adding value to coffee:** Training modules for leaders or representatives, members' sons and daughters and members of the boards of directors of small coffee farmers´ organizations will be developed, as well as for specialized technicians that will be hired for farmers´ organizations and community promoters and MAGA extension agents. The purpose is to form a group of members and children of members who will run the companies, and the technicians who will replicate these trainings.
- **Technical assistance:** local promoters, agricultural extension agents, three field promoters and three technicians specializing in coffee, who will be engaged by the project, will help provide technical assistance. A marketing and organizational strengthening technician will also be hired to help strengthen administrative, accounting and fiscal aspects of the organizations that will be created as part of the project. This technician will also be responsible for developing the traceability system for coffee produced in the field until it reaches the parchment stage. To ensure sustainability, a small group of ten promoters will be selected and take part in an intensive training process on comprehensive coffee crop management. They will become the organizations' local technicians in the future.
- **Building productive infrastructure to provide added value:** this activity means building coffee processing plants, which include manual pulping machines, a fermentation area and solar drying structures. Due to the average areas managed by small farmers, they will be organized in groups of two families and a pulping machine, a fermentation tank, a washing tub and a greenhouse-type solar dryer will be assigned to each group. This process will take coffee from cherry to parchment stage (with 10 to 12% humidity). Each group of families will also receive a biofactory for production of agro-environmental inputs (fungicides and bioferments) to improve nutrition and plant health management.
- **Coffee gathering and sale:** Once it reaches the parchment stage, the coffee will be transported to gathering centers located at the offices of community enterprises, where it will be weighed and sold to an exporting company or exported directly.

Component 2. Supporting efficient water management for agriculture to reduce the impact of increased water scarcity.

464. Agricultural crops require water for vegetative growth and development; it must be of the right quality, in appropriate amounts and supplied at the right time. Crops have specific requirements, which vary depending on local climate conditions, the production technology adopted and the corresponding yields.

465. Water required for growth and development of agricultural crops depends on each crop and on local climate and soil conditions and the production technology adopted. In this regard variations in water availability, which is increasingly lower, and greater demand for water mean that this resource must be used more efficiently and that its quality for

production must be conserved, especially for small-scale agriculture, which usually relies only on rainfall.

466. According to IICA (2015), there is enough evidence that shows that appropriate and responsible water use in small production areas through water capture/storage technologies and irrigation and drainage systems reduces negative impacts on crops and their production due to climate instability, and promotes the generation of higher income as well as soil productivity and protection.

467. Through this component, the project proposes different practices for better water management, especially for below-subsistence and subsistence growers, by developing management plans, forestry practices for water conservation and regulation, and implementation of appropriate harvesting, storage and agricultural use technologies.

Output 2.1 Community-led Water Management Plans developed and implemented at micro-basin level to promote climate resilience and enhance economic productivity.

468. Water management plans in each of the micro-watersheds, including aquifers and surface water, will be implemented as part of this Product. These plans will help reach a shared understanding among communities and different water users in each micro-basin, on the best ways to access, conserve and utilize the available water resources. This is crucial, since this resource will be increasingly important with climate change, which will affect water supply in the near future.

469. The micro-watershed approach allows communities and farmers to develop comprehensive activities to ensure maintenance of surface and groundwater levels, water storage and distribution during the dry season. Practices to ensure comprehensive water management, training activities and the implementation schedule will be defined in these plans. Product activities will include supporting water management plan implementation, as well as the strengthening of local capacities among municipal governments, community and indigenous authorities, women's groups, farmers' organizations and other actors, and the development council system at its different levels. The activities also include protecting river basin headwaters through soil and water conservation and restoration of forests and other plant covers (this will be developed in product 2.2, Promoting landscape restoration to improve water regulation).

470. In a context of climate change, water resources will become scarcer in areas prioritized by the project; which justifies this component (For more information, see section C.1.4, The climate problem, water and forests.). Actions must therefore be undertaken at the watershed level to promote comprehensive management of water resources, which will lead to sustainable and climate-resilient productive systems.

471. For comprehensive water management, the watershed must be considered as a natural geographic unit to diagnose, plan and assess impacts on different resources and aspects related to water and associated natural resources. However, a micro-watershed is a smaller

space in terms of scale, which allows organization at the local level, as well as improved livelihoods depending on the potential of the parts (high, medium and low). Work will be done at this level.

472. The three activities shown below are proposed as part of this Product.

Activity 2.1.1. Establish or strengthen the capacity of 14 Local Water Committees for climate risk-informed integrated water resource management and planning instruments related to public policy on climate change.

473. For sustainable management of water resources and their associated resources, the first step is to promote the training of human resources able to lead this management and create the entities that will design and implement the aforementioned actions.

474. The project will train local government organizations (Municipalities, MAGA, MARN, and INAB) on incorporating climate change adaptation and comprehensive water resource management considerations into planning processes. Emphasis will be placed on promoting inclusion (of women, young people and indigenous groups) in decision making, economic empowerment and local planning to implement climate change adaptation actions.

475. The key administrative structures for identifying and implementing micro-watershed development and sustainability actions will be developed through this activity.

476. These structures might take the shape of micro-watershed committees, commissions, councils or boards, but because their creation will be part of a participative process, the chosen structure will depend on decisions taken on each of the micro-watersheds. It is expected that they will be formed by the Community Development Councils (COCODES), committees, cooperatives, private sector representatives and other legally recognized groups. The inclusion of second-level COCODEs will provide advocacy on the Municipal Development Council (COMUDE) and the Departmental Development Council (ODEDE) development plans.

477. These watershed management committees, commissions, councils or boards will be the watershed management plan coordinating and implementing bodies, which will be made up of community authorities, women leaders and irrigation council representatives and other actors that use or are involved in water management.

478. The actions planned in this activity are:

i. Conducting an awareness raising process aimed at municipal and local authorities, men and women leaders on: (a) the importance of the watershed approach, natural resource management with a watershed and climate change approach; (b) creating micro-watershed councils; and (c) developing micro-watershed management plans with emphasis on climate change.

ii. Training micro-watershed councils to develop and strengthen capacities on the watershed management and joint management approach, resilience to climate change, project planning, organization and management, political participation and advocacy and promoting forest incentives.

iii. Promoting the creation of interagency micro-watershed management commission.

Activity 2.1.2. Provide technical assistance to Local Water Committees to develop and implement 14 climate risk-informed water management plans at micro-basin level which correspond to the project site[55].

479. The planning instrument that will guide actions to be implemented to promote sustainable management of water and associated natural resources will be developed through this activity. The actions to be developed under this practice are:

i. **Biophysical characterization:** provides information regarding the different plant and animal aspects and climate characteristics through the existing primary and secondary information.

ii. Primary and secondary information will show the specific characteristics of the micro-watershed with regard to organizational aspects and the main economic activities inside the micro-watershed.

iii. **Environmental characterization:** refers to the possible impacts of project interventions. There is an exhaustive list for categorizing the impact and the environmental management tools to be used are provided by the Ministry of the Environment and Natural Resource (MARN).

iv. **Cultural aspects:** to learn about the different cultural, religious and non-religious activities of the communities present in the micro-watershed (which are strongly related to crop, water, forest and soil management). This information is gathered during focal groups through form used to collect information.

v. **Institutional aspects:** involves the mapping the actors with which the communities interact and with which actions will be coordinated.

vi. **Political and legal aspects:** consist of describing governance and organization aspects at the national and local level. This information will be obtained through a bibliographic review, focal groups and interviews.

vii. **Watershed potentials:** watershed potentials will depend on the results of the different thematic maps developed to identify soil uses and capacity and water quality for different purposes, as well as on observations made during field visits and direct interviews with key actors (growers, promoters, extension agents, etc.).

[55] The number of watersheds needed to develop a micro-basin water plan was estimated by a group of experts, based on the size of the watersheds of the region and the number of hectares where RELIVE is going to promote adaptation practices.

viii. **Water uses:** this information will be gathered in coordination with local authorities and water committees, and obtained through visits to water sources to perform gauging's and quality sampling. This information will show the water volumes used for different purposes.

ix. **Relevant issues:** determined in a participatory way with the information gathered or through observation visits with the actors involved.

x. **Participative construction of the management plan:** consists of developing a solution to the issues identified, as well as the short, medium and long-term actions to be conducted for the purpose. An important part of these actions is assigning those responsible for implementation and the budget required for its implementation.

xi. Strategy for implementing the micro-watershed management plan: the organizational model to be used to set up the micro-watershed council or commission, in the framework of joint water management and other aspects, that will be responsible for carrying out the plans. As part of this activity it is crucial to use MARN Ministerial Resolution 335-2016, which provides the main guidelines for its implementation.

Output 2.2 Landscapes are climate resilient and sustain critical ecosystems services for water availability in drought periods.

480. The project will seek to integrate restoration of the forest landscape as a climate change adaptation strategy for increasing forest cover, improving the water cycle, increasing the amount of water available and regulating surface and groundwater flows, at the same time as water supply and quality are maintained and improved. The project's landscape approach will ensure that land degradation is reduced (or reversed) and that water productivity is maintained and resists climate change impacts, thus helping to improve communities' food security and resilience. Restoration activities will be included as part of water management plans that prioritize key areas with a high potential for restoring the water cycle.

481. This Product is based on the fact that forest masses are an effective tool against climate change, not only because they absorb greenhouse gases (GH), but also because they create more resilient landscapes. This is because (as already explained in section C.1.4., The climate problem, water and forests), forests regulate water flow. In other words, to the extent that natural forests retain their characteristics (composition, coverage, etc.) they will help generate exosystemic services in quality and quantity and, therefore, favor conditions in the territories (watersheds or landscapes), in this case as water reservoirs, improving their resilience against the effects of climate change, such as drought and aridity.

482. The measures in this Product will be supported in the preparation of projects that will be the object of forest incentive mechanisms (PROBOSQUE or PINPEP) promoted by INAB. These financial mechanisms will provide resources to facilitate the implementation of appropriate forestry practices to protect forest cover. Part of the measures implemented

includes promoting local governance processes and mechanisms to facilitate interaction among actors; Local Extension Systems will be promoted as a space for coordination and articulation among local actors who participate by conducting extension activities, in addition to reaching agreement on interagency agendas to prevent duplication of efforts and optimizing the use of resources allocated to managing incentives.

483. The practices that will be implemented to restore the forest landscape include: (a) forest protection for water supply; (b) forest management for water production; (c) forest management for forest and water production; and (d) reforestation of strategic areas for water and forest production.

484. It is worth mentioning that agroforestry systems play an important role in regulating the water cycle, which means that coffee and cacao systems will also be part of this measure and included in forestry incentive payment schemes; but since the way they will be established in the field was already explained, they will not be described in this section (For more details see Component 1).

485. In activity 2.2.1, the evaluation and preparation of technical reports to facilitate farmers' access to forest incentives will be financed by KOICA as well as the technical assistance funded by KOICA aims to resolve three bottlenecks that a small holder farmer or owner has to access forest incentive programs: a) the cost of preparing forest management plans (technical expert from the Project will prepare the forest (agro) management plans); b) documentation of the rights of possession or ownership of land (technical expert from the Project will facilitate this process); and c) access to vegetative material (coffee, cocoa, forest species) for the implementation of the incentives via planting agroforestry systems. KOICA funding will cover costs of technical experts who will prepare the forest management plans. The GCF grants will support (i) trainings to extension technicians and INAB staff to better integrate a climate change perspective and agroforestry systems in their standards and requirements and strengthen the technical capacities and effective support to smallholder farmers (Activity 2.2.2) and (ii) the planning and implementing of forest conservation interventions on 13,000 ha through reforestation and agroforestry (Activity 2.2.3). In activity 2.2.4, INAB's co-finance will be allocated for projects selected under the forestry incentive programs, PINPEP and PROBOSQUE, added to MAGA's in kind contribution for the Operational Plan of the Project (human resources, inputs, logistics, etc.).

486. GCF grants will enable an innovative pathway and will create long-term impacts by integrating climate lens in the forest incentives (which is a new approach in the programs of forest incentives in the country) thus providing opportunities for smallholder farmers to access finances for promoting climate resilient agricultural practices.

Activity 2.2.1. Technical support to 19,239 smallholder farmers (women in particular) to access forest incentives.

487. This activity considers several practices, each one linked to one of the modalities of forest incentives, which are described below.

PRACTICE 23. Protecting forests for water supply (protection of 150 hectares)

488. This practice consists on planning and implementing forestry practices to manage forest cover (natural forests) and ensure the generation of environmental goods and services, especially water infiltration and recharge, in addition to reducing risks. The purpose of this measure is to improve forest and agroforestry cover, and to restore hydrological function, especially those related to rainwater collection, and surface runoff reduction and regulation.

- Develop the management plan: establishing protection/conservation activities and the method for recovering the forest mass (restoration, whenever required), as well as implementing forest protection measures.

489. Implement the management plan: developing the actions described in the management plans. These activities will be approved by the governing entity (INAB) after the plan is approved.

490. The forest management plans will include the following items:

- Definition of protection objectives:

491. The main objective of the plan must be defined in terms of which resource will be protected when implementing the activities. The actions will be directed towards the main protected resource (soil, wildlife, water, flora, etc.). It is important to define the resource (s) to be protected.

- Forest inventory:
    - Description of biophysical characteristics (climate, hydrography, type (s) of forest (s): Using existing national cartography and with the geo referenced location of the area the biophysical characteristics have to be described. This has to be validated in the field to assure that the description fits reality.
    - Justification of the resource to protect: Definition of the reasons of protecting the selected resource. It could be in terms of its importance for human settlements, genetic banks, means of production, etc.
    - Forest characterization
        - Diametric classes per species: This refers to the distribution of the diameter in each of the forest species that make up the forest. To

obtain this data it is necessary to implement measurement units distributed in a statistical way within the forest (randomly, systematically, etc.). The data to be obtained is the diameter to breast high, total high, common name of the tree, uses, amount of natural regeneration per hectare etc.). This data will be then analyzed to obtain the conditions in terms of quantity and quality of the forest. The quantity and area of measurement units will be defined based in the forest surface and its homogeneity or heterogeneity conditions. Based on this information, actions will be generated to be implemented in the forest.

- Protection measures
    - Prevention and control of forest fires: Areas of the forest that are more at risk of fires will be identified to prevent forest fires. If the area does not have a natural barrier (river, water creeks, etc.) the action would be building a round firewall across the risk area. This firewall has to have three meters wide and it has to be clean of organic material. Depending on the area and risk areas, the forest will have to have interior intermediate firewalls
    - Prevention, control and monitoring of pests: Presence of pests depend on the forest species. The control relies on efficient monitoring considering the seasonality of pests and the preventing actions.
    - Illegal logging monitoring: Identify risk areas where the illegal logging is taking place and implement fences and monitoring.
- Restoration methods
    - Forest enrichment: For this activity, native species that have ecological importance to the ecosystem must be identified and plant them in areas where they do not exist. The rate of sowing is 400 trees per hectare, taking into consideration biodiversity and avoiding the inclusion of a sole species, as a monoculture. Before planting, the area has to be free of weed or at least each plant has to have one sq. meter free of weed in a form of a round dish.
    - Planting: The use of native species (commercial or non-commercial) is required due to the ecological importance in the ecosystem. The rate of sowing is 1,111 trees per hectare; the recommendation is to plant them at 3 X 3 between grooves.

- Natural regeneration management: For this method, it is necessary to rely on the inventory data, which provides the regeneration per hectare, so that to obtain an average of 75% to 60% of the original amount of natural regeneration during the project´s implementation. Monitor the regeneration each year is required, taking off the weed around it in a diameter of one meter and trying to keep the sunlight open so it can grow properly.

- Characteristics of hydric resources to protect
  - Type of hydric resource (lake, river, water creek, etc.): First step is to identify the hydric resource intended to protect, which has to be a permanent hydric resource. If it does not have a permanent source, it cannot be protected through forest incentives. Species along the riparian forest have to be identified, as well as its location to comply with the correct restoration method. Basic information at this respect will be described in the forest inventory that is done at the beginning of planning.
  - Water use (irrigation, human consumption, industry, etc.): This part of the plan includes a description of the use of the hydric resource to justify its protection. It is important to describe number of beneficiaries of the hydric resource.

PRACTICE 24. Forest management for forest and water production (100 hectares)

492. This practice consists of managing the forest mass through different forestry practices for conservation/protection of water sources and other environmental services, and using timber and/or firewood by applying the practices that are best suited for the type and size of the forest. This practice includes the following components:

- Management proposal: defining all the activities for forest use and water conservation in a document. The relevant activities include regulating the area to be used based on actual use of the soil, defining the type of forest and development categories, mapping the intervention areas and areas to be protected based on the criterion of water source production or protection, defining the duration of the management plan and the forestry practices to be implemented.
- Development of the management plan: this activity consists of establishing the annual allowable cut, calculating the amount of timber and non-timber products by species that will be felled and a description of utilization activities and the method for recovering the forest mass, as well as implementation of forest protection measures.

- Implementation of the management plan: field implementation of the activities described in the management plan. These activities will be approved by the governing entity (INAB) after approval of the plan.

493. Actions in this practice are described in the practice for forest conservation for water production.

- Forest inventory:
    - Description of biophysical characteristics (climate, hydrography, type (s) of forest (s)): Using existing national cartography and with the geo referenced location of the area the biophysical characteristics have to be described. This has to be validated in the field to assure that the description fits reality.
    - Justification of the resource to protect: Definition of the reasons of protecting the selected resource. It could be in terms of its importance for human settlements, genetic banks, means of production, etc.
    - Land use characterization: Using existing cartography and with the geo referenced location of the area the characterization of the land use has to be described in terms of percentage of land use. This has to be validated at field level to assure that the description fits reality. This is important so that the activities planned won´t overuse or underutilize soil.
- Forest characterization
    - Diametric classes per species: This refers to the distribution of the diameter in each of the forest species that make up the forest. To obtain this data it is necessary to implement measurement units distributed in a statistical way within the forest (randomly, systematically, etc.). The data to be obtained is the diameter to breast high, total high, common name of the tree, uses, amount of natural regeneration per hectare etc.). This data will be then analyzed to obtain the conditions in terms of quantity and quality of the forest. The quantity and area of measurement units will be defined based in the forest surface and its homogeneity or heterogeneity conditions. Based on this information actions will be generated to be implemented in the forest.
    - Forest products distribution (log, firewood, etc.): Based on the information from the forest characterization and according to market demands in terms of diameter of commercial species, the forest products distribution may be obtained. The base line information described in the forest inventory provides the required information for the allowable annual cut based on the timber annual increase or establishing a minimum cutting diameter, depending on economic issues.
- Protection measures

- Prevention and control of forest fires: Areas of the forest that are more at risk of fires will be identified to prevent forest fires. If the area does not have a natural barrier (river, water creeks, etc.) the action would be building a round firewall across the risk area. This firewall has to have three meters wide and it has to be clean of organic material. Depending on the area and risk areas, the forest will have to have interior intermediate firewalls
- Prevention, control and monitoring of pests: Presence of pests depend on the forest species. The control relies on efficient monitoring considering the seasonality of pests and the preventing actions.

- Restoration methods
    - Forest enrichment: Identification of native species that have ecological importance to the ecosystem to plant them in areas that do not have this species. The rate of sowing is 400 trees per hectare; it is necessary to consider biodiversity and not planting as sole species as a monoculture. Before planting, the area has to be free of weed or at least each plant has to have one sq. meter free of weed in a form of a round dish.
    - Plantation: Use native species (commercial or non-commercial) that have an ecological importance in the ecosystem. If the main objective is industrial use, the rate of sowing is 1,111 trees per hectare planting them at 3 X 3 between grooves:
    - Natural regeneration management: This method relies on the inventory data where the amount of regeneration per hectare is established, so to achieve an average of 75% to 60% of the original amount of natural regeneration during the ten years of the project. It is necessary to monitor the regeneration each year, taking off the weed around it in a diameter of one meter and trying to keep the sunlight open so it can grow properly.
- Characteristics of hydric resources to protect: First step is to identify the hydric resource intended to protect, which has to be a permanent hydric resource. If it does not have a permanent source, it cannot be protected through forest incentives. Species along the riparian forest have to be identified, as well as its location to comply with the correct restoration method. Basic information at this respect, will be described in the forest inventory which is done at the beginning of planning.
- Water use (irrigation, human consumption, industry, etc.): This part of the plan includes a description of the use of the hydric resource to justify its protection. It is important to describe number of beneficiaries of the hydric resource.

PRACTICE 25. Agroforestry systems for water provision (18,957 hectares of cocoa and coffee)

494. As in the case of forests, agroforestry systems (if well managed) improve water recharge and productivity during the dry season. Therefore, this practice will encourage the incorporation of agroforestry systems located in strategic areas of the watersheds the Forest Incentive Programs (PROBOSQUE – PINPEP). The following actions shall be developed for that purpose:

- Management proposal.
- Development of the management plan.
- Implementation of the management plan.

495. The actions are not detailed in this section, since they were described in activity 1.2.1.

Activity 2.2.2. Training of 90 technicians from extension services, forest regents and INAB.

496. This practice was designed to support extension strengthening described in Component 3 and especially Practice 29, and will consist of strengthening the forestry institution (INAB). It will be carried out throughout the implementation of incentive modalities, technical counseling for beneficiaries and supervision of incentive areas to be established through the RELIVE Project. Eight INAB technicians will also be hired to support the record review and approval process for accessing forest incentives in the project area.

Activity 2.2.3. Restore 13,000 ha through reforestation and agroforestry.

497. As for agroforestry systems restoration, this activity will be implemented through the actions proposed in activity 1.2.1. (Implement adaptation practices and gender-sensitive technology packages for staple crops, coffee, and cocoa in 6,195 family farms), specifically though Practices 3 (Agrobiodiversity diversification and creation of a favorable microclimate in the coffee parcels), 7 (Establishment of improved, rust and drought-resistant coffee hybrid), 8 (Adaptation and diversification of the shade canopy structure-architecture with leguminous arboreal, fruit and timber plants with greater resiliency to the climate conditions in the coffee parcels), 9 (Adaptation of coffee plant spatial arrangement and architecture to climate change effects forecasted for the region), 12 (Establishment of productive cacao clones resistant to the main diseases), and 13 (Shade canopy structure-architecture adaptation and diversification with plants and trees (legumes, fruit and timber trees) appropriate for the climate conditions forecasted for the cocoa parcels in the region). For forestry restoration, the actions to be implemented are the ones described in Activity 2.2.1, specifically on Practices 23 (Protecting forests for water supply), and 24 forest management for forest and water production. This activity will also be developed based on management plans that are part of Activity 2.2.1.

Activity 2.2.4 Evaluate forest management plans and certify their compliance to manage and allocate the necessary funds to reforest and manage 13,000 hectares of plantations and agroforestry systems

498. To pay forest incentives, the technical forest agents of INAB has visits the farmers to provide technical support to producers for the development of the forest management plans. After developed, and if the forest management plan meets all the requirements, the forest agents approve it. During the following year, the forest agents proceed with a series of visits to evaluate the accomplishment of the actions proposed in the management plan. If the plan and the minimum trees density required have been accomplished, INAB proceeds with the payment of the forest incentive.

This activity is essential for RELIVE to have the INAB counterpart (USD24.1 million). INAB promotes the forest incentives through organization of events to present the Incentive Program to forest and agricultural producers, landowners or owners of forest lands. In these events, the causes and impacts of climate change variability and the adaptation and mitigation measures and practices that can be implemented are made known, among them those related to the management and recovery of degraded lands and forests and the financial support that forestry incentives mean for forest recovery and restoration plans. The legally mandated (technical) administrator of the programmes is INAB, which has a technical, legal and administrative structure for promoting incentives, reviewing and approving forest and/or agricultural management plans and certifying compliance with these plans. Once INAB certifies compliance with a management plan, it notifies the Ministry of Public Finance to make payments to the land holders/owners who, in the present case, would be the beneficiaries of the Project. The financing of the forestry incentives comes from the Government of Guatemala, which under specific laws for the PINPEP and PROBOSQUE programmes, allocates annually the financial resources for the owners/holders of forest lands, assessed, supervised and certified by INAB. The financial resources come from the regular income of the Government, i.e. taxes from Guatemalans. The total amount of resources available, according to specific laws, amounts to 1.5% of the annual income of the public treasury. The amount of these incentives represents the co-financing provided by INAB to this project. The incentives are granted, according to the forest or agroforestry management modality, for 6 or 10 consecutive years from the year in which a project is accepted and approved by INAB. All technical and administrative aspects related to the administration and management of forest incentive programs are established in specific laws (Decree Law 51-2010, Law on Forest Incentives for Holders of Small Areas of Land with Forestry or Agroforestry Vocation - PINPEP -, and Decree 02 - 2015, Law for the Promotion of the Establishment, Recovery, Restoration, Management, Production and Protection of Forests in Guatemala – PROBOSQUE)-.

499. The financial resources of the forestry incentive programs, PINPEP and PROBOSQUE, are allocated annually to INAB based on a projection that INAB presents to the Ministry of Public Finance and which is approved yearly along with the national budget by the Congress of the Republic. Approval of a forest (agro) management plan by INAB is followed by the issuance of a resolution to guarantee the user of the incentive for a given period of time (6 to 10 years, depending on the forest management modality established in the management plan). INAB will provide the user annually with an amount of financial resources (money), once he/she has complied with the activities of the approved management plan. The

resolution issued by INAB is a sufficient guarantee for a producer to have the forestry incentives, since it is part of the laws and regulations governing the administration of the two programmes. The Project, implemented by FAO, supports the producer in the elaboration of the plan and its implementation. Under this condition, an agreement between INAB and FAO is not necessary, since the law obliges INAB to establish agreements with the users of the programmes, through the Resolution, which has legal and administrative effects. INAB, in the same resolution, states that the financing of the incentive is subject to the allocation that the Ministry of Finance makes available under the Organic Law of the Budget of the Republic approved annually by the Congress.

500. The Operational Plan of the Project, which is approved by the authorities of MAGA, MARN and INAB, defines MAGA's in kind contribution (human resources, inputs, logistics, etc.).

Output 2.3 Local water collection and irrigation farm systems implemented to secure water supply for resilient livelihoods

501. This product focuses on water harvesting, understood as the practice of gathering, storing and utilizing rain water through different technologies for its subsequent use. This practice is used mainly in arid areas or where water is scarce at certain times during the year (Carvajal, 2015) and (Pizarro, y otros, 2015) and will be implemented at the family garden level.

502. The use of rain water harvesting technologies for use on basic grains, family gardens and poultry raising is proposed in the framework of this project to cover the water requirements for raising crops and/or animals and increase its availability.

503. The beneficiaries of the water collection and irrigation farm systems are the same ones that will be beneficiated from the family gardens. The selection criteria are presented in section C.3.4 (Criteria for selecting beneficiaries when implementing the project).

Activity 2.3.1. Provide trainings to improve technical capacity of 2,500 local officials and members of community organizations on the implementation and maintenance of micro-basin infrastructure.

504. This activity will strengthen the practices and actions proposed in Activity 2.2.1, as well as sustainable water management planning in Activity 2.1.2; and Practice 29. A series of landscape restoration and management and green infrastructure workshops and training sessions will be implemented.

Activity 2.3.2. Install farm-level drip irrigation system for using harvested water at 250 ha of farm land.

This is a complementary action to those linked to crop management and agroforestry systems. It is developed to ensure irrigation water for agricultural productive systems.

PRACTICE 26. Utilizing rain water to improve below-subsistence and subsistence families' productive systems by implementing rain water harvesting and efficient irrigation technologies.

505. Water management is crucial for improving profitability and increasing yields, for food security and to make agriculture possible in areas where the possibility of growing crops and raising animals did not exist due to water scarcity (Prinz, 1996) and (FAO, 2000).

506. Implementing this system may provide considerable benefits for adaptation, since it fosters water conservation by using an alternative source for agriculture and livestock; favors production diversification and stabilization throughout the year; and allows growers to plant or establish crops during seasons with lower rainfall and/or shifts in rainfall patterns (e.g. prolonged midsummer droughts), which helps improve production efficiency, generate more income and improve growers' and families' food security, especially at the below-subsistence and subsistence level.

507. Another very important benefit for below-subsistence and subsistence level farmers in Guatemala located on steep slopes is reducing the risks associated with water erosion during the intense rains that occur during rainy seasons. These systems gather the surplus runoff and store it for subsequent use (JICA, 2015) and (FAO, 2000).

508. This practice is more effective if implemented jointly with practices such as efficient water use, stubble management, not burning stubble and using dispersed trees. Implementing the system best suited for each locality and farm requires that important aspects such as rainfall intensity and distribution, soil characteristics, the slope, construction costs, crop water requirements and evapotranspiration should be taken into account. Another important requirement is knowing the actual precipitation56 .

509. Soils are the fundamental basis to quantify the required dimensions for implementing a water gathering system, since soil diversity in arid and semiarid areas is very broad. Placing the water catchment area in places with high surface runoff is recommended to gather the largest possible amount of water, whereas the crop should be located in fertile and sufficiently permeable areas. Physical soil characteristics, such as texture, structure, depth, fertility and infiltration are required to calculate the field's capacity and permanent wilting point. Knowing the duration of the cycle and the crop's water requirements or crop coefficient (Kc) is important after determining soil characteristics. It shows the water volume extracted by the plant from planting to harvest, considering the crop, the climate and evaporation of the water contained in the soil. The values calculated to cover bean and maize water needs are 300-500 mm and 500-800 mm, respectively. These values are for the total vegetative period (FAO, 2000).

[56] Not all rainwater is available for the crops. Part of it is lost through surface runoff, another part through deep percolation to aquifers and another part is permanently stored to the capacity of the field, where it may be utilized by the plants; that is the portion called "effective precipitation". The CROPWAT method developed by the USDA is used to calculate effective precipitation. Monthly precipitation data for the entire year are needed (Carvajal, 2015).

510. Rainwater collection systems are empirical techniques that have been developed over time; there is a large variety of techniques adapted to the specific situations in each place.

511. The irrigation activities refers to family vegetable plot irrigation system for the beneficiaries included in the adaptation practices for basic grains and family gardens, and it is focus on food security. Each irrigation systems will consist of not more of 0.1 Ha each (250 ha in total) located close to the small farmers houses.

512. The harvested rainwater will be drip irrigated by gravity (table 52 provides the list of the implements needed for the irrigation system, and the Annex 4 provides the estimation of the cost). The cost and the maintenance of each unit is minimum, but without the support of GCF it would not be possible to be implemented

513. Some examples of water capture techniques that will be used in the project are shown below (García, 2012) (PNUD, 2015),:

514. **Collecting rainwater from roofs**: as can be seen in Figure 58, rainwater is collected on the roof of a house, shed or building; rainwater that falls on the effective roof area is usually transported in pipes to the discharge or storage area and finally stored in an above-ground, underground or raised concrete, ferroconcrete metal or plastic tank. It is estimated that one millimeter of water that falls on a square meter of roof can collect a liter of water; however, there may be losses of 20% due to splashing and possible losses along the gutters, which reduces the water per millimeter of water that falls on a square meter of roof to 0.8 liters of water.

Figure 58. Rainwater storage structures or reservoirs.

515. **Drip irrigation system for using harvested water:** rainwater is collected in a raised tank; when required by the crop, water is released through drip pipes or tapes with small holes located directly at the planting point or very near the plants. The water is only applied to the growing areas, preventing waste and saving a large amount of water through very focused application (Figure 59).

Figure 59. Drip irrigation using captured rainwater.

516. Each tank will collect 20,000 liters. The list of materials for its construction is summarized in the next table:

Table 52: List of material for the construction of a rain water harvesting tank of 20,000 Liters

Product description	Unit	Quantity
Cut sheets of Geomembrane HDPE 40MIL (1 mm) width 6.86mts x 7mts	Cut sheets	1
Corrugated millimeter electrogrid (width 2.5 mt by 6 mts long) with frames	Unit	2
Tie wire	Pound	3
Metal channel with top and bottom of 2.40 meters long	Unit	1
2.40 meter long metal channel	Unit	1
Smooth metal channel 2.40 meters long	Unit	1
3-inch 90 degree PVC elbow	Unit	2
3-inch PVC downpipe tube	Unit	3
Plastic straps	Unit	50
Metal hooks for channel support	Unit	9
1¼ inch thick galvanized tube	Unit	2
1/2 pipeline	Roll	1

1 "90 Degree PVC Elbows	Unit	2
Union smooth PVC 1 "	Unit	2
1 "PVC pipe	Pipe	3
He had 50 grams of PVC glue	Unit	1
3/4 "Teflon roll	Unit	1
1 "inch plastic ball valve	Unit	1
1 "inch 120 mesh filter	Unit	1
1 "inch flat female plug	Unit	1
Starter connector with 12 mm hose packing	Unit	5
12mm Blind Hose	Meter	10
12mm T for drip hose	Unit	6
12 by 12 mm couplers for drip hose	Unit	10
1 "PVC female adapters	Unit	2
Male adapters with 1 "PVC thread	Unit	2
Female adapters with 1 "PVC thread	Unit	4
12 mm valves for drip hose.	Unit	5
12mm drip hose at 10 cm.	Meter	50

Component 3. Improved enabling conditions for climate resilient livelihoods.

517. According to Ojeda (2005), cited in (Calvo & Gutiérrez, 2010), governance is "a broader notion than government, since it does not refer to specific structures but to a series of procedures and practices that involve a broad range of actors and network". This is understood as the set of processes and institutions (formal and informal) where standards, behaviors and organization modalities are defined; in other words, persons, organizations, groupings or groups state their interests, negotiate their differences and exercise rights and obligations through these processes and with regard to Access and use of the topic of interest.

518. Adoption and adaptation of climatically intelligent systems requires better and greater technical and functional capacities. In other words, complementing technical knowledge with functional capacities is crucial for obtaining sustainable results. Functional capacities aligned with climatically smart agriculture include their ability to formulate and implement policies and undertake regulatory reforms; generate, manage and Exchange data, information and knowledge; implement programs and projects; and participate in multisector networks, partnerships and platforms with subnational sectors and non-governmental actors. Boosting and organizational and institutional capacities and networks, improving their coordination for better joint planning, assigning roles and responsibilities, facilitates processes (FAO, 2018a).

519. Component 3 will center on strengthening institutional capacities at all levels for comprehensive governance based on the risks for agricultural systems and water resources at the micro-watershed level, promoting interagency platform management to coordinate and improve knowledge management. These enabling factors will support effective

implementation of the activities of Components 1 and 2. This component is crucial for achieving replicability and improving resilient agricultural practices at the landscape level and achieving the expected paradigm change. Component 3 is made up of two Products, described in the following sections.

Output 3.1 Institutional systems strengthened to govern climate resilient initiatives at national and local level.

520. This Product seeks to improve comprehensive governance for climate adaptation in project intervention territories by strengthening national and municipal environmental units, local development associations and communities, to promote their active participation in water management boards and ensure that all actors contribute effectively to water collection, management and sustainable use with a landscape approach. This will all be achieved by promoting multi sectoral dialogue and strengthening institutional information management systems and the national and local level.

521. At the national level, dialogue will help turn this topic into a priority for MAGA and INAB, and other relevant agencies. This will include discussions on how to broaden extension services' mandate to include climate change resilience. Given that the institutional structure is fragmented with respect to water resources, the project will finance development of platforms (if they do not exist) and their strengthening (if they have already been established) at the national level and regional working groups for discussion of water or micro-watersheds for multiple participative and governance dialogues on water resource and climate change management. To this end, the project will work with local authorities, extension services, forestry agents, water users and other relevant stakeholders to develop institutional arrangements for institutionalization of water governance structures.

522. MAGA and the Ministry of the Environment and Natural Resources (MARN, as AND for the FVC) will lead the dialogues to incorporate climate change in sectors related with water and territorial planning documents, solving conflicts and following a common comprehensive water resource management vision.

523. At the municipal level, the project will promote cooperation among extension service workers, forestry agents and the relevant municipal officials, farmers and other important local actors for information management on resilience and climate change, coordination and management of the selected micro-watersheds.

Activity 3.1.1. Provide training of 100 technicians from 28 municipal environmental units and other local governance agencies on climate adaptation planning and climate resilient agricultural solutions.

524. Strengthening established structures at the national and local level linked to project actions will be promoted. These seek subsistence and below-subsistence agricultural system resilience and water resource management for agriculture. To the extent possible, existing structures (platforms, discussion groups, etc.) will be used. However, if they do not exist,

they will be created in coordination with and convening the relevant actors. Institutions and organizations will be strengthened to focus on coordination and conflict settlement instruments related with territorial management and water resources.

525. Work with local actors (municipal environmental units and other local governance agencies) under this practice will also seek to incorporate the climate change variable into planning instruments, to ensure that actions are contemplated to reduce its causes (mitigation) and, especially, in line with this project's objectives, reducing impacts on people and their livelihoods (adaptation).

526. As part of strengthening the capacities of local governance structures, working meetings and training and/or discussion sessions will be held with the relevant actors to identify the existing governance structures and determine whether they are suitable for project implementation. This activity includes a review of local planning tools to promote inclusion of the climate change variable in it.

Activity 3.1.2. Facilitate 4 meetings of 2 water management and climate change thematic roundtables including the participation of MAGA, MARN and other relevant actors to integrate agricultural resilience practices in the national action plan on adaptation to climate change.

527. This activity is considered complementary to project management and for strengthening capacities for climate adaptation and water resource management for agriculture, promoting trans-sectoral dialogue and participate decision making on territorial management to improve resilience. A necessary condition for participative decision making is including all stakeholders, which may require organization and dialogue at different levels, to strengthen each group of actors according to their specific needs and also respecting any forms of organization that might already be established. For this purpose, two water management and climate change thematic roundtables will be created. These tables will allow the promotion of inter-institutional coordination on climate adaptation and water resources management.

Output 3.2 Strengthened knowledge transfer and awareness raising among institutions at national, sub-national and local levels.

528. Capacity building is the process whereby persons, organizations and societies obtain, strengthen and maintain the necessary skills to reach their own development goals over time (PNUD, 2009). This means that capacities represent the means for planning and achieving goals and, by development, point the way for reaching those goals.

529. Knowledge sharing and counseling in rural areas are important tools for supporting farmers in managing changes and responding to different challenges and/or opportunities. Knowledge is shared by different types of actors, such as growers, extension agents, advisors, facilitators and others, which offer communities in rural areas a variety of services, helping them to develop technical, organizational, entrepreneurial and managerial

knowledge. In this regard, promoting climatically intelligent agricultural approaches is a major challenge that implies changing the traditional paradigms of many farmers´ agricultural practices. However, this transition that focuses on climatically intelligent strategies promotes new information and tools that foster farmers' livelihood resilience and contribute to their sustainable development (FAO, 2018a).

Activity 3.2.1. Train and assist 90 staff members from INAB, MAGA and MARN on the management and dissemination of climate information.

530. This activity would be carried out through the following practice:

PRACTICE 27. Strengthening capacities for access to climate information as the basis for adaptation planning.

531. The project will address the urgent need to develop national, sub-national and local institutions' capacities on climate change adaptation. At the national level, the project will be based on the progress achieved by MARN and other organizations in establishing the National Climate Change Information System (SINCC)57. It will support climate information gathering and dissemination for agriculture and place it at farmers' disposal.

532. To facilitate implementation of this measure, it is necessary to work with public and private institutions that provide basic grain producers with climate information, extension and seeds to create an enabling environment for sharing information and/or services among the different actors.

533. All of the above will be developed based on a study that will analyze the information state of the art and propose strategies to strengthen the issue. The results of this study will also provide elements that might be consolidated in a project under FVC Readiness funding to help prepare or improve information flow platforms/applications. Specific activities under this practice are:

- A study to analyze the state of the art of national climate information, its platforms and actors, including proposals to improve climate information availability, quality and flow.
- Develop a proposal for readiness fund financing to implement measures that will improve t information availability, quality and flow in Guatemala.
- Implement measures to improve local actors' access to information at the short term.

Activity 3.2.2 Train 100 experts at departmental and municipal level and agricultural extension workers and other staff from SNER on climate risk-informed agricultural adaptation strategies.

534. At the subnational and municipal level, the project will work with the MAGA's National Rural Extension System (SNER) through extension agents, volunteer promoters incorporated by the SNER and promoters and extension agents hired by the project and local partners,

[57] The SNICC is a platform for decision making related to vulnerability and adaptation to climate change in Guatemala. Even though this platform is designed to facilitate the exchange of information, it is required to to strengthen the knowledge transfer between institutions at national, sub-national, and local levels to ensure the information reach the user in the different levels.

giving them specific training in the municipalities on climate information use and analysis, informed planning on climate risk, developing strategies for resilient agriculture and everything that has to do with forest incentives and managing different modalities that the project will promote/implement. This will directly improve the provision of technical assistance to beneficiaries in the target municipalities.

535. The actions to be implemented in this activity are:

- At the national level, supporting the existing national systems for climate information management and improving coordination among institutions for sharing knowledge and lessons learned.
- At the subnational and municipal level, improving the technical capacities of agricultural extension workers and SNER staff.

536. This activity will not be limited to extension technicians working for government institutions in order to reduce the risk caused by changes in government priorities and the current limitations of the MAGA extension system. The activity will also include volunteer promoters who are currently being trained by MAGA extension agents and those working for private or non-governmental institutions.

Activity 3.2.3. Train 300 community promoters on the use of climate information and planning instruments for agriculture adaptation strategies and strengthen the capacity of 80 CADERs.

537. Also at the local level, the project will improve the technical capacity of Rural Development Learning Centers (CADERs) and other local organizations (for example, Community Centers for Adaptation) through field demonstrations and the farmer to farmer approach, to facilitate learning among families on how to implement the proposed crop (basic grain) and agroforestry system (coffee and cacao) adaptation practices. Like the previous activity, this one will not be limited to extension technicians of government institutions to reduce the risk due to changes in government priorities and the current limitations of the MAGA extension system. The activity will also include volunteer promoters who are currently being trained by MAGA extension agents and those working for private or non-governmental institutions.

D.6.2. Innovative measures in the project activities

538. The technical solutions proposed by RELIVE in components 1 and 2, adopt tested solutions, which have proven to build resilience in the agricultural systems. Although the solutions proposed are based on the experience and lesson learned from initiatives implemented in other countries by FAO and The Tropical Agricultural Research and Higher Education Center (CATIE), they consist of innovative practices for the country and especially for the smallholder farmers, who currently use conventional and often unsustainable agricultural practices. The proposed interventions take a landscape and ecosystem approach (through agroforestry systems, water storage and irrigation) to increase the

resilience to climate change of vulnerable communities and region, of ecosystems and ecosystems services and, enhance water and food security.

539. The practices that are proposed to be implemented are based on traditional practices in the region, enhanced with scientific knowledge and know how to better address climate challenges such as droughts. This includes improved drought-resistant seeds and varieties, stubble management and non-burning, diversification through the introduction of trees of nutritional value and post-harvest management for the conservation of seed for sowing and self-consumption. A further innovation is the strengthening of the basic grain value chain. The platform developed for this purpose will provide timely information to seed suppliers on seed availability enabling producers to have a seed portfolio available and climate-adapted. The access of farmers and extension officers to technical assistance with a specific focus on climate change consist an innovative measure; as well as the access of farmers to financial services for adaptive practices and access to markets. Links to the private sector will open market niches to ensure the farmers' production is purchased and access to national and local markets will increase farmers' income, thus guaranteeing the continuous implementation of resilient practices.

540. Another innovative aspect is the use of meteorological and detailed satellite climate information such as the Normalized Difference Vegetation Index (NDVI) and data from "Climate Hazards Group InfraRed Precipitation with Station" (CHIRPS). The CHIRPS data (5 kilometers away) will be linked with NDVI (250 meters away) to produce highly detailed weather information. Using simulation models, possible three-month climate scenarios will be generated which will be made available to farmers. Another system to be used would be the Agricultural Stress Index System (ASIS) developed by FAO to detect agricultural areas where crops could be affected by drought. This system is based on 10-day satellite data (dekadal) of vegetation and land surface temperature produced by the METOP-AVHRR sensor that has a resolution of 1 km. Additionally, the very innovative meteorological forecast system developed for Guatemala by INSIVUMEH (2020)[58] will also be an instrument made available to extension officers and farmers to access accurate and timely meteorological information relevant for the successful implementation and management of climate resilient agricultural systems.

541. The proposed rainwater collection systems are empirical techniques that have been developed over time in the region and that will be innovative for the farmers targeted by the project. Farmers will collect rainwater on the roof of a house, shed or building. The water collected will be drip irrigated by gravity.

542. In Component 3, trainings, dialogues, management and dissemination of information integrating climate change as a priority for INAB, MAGA, MARN and other relevant

[58] Government of Guatemala. National Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH). https://insivumeh.gob.gt/meteorologia/pronostico-wrf/wrf-kainfritsch/

stakeholders consist an innovative and essential approach to achieve increased climate resilience in the region targeted by the project and in country.

543. The table below presents some adaptation measures and innovative practices proposed in the project activities.

544. .

Table 53: Adaptation measures and innovative practices and references of use in Guatemala or in the Mesoamerican region

ADAPTATION MEASURE	INNOVATIVE PRACTICES AT FARM LEVEL	EVIDENCE OR REFERENCE OF THE USE OF SUCH PRACTICES
1. Training and knowledge exchange on climate adaptation to facilitate access and socialization of the information generated by the project.	- Use of detailed satellite climate information such as the Normalized Difference Vegetation Index (NDVI) and data from "Climate Hazards Group InfraRed Precipitation with Station" (CHIRPS). - Use of the early warning system for coffee cultivation, based on the use of mobile applications to collect data on: pest behavior, agro-ecological variables and a web module with the orderly delivery of data to facilitate its analysis, interpretation and tracing. - Use of the Agricultural Stress Index System (ASIS) developed by FAO to detect agricultural areas where crops could be affected by drought. - Use of the ACToday system, a project that has generated capacities in the country that include the co-development of a state-of-the-art seasonal forecasting system, whose purpose is to provide climate services to rural communities that depend on rainfed agriculture for their survival. FAO will be the facilitator of these processes of translation and transfer of climate information in the areas of project implementation, through the facilitation of training processes for trainers in the areas of influence of the project for climate information management, with the aim of reducing the hunger, support food and nutrition security and promote sustainable agriculture. - Based on a system of validation and dissemination of technologies called "Mass Participatory Evaluation-EPM" (triadic comparisons of technologies, tricot). - Use of field schools (ECAS).	SATCAFE has been used by FAO in the Huistas, Huehuetenango (SATCAFE), San Marcos, Quiche and Oriente regions. Then it has been used by the National Coffee Association, the Ministry of Agriculture, Livestock and Food. http://siatma.org/satcafe.php https://www.oirsa.org/noticia-detalle.aspx?id=7644 The ASIS system has been used by FAO. It can be applied in the 340 municipalities of the country . http://www.fao.org/guatemala/noticias/detail-events/es/c/1146216/ References for use and benefits of these innovative practices: - Áskorun, E y Vilhjálmsson 2009 - Chen, J. et al. 2004, citado por Van Etten et al. en prensa - European Comission 2014 - FAO 2017, FAO 2015, FAO, 2018b Agricultura climáticamente inteligente) - Finquelievich y Fischnaller 2014. - Fenwick 2001 - Mercado, et al, 2017
2. Production of basic grains - corn and beans - from drought-resistant and open-pollinated varieties, supported by the use of climate information in diversified systems.	- Introduction and use of different varieties of improved seeds of basic degrees resistant to drought, open pollination. - Diversification of agrobiodiversity and creation of a favorable microclimate on the plot. - Improvement of organic matter content and soil moisture retention capacity through stubble management and elimination of burning practice. - Harnessing rainwater to improve the resilience of productive systems of subsistence and subsistence families through the implementation of technologies for harvesting rainwater and	Practices used by FAO, CATIE, MAGA and other entities in Projects of the Central and Eastern Dry Corridor of Guatemala. Some references of use and benefits of these practices, used in Guatemala and the Central American region or similar regions, are:- Carvajal, 2015; Pizarro et al, 2015 - CATIE 2018a. - CGIAR Challenge Program on Water and Food. - de Sousa et al. (2017)

ADAPTATION MEASURE	INNOVATIVE PRACTICES AT FARM LEVEL	EVIDENCE OR REFERENCE OF THE USE OF SUCH PRACTICES
	efficient irrigation. - Post harvest management to avoid losses of corn production. - Strengthening of the basic grain value chain.	- FAO, 2000 - FAO 2017). - ICTA 2018, y consultas con personal de ICTA en Guatemala y Zamorano en Honduras. - JICA, 2015 - Kumar & Kalita 2017. - IICA 2013; Mendoza et al. - León y Arroyo 2011. - PNUD (2015 - Posada 2012, - Prinz, 1996; - Villareina et al. 2016 - Xicay, 2016
3. Increasing the resilience of coffee producers through the establishment or renewal of agroforestry systems, with innovations in the diversification and structure of the system, and with agronomic-agroforestry management, adapted to the climate conditions and risks expected for the region. Result in terms of climate regulation at farm / parcel level: A suitable microclimate under shade is promoted for coffee cultivation, where the average temperature can decrease between 2 and 5 °.de café, donde la temperatura en promedio puede disminuir entre 2 y 5°.	- Establishment of improved rust tolerant and drought tolerant coffee hybrids. - Adaptation and diversification of the structure-architecture of the shade canopy with plants and trees (legumes, fruit trees and timber), with greater resilience to the predicted climatic conditions for the region. - Adaptation of the spatial arrangement and architecture of coffee plants to the predicted CC effects for the region. - Management of nutrition (fertilization) of coffee in the agroforestry system. - Management of coffee pests and diseases (emphasis on rust) according to projections and projected climatic anomalies for the region, such as increased temperatures and stronger droughts (Use of the Early Warning System, SATCAFE). - Training and dissemination of knowledge on adaptation to CC to access and socialize information. It covers topics on crop production, the early warning system (SAT Café).	This practice has been used at various sites in the Guatemalan dry corridor. References for this practice: - ANACAFE 2015. - Bertrand et al. 2011 - Beer et al. 1998, Somarriba et al 2001 a. Para fijación de carbono: Meléndez 2018. - CIMMYT 1999 - de Sousa et al. 2016 - Espinosa et al. 2003; - Hergoualch et al. 2012 - ICAFE 2011 - Somarriba 2005. - Villarreyna et al. 2016 - WCR 2016
4. Increasing the resilience of cocoa farms through renovation / establishment of agroforestry systems, with innovations in the diversification and structure of the system, and with	- Establishment of productive and resistant cocoa clones to the main diseases (moniliasis and black pod) and of good grain quality. - Adaptation and diversification of the structure-architecture of the shade canopy with plants and trees (legumes, fruit trees, timber) appropriate to the projected climatic conditions for the región. - Adaptation of the architecture of cocoa trees to prevent the effects of CC, through new criteria for pruning training and maintenance.	In Guatemala, these clones have been established in producer cooperatives (e.g. ASECAN, APROCA and Cooperativa Tuneca), Institutes of technical education (Instituto Fray Domingo de Vico) and the experimental station of the Faculty of Agronomy of the University of San Carlos in Guatemala (FAUSAC). Practice references:Beer et al. 1998

ADAPTATION MEASURE	INNOVATIVE PRACTICES AT FARM LEVEL	EVIDENCE OR REFERENCE OF THE USE OF SUCH PRACTICES
agronomic-agroforestry management adapted to the projected climatic conditions and risks for the region Results in terms of climate regulation at farm / parcel level: A suitable microclimate under shade is promoted for the cultivation of cocoa, where the average temperature can decrease between 2 and 5 °; With this, an improvement in the quality and yield of the main crop is obtained and additional income is obtained by diversifying the cultivation of products such as fruit, wood or firewood.	- Managing the nutrition (fertilization) needs of the agroforestry system. - Management of cocoa pests and diseases according to projections and projected climatic anomalies for the region. - Institutional innovation: Alliances with producer organizations, the private sector, and research centers to create ideal conditions for agroforestry producers so that they become providers of superior genetic material. - Climate information systems: use INSIVUMEH climate information and promote the incorporation of cocoa cultivation in SATCAFE.	- Cerda 2008. - Cerda et al. 2014 - Cerda et al. 2017. - de Sousa et al 2017. - FAO, 2018. - Harvey et al. 2014, - INTA 2010 - Somarriba et al. 2008 - Somarriba et al. 2013 - Somarriba et al. 2013 - Tscharntke et al. 2011 - Villarreina et al. 2016
5. Promotion and development of diversified family gardens adapted to the projected climatic conditions and risks in the 29 prioritized municipalities	- Sustainable diversification and intensification of production in sustainable orchards, including branches, roots and tubers. - Diversification of agrobiodiversity and creation of a favorable microclimate in the garden. - Backyard poultry production based on efficient feeding based on homemade concentrates. - Harvesting rainwater with the use of an efficient irrigation system.	In Guatemala, family gardens are one of the pillars of food and nutritional security for rural families, since vegetables, basic grains, fruit trees, and medicinal plants are grown ((Villanueva, 2014./ FAO 2005, cited by Villanueva, 2014). References on the use and benefits of the practice: - CATIE (2013) - CATIE 2018a. - CGIAR Challenge Program on Water and Food - Cifuentes 2011 - Dilruksh 2012, Ruíz et al. 2014. - FAO 2009 - IICA 2016, Jiménez & Sepúlveda 2015 y Rodríguez et al. 1984 - Ruiz, H., G. Galileo R.P., I.A. Gutiérrez. 2018Villanueva et al. 2015 - Villareina et al. 2016
6. Management of Natural Forests for conservation	- Fire rounds / breaches (integrated forest fire management) - Controlled burning - Signaling - Soil conservation - Promotion of natural regeneration	This practice is widely used in Guatemala. For 23 years, it has been supported by forest incentive programs to support the forest producer in the application of silvicultural and forest protection measures. Restoring damaged or degraded forest ecosystems can help forests "buffer" the effects of climate change.

ADAPTATION MEASURE	INNOVATIVE PRACTICES AT FARM LEVEL	EVIDENCE OR REFERENCE OF THE USE OF SUCH PRACTICES
	- Enrichment with native species - Conservation of biodiversity - Protection of riparian forests and water recharge areas.	References of use and benefits of the practices: - Bruijnzeel, 1988. - Bruijnzeel, 1990. - FAO, 2005. - FAO, 2010. La gestión de los bosques ante el cambio climático - Lamprecht, 1990 - Stadmuller T. 1994 - Wadsworth, 2000.

The references mentioned in Table 53 are listed below:

1. ANACAFE 2015. Anacafé-14, la variedad de café de Guatemala resistente a la roya. El Cafetal, 41, 4-5.
2. Áskorun, E y Vilhjálmsson 2009
3. Bruijnzeel, L. (1988). (De) Foresttion and dry season flow in the tropics: a closer look. Journal of Tropical Forest Science, 229 - 243.
4. Bruijnzeel, L.A. (1990). Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review. Humid Tropics Programme of the International Hydrological Programme of UNESCO, Paris, and Vrije Universiteit, Amsterdam, 224 pp.
5. Beer, J. Muschler, R., Kass, D., & Somarriba, E. (1998). Shade management in coffee and cacao platations. Agroforestry Systems, 38, 139-164.
6. Carvajal, 2015 Estudio de viabilidad de cosecha de agua de lluvia en Reserva Conchal para su utilización en riego del campo de golf. Universidad de Costa Rica. San José, Costa Rica. 85p.
7. CATIE 2018a. Innovaciones para la adaptación al cambio climático en los sistemas agrícolas y ganaderos de américa latina y el caribe. Informe preparado para FONTAGRO.
8. Cerda 2008.
9. Cerda, R (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. Agroforestry Systems, 88(6), 957-981. doi: 10.1007/s10457-014-9691-8Cerda et al. 2017.
10. CGIAR Challenge Program on Water and Food
11. Cifuentes 2011
12. CIMMYT 1999
13. de Sousa et al 2017. Suitability of key Central American agroforestry species under future climates: an Atlas. Turrialba, Costa Rica, ICRAF. (Occasional Paper No. 26).
14. Espinosa et al. 2003. Tecnología y producción de semillas de híbridos y variedades sobresalientes del maíz de calidad proteínica (QPM) en México. Agronomía Mesoamericana. 6p.
15. European Comission 2014. Green paper on Citizen Science for Europe: Towards a better society of empowered citizens and enhanced research. SOCIENTIZE.
16. FAO, 2000. Manual de Captación y Aprovechamiento del Agua de Lluvia: Experiencias en América Latina. Santiago, Chile. 235 p. http://www.fao.org/tempref/docrep/fao/010/ai128s/ai128s00.pdf
17. FAO 2005. Los bosques y el agua. Estudios FAO Montes 155.
18. FAO 2009. Manual “Una Huerta para Todos”. Capítulo 9: Cría y almacenamiento de gallinas y conejos en la huerta. Manual de Auto-instrucción 3ª edición. Disponible en:

https://coin.fao.org/coin-static/cms/media/1/12956304968670/cartilla_una_huerta_para_todos.pdf

19. FAO, 2010. La gestión de los bosques ante el cambio climático. 20 p.
20. FAO, 2013 Captación y Almacenamiento de Agua de Lluvia: Opciones Técnicas para la Agricultura Familiar en América Latina y el Caribe. 1 ed. FAO, Santiago, Chile. 272 p.
21. FAO 2015. Agricultural Stress Index System (ASIS). http://www.fao.org/resilience/news-events/detail/en/c/296089/
22. FAO 2017. Centroamérica utilizará innovador sistema para monitorear la sequía agrícola. http://www.fao.org/americas/noticias/ver/es/c/1027415/
23. FAO, 2018a. Caracterización de los sistemas agroforestales Kuxur rum y Quesungual en el Corredor Seco de Guatemala y Honduras. Ciudad de Panamá. 49 p.
24. FAO, 2018b. Libro de consulta sobre la agricultura climáticamente inteligente. Resumen de la segunda edición. Disponible en http://www.fao.org/3/I7994ES/i7994es.pdf.
25. Finquelievich y Fischnaller 2014. C. 2014. Ciencia ciudadana en la Sociedad de la Información: nuevas tendencias a nivel mundial. Revista Iberoamericana Ciencia y Sociedad. http://www.revistacts.net/files/Volumen_9_Numero_27/FinquelievichEDITADO.pdf
26. Harvey et al. 2014. Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. Conservation Letters, 7(2), 77-90. doi: 10.1111/conl.12066
27. Hergoualch, k., et al. (2012). Changes in carbon stock and greenhouse gas balance in a coffee (Coffea arabica) monoculture versus an agroforestry system with Inga densiflora, in Costa Rica. Agriculture, Ecosystems & Environment, 148, 102-110. doi: 10.1016/j.agee.2011.11.018
28. ICTA (Instituto de Ciencia y Tecnología Agrícolas). 2018. ICTA B15$^{ACP+ZINC}$ Maíz blanco fortificado: Variedad de maíz con alta calidad de proteína y más contenido de zinc. Guatemala. 2p.
29. IICA 2013. Post-harvest Losses in Latin America and the Caribbean: Challenges and Opportunities for Collaboration. Washington, DC. Retrieved from http://www.iica.int/Esp/Programas/SeguridadAlimentaria/Documentos Seguridad Alimentaria/Report on Post-Harvest Losses in Latin America and the Caribbean 9-20-2013.pdf
30. IICA 2016. IICA (Instituto Interamericano de Cooperación para la Agricultura) 2016. Establecimiento y uso de sistemas silvopastoriles en República Dominicana. Santo Domingo, República Dominicana. 35p.
31. JICA, 2015. JICA 2015 Guía práctica para cosechar el agua de lluvia. Proyecto de Desarrollo Rural Integral Sostenible en la Provincia de Chimborazo. Ecuador. 23 pág.
32. Jiménez J. Sepúlveda C. 2015. (En línea) Sistemas silvopastoriles y buenas prácticas para la ganadería sostenible en Oaxaca. Repositorio Digital Especializado, Consultado el 25 junio de 2018. Disponible en:

http://www.monitoreoforestal.gob.mx/repositoriodigital/items/show/542

33. Kumar & Kalita P. 2017. Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries. Foods, 6(1), 8. https://doi.org/10.3390/foods6010008
34. Mendoza et al. 2017. Traditional maize post-harvest management practices amongst smallholder farmers in Guatemala. Journal of Stored Products Research, 71, 14–21. https://doi.org/10.1016/j.jspr.2016.12.007
35. Mercado, et al, 2017. Programa Ambiental Mesoamericano (MAP) Noruega 2013-2017: Principales resultados y lecciones aprendidas. Turriaba, Costa Rica.
36. Meléndez 2018. Rumbo a una caficultura baja en emisiones GEI. El Cafetal, Enero-Marzo, 4-6.
37. Pizarro et al, 2015. Manual de diseño y construcción de sistemas de aguas lluvias en zonas rurales de Chile. Documentos Técnicos del PHI-LAC, N° 36. UNESCO. 103p.
38. PNUD 2015. Cosecha de agua de lluvia para enfrentar la escasez de agua en áreas de secano. Guía práctica campesina. Programa de las Naciones Unidas para el Desarrollo. Chile.48p.
39. Prinz, 1996. Water Harvesting: Past and Future. In: Pereira, L. S. (ed.), Sustainability of Irrigated Agriculture. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21-26.03.1994, Balkema, Rotterdam, 135-144
40. Posada 2012. Impacto del Sistema Agroforestal Kuxur Rum en la sostenibilidad de los medios de vida de las familias rurales en Camotán y Jocotán, Guatemala. sometido a consideración de la Escuela de Posgrado como requisito para optar por el grado de *Magister Scientiae* en Socioeconomía Ambiental. CATIE.
41. Rodríguez et al. 1984. La fijación de nitrógeno atmosférico: una biotecnología en la producción agraria. Temas de Divulgación 1ª edición, instituto de recursos naturales y agrobiología. Disponible en: Http://www.ceresnet.com/ceresnet/esp/servicios/teleformacion/agroambiente/nitrogeno_atmosferico.pdf
42. Ruiz, H., G. Galileo R.P., I.A. Gutiérrez. 2018). HUERTOS FAMILIARES: AGROBIODIVERSIDAD Y SU APORTE EN LA SEGURIDAD ALIMENTARIA EN TERRITORIOS RURALES DE GUATEMALA. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE). Instituto Interamericano de Cooperación para la Agricultura (IICA). Costa Rica. Agroecología 9(1y2): 85-88 2014. Accesado el 29 de junio de 2018. URL: https://mail.google.com/mail/u/0/#inbox/164510792fd23064?projector=1&messagePartId=0.1
43. Somarriba et al. 2008. Cocoa in Central America. Global Research on Cocoa, 14, 5-7. doi: 10.1371/journal
44. Somarriba E. 2013. Oferta mundial de tecnologías de producción de cacao prioritarias para elevar los rendimientos, mejorar la calidad del cacao y asegurar la sostenibilidad y

seguridad alimentaria de las familias cacaoteras de Centroamérica. Informe Final Consultoría (pp. 36). Costa Rica: RUTA-UNOPS.

45. Somarriba et al. 2013. Carbon stocks and cocoa yields in agroforestry systems of Central America. Agriculture, Ecosystems & Environment, 173, 46-57. doi: 10.1016/j.agee.2013.04.013
46. Stadmuller T. 1994. Impacto hidrológico del manejo forestal de bosques naturales tropicales: medidas para mitigarlo. Una revisión bibliográfica. CATIE, 1,994. 63 p.
47. Tscharntke et al. 2011. Multifunctional shade-tree management in tropical agroforestry landscapes - a review. Journal of Applied Ecology, 48(3), 619-629. doi: 10.1111/j.1365-2664.2010.01939.x
48. Van Etten et al. en prensa
49. Villanueva et al. 2015. 2015. Manual de producción y manejo de aves de patio. 1o ed. – Turrialba, C.R: CATIE, 2015.64 p. : il. – (Serie técnica. Manual técnico / CATIE; no.128).
50. Villareina et al. 2016. Priorización de inversiones en Agricultura Climáticamente Inteligente (ACI): Prácticas agropecuarias de huertos caseros, granos básicos, sistemas agroforestales y pasturas priorizadas en el territorio Trifinio (Borrador).
51. Xicay, 2016. Relación agua, comunidades y valoración económica de los beneficios derivados de un programa de tecnologías de cosecha de agua de lluvia en la microcuenca del río Olopa, en la región del trifinio Guatemala. CATIE. Turrialba, Costa Rica. 91p.

D.6.3. Gender

545. In Guatemala, and in particular in the proposed areas of intervention of the project, women have been consistently categorized as groups of vulnerable populations due to the systemic discrimination they face, such as a lack of access to education, decent and remunerated work and income, and participation in decision-making platforms. In addition, in this context women have less access to land and natural resources (which in turn has prevented them in many cases to qualify for access to credit from financial institutions that tend to ask for land and capital ownership as collateral) (see Annex 8 of the Funding Proposal on the Gender analysis for more details). Because of the all of the above, RELIVE will carry out a nuanced analysis on the gender-specific division of tasks before giving start to an initiative that seeks to tackle to impacts of climate change in rural areas. This is key in order to establish gender roles and to identify the needs specific to men and women in their tasks around different productive livelihoods.

546. Within the project area of intervention, 14% of households have a single-parent female head. The Agricultural and Livestock Census established that in the area of the project's intervention, the relationship that women have with farms is very limited, since only 4.79% identified themselves as producers of these farms, and it reported that there were 11,563 agricultural enterprises identified, of which only 566 were owned by women and 10,997 were owned by men.

547. Moreover, although Guatemalan law recognizes the right to co-ownership of land for women, this has not translated into real access to land or other resources to work it on. As a result, banks and credit institutions deny access to women in rural areas, which in turn prevents them further from accessing land.

548. The project has mainstreamed gender actions throughout the project activities ensuring that 40% of the beneficiaries will be women. The project's strategy for gender equality (see annex 8 Gender assessment) focuses on making the proposed interventions inclusive, sustainable and resilient, while promoting gender equality to provide an efficient and timely response to climate problems faced by different population groups. In particular, the project

549. This strategy defines the RELIVE framework for action on gender issues, and focuses mainly on supporting the most vulnerable populations to climate change, understood as those groups whose most important livelihood is subsistence agriculture. This activity is characterized by being highly dependent on the weather, mainly rain; In addition, those who practice it are mostly women, young people and indigenous peoples, who have rates of acute poverty and limited access to the main productive resources such as land and inputs for agricultural production, technical assistance and financing.

550. On the other hand, the strategy contributes to reducing social inequalities, including gender inequality, through the empowerment of women, young people and indigenous

groups. The strengthening of the producer association processes and the development of new leadership in the communities, contributes to improve governance in the territories. The objective is to create the conditions that allow vulnerable populations to have access to the services and benefits of the project, ensuring their full participation in the processes of improving their technical and associative capacities and their livelihoods, and making a special effort to include women in all phases of the project.

551. While, RELIVE project does not have the direct objective to enhance the access to women to credit products, it will enhance the enabling conditions through capacity building and assistance to access to forest incentives. One of the prerequisites for accessing forest incentives is that the farmer applicant needs to have a document for the possession of the land. It is particularly difficult for women farmers to obtain such document of land possession (due to the multiple gender gaps discussed in the Gender Analysis). Through RELIVE project, women farmers are especially targeted to be assisted in this process and to be facilitated to access the forest incentives. As an outcome of this intervention, women are expected to have more opportunities to access finance products due to strengthened capacity, knowledge and documents of land possession.

552. RELIVE will coordinate and explore the suitability of the financial mechanisms promoted by the GCF-CABEI projects– (1) Ecosystem-based Adaptation to increase climate resilience in the Central American Dry Corridor and the Arid Zones of the Dominican Republic and (2) Productive Investment Initiative for Adaptation to Climate Change (CAMBio II). Please see Section B.4.

553. CABEI Projects focus on enhancing financial mechanisms for adaptation measures, in particular promoting ecosystem-based adaptation solutions for water resources and productive systems. The beneficiaries for these two projects are envisioned to be Small and Medium-sized Enterprises (MSMEs).

554. RELIVE project promotes agroforestry, which is an ecosystem-based adaptation measure, and the design of the financial mechanisms is not part of the project, however, the project will explore how the financial mechanisms proposed under CABEI projects may be replicated for the RELIVE project context and beneficiaries in particular for promoting agroforestry and specially related with the development of incentives for women-farmers to access credit at lower interest rates.

D.6.4. Private sector engagement and market access

555. The project will strengthen community-based organizations such as cooperatives, micro-enterprises, and farmers’ associations to facilitate access to finance from commercial banks for climate resilience-agriculture activities. Coordination with CAMBIO II (Please see Section B.4) is extremely important, since it aims to institutionalize the provision of financial and technical assistance to the banking sector across seven countries (Guatemala included),

thus removing barriers to access financial services for adopting and implementing climate change adaptation measures. While the beneficiaries of CAMBio II are micro, small and medium sized enterprises, the project is serving as a demonstration platform to prove that investments on adaptation practices in agriculture can be attractive to commercial banks and financial institutions previously not experienced in environmental/adaptation projects. Both projects will work closely together, so the financial mechanisms promoted by CAMBio II can be also available for the specific adaptation solutions and beneficiary groups of RELIVE. In output 1.2, capacity building will unlock access of farmers to financial services (coordinated with the CAMBio II Project).

556. In Output 1.3, the project will create access to markets by linking with the private sector and Government institutions that will purchase RELIVE's production. The project activities help to improve output, ensure a predictable yield and increase prices earned by growers, thereby making them more bankable. Output 1.3 also promotes the diversification of productive units in home gardens for 2,500 farm families and install 370 greenhouses micro-tunnel facilities for vegetables and poultry. This activity includes proper coordination with the Ministry of Education (MINEDUC) to ensure the School Feeding programs purchase this production, thus opening market opportunities for the 2,500 farm families. This Output also includes training for 2,500 farmers to improve technical skills for enhancing coffee and cocoa value chains and to strengthen organizational capacities of producers' associations to access markets infrastructure. Trainings will include strategies to introduce these products into the national and local market and adding value to retain it at the origin, thus improving their income as a way of increasing their resilience. Market access based on the differentiated characteristics of the national product will be promoted, by developing links to local and national markets through the association with coffee and cocoa guilds identified in a participatory manner by the farmers. Thus, the project will unlock potential private sector engagement with companies that will purchases RELIVE's production.

557. Table 54 below presents the value chain of agricultural products in Guatemala that will be improved by the project and related private sector entities involved in different steps (Sources: FAO (2018)59; MAGA (2016)60).

Table 54: Value chain of agricultural products and related private sector entities

[59] FAO 2018. Medios de vida resilientes para pequeños agricultores vulnerables al clima (RELIVE-Guatemala. Documento complementario. PRODUCTO 2.1. Estudios de la cadena de valor y mercado para los productos propuestos en las medidas de adaptación a implementar. Guatemala 2018

[60] MAGA 2016. Plan Estrategico de la Agrocadena de cacao en Guatemala 2016-2025 PEDAC. Guatermala.

Value chain of agricultural products in Guatemala that will be improved by the project					
Value chain	Phases of the value chain				
	Inputs	Production	Gathering	Commercialization	Operational and strategic services
1. Production of basic grains – **maize and beans** – from drought-resistant and open-pollinating varieties, supported by the use of climate information in diversified systems.	Maize: Semillas S.A. Prosemillas S.A. Chadie Valle Verde Semigua. Beans: seeds and inputs in local agroservices Local services, distributors: DISAGRO, Bayer y Syngenta	Small producers (subsistence and surplus, medium producers, INPASA (Peten's Food Industry)	Cooperatives and Associations, Private Companies (ADECRO, ADEGO, ACOCARC, APAC, AMO, AMCO, ASEJO, ADISQUE, CHORTIJOL ATESCATEL)	Maize: Squares (departmental and communal level), Intermediaries at: a) Mercado de La Terminal, b) Zona 1, c) y CENMA (Capital City) Fabricantes de Concentrados MERCADESA Beans: Communal Squares and municipalities, intermediaries and markets in Guatemala City Zone 1. Terminal, CENMA Storage and industries: El Chamaco, El Paraiso, Isaac Mejia, DEMAGUSA, NUTRICA, ALBAY, Walmart, Ducla, Alimentos Kerns, Malher	Transport of inputs and production: local and regional carriers
2. Increasing the resilience of **coffee** producers through the establishment or renovation of agroforestry systems, with innovations in the diversification and structure of the system, and with agronomic-agroforestry management, adapted to the climatic conditions and risks envisaged for the region.	Seeds and seedlings: Pilones de Antigua ANACAFE Individual producers (Farms) FEDECOVERA Inputs: Local agroservices, distributors of: DISAGRO, Bayer y Syngenta	Small medium and large producers (Private farms) Cooperatives (FEDECOVERA),	Farm and profit intermediaries	FEDECOVERA, Kape Coban, Café Mar, CAMEC, S.A., FEDEAGRO, S.A., Comercial Otto Chavarria Farm and profit intermediaries FEDECOCAGUA FECCEG YALIPUR	Financial services training: Proyecto Cambio (BCIE), BANRURAL, GENESIS EMPRESARIAL Transport of inputs and production: local and regional carriers. Certification: Rainforest Alliance,

					Mayacert
3. Increasing the resilience of **cocoa** farms through the renovation/establishment of agroforestry systems, with innovations in the diversification and structure of the system, and with agronomic-agroforestry management adapted to the climate conditions and risks projected for the region	Comercial Otto Chavarria CHOICE HUMANITARIAN, FUNDALACHUA, FRAY DOMINGO DE VICO	Private farms (Schellenberg, Buenos Aires, La Cruz, Ujushtes, Madeira, Chimel), Mypimes: , PROPETEN, Mipymes de Ixcan, Cooperatives and associations: APROCAV, FEDECOVERA, ASOSELNOR, ASODIRP, KATBALPOM, ADIOSMAC, Fray Domingo de Vico, UNIP, S.A., COACAP, ADAC	FEDECOVERA, FUNDALACHUA, UNIP	FEDECOVERA KAMPURA, Cacao Verapaces, UNIP, Encarnacion Pop Transformadores: La Grecia, Granada, Zurich, Chocolate Imperial, Dona Pancha, La Vienesa, Chocomuseo, Chocolates de Mixco, Fray Domindo de Vico, Itzel Chocolate de Peten	Financial services training: Proyecto Cambio(BCIE) BANRURAL, GENESIS EMPRESARIAL Transport of inputs and production: local and regional carriers

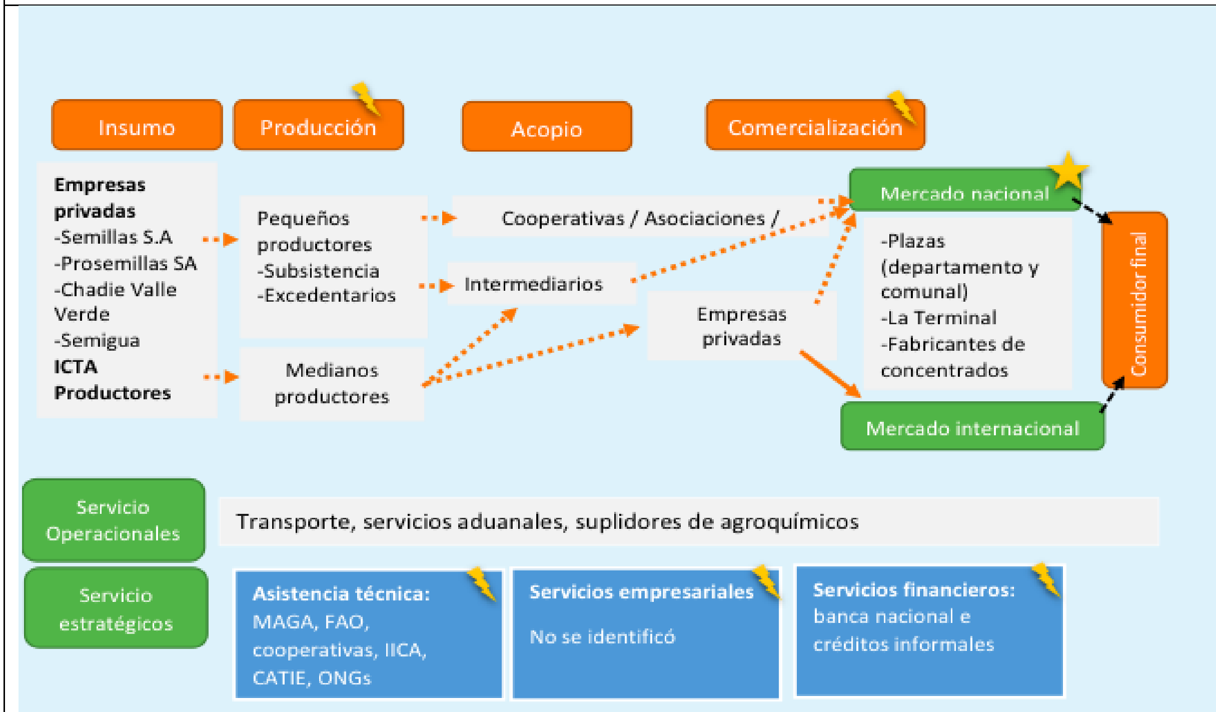
The diagrams in the Figure 59 below illustrates the corn, coffee and cocoa value chains and different stakeholders involved

Value chain of agricultural products in Guatemala that will be improved by the project					
Value chain	Phases of the value chain				
	Inputs	Production	Gathering	Commercialization	Operational and strategic services
1. Production of basic grains – **maize and beans** – from drought-resistant and open-pollinating varieties, supported by the use of climate information in diversified systems.	Maize: Semillas S.A. Prosemillas S.A. Chadie Valle Verde Semigua. Beans: seeds and inputs in local agroservices Local services, distributors: DISAGRO, Bayer y Syngenta	Small producers (subsistence and surplus, medium producers, INPASA (Peten's Food Industry)	Cooperatives and Associations, Private Companies (ADECRO, ADEGO, ACOCARC, APAC, AMO, AMCO, ASEJO, ADISQUE, CHORTIJOL ATESCATEL)	Maize: Squares (departmental and communal level), Intermediaries at: a) Mercado de La Terminal, b) Zona 1, c) y CENMA (Capital City) Fabricantes de Concentrados MERCADESA Beans: Communal Squares and municipalities, intermediaries and markets in Guatemala City Zone 1. Terminal, CENMA Storage and industries: El Chamaco, El Paraiso, Isaac Mejia, DEMAGUSA, NUTRICA, ALBAY, Walmart, Ducla, Alimentos Kerns, Malher	Transport of inputs and production: local and regional carriers
2. Increasing the resilience of **coffee** producers through the establishment or renovation of agroforestry systems, with innovations in the diversification and structure of the system, and with agronomic-agroforestry management, adapted to the climatic conditions and risks envisaged for the region.	Seeds and seedlings: Pilones de Antigua ANACAFE Individual producers (Farms) FEDECOVERA Inputs: Local agroservices, distributors of: DISAGRO, Bayer y Syngenta	Small medium and large producers (Private farms) Cooperatives (FEDECOVERA),	Farm and profit intermediaries	FEDECOVERA, Kape Coban, Café Mar, CAMEC, S.A., FEDEAGRO, S.A., Comercial Otto Chavarria Farm and profit intermediaries FEDECOCAGUA FECCEG YALIPUR	Financial services training: Proyecto Cambio (BCIE), BANRURAL, GENESIS EMPRESARIA L Transport of inputs and production: local and regional carriers. Certification: Rainforest

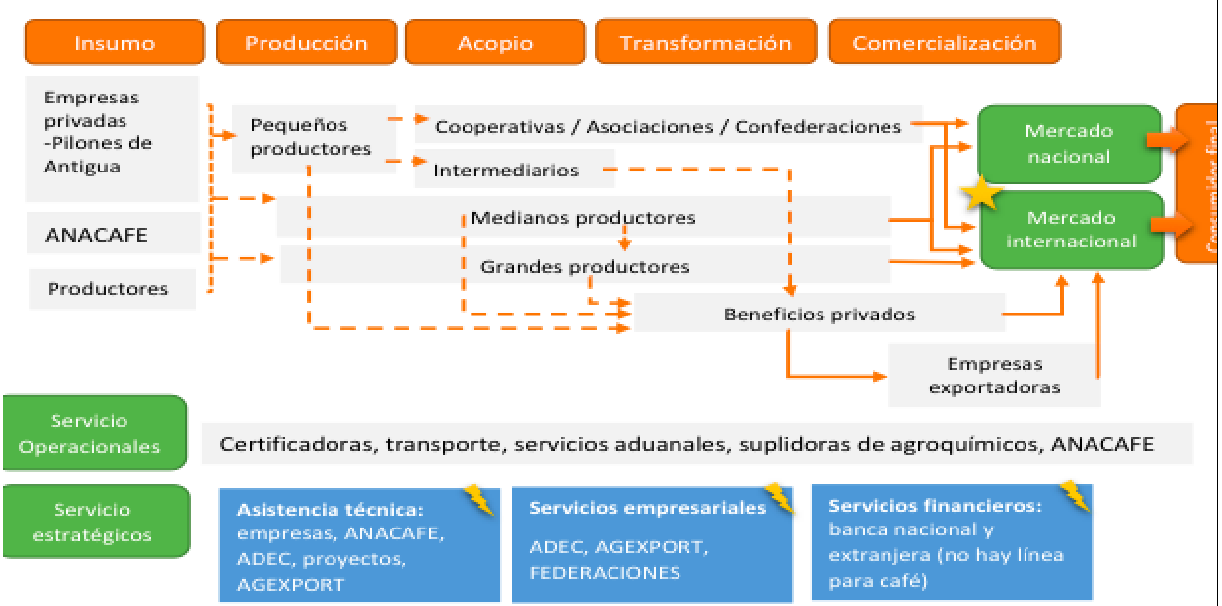
					Alliance, Mayacert
3. Increasing the resilience of **cocoa** farms through the renovation/establishment of agroforestry systems, with innovations in the diversification and structure of the system, and with agronomic-agroforestry management adapted to the climate conditions and risks projected for the region	Comercial Otto Chavarria CHOICE HUMANITARIAN , FUNDALACHUA, FRAY DOMINGO DE VICO	Private farms (Schellenberg, Buenos Aires, La Cruz, Ujushtes, Madeira, Chimel), <u>Mypimes:</u> , PROPETEN, Mipymes de Ixcan, <u>Cooperatives and associations:</u> APROCAV, FEDECOVERA, ASOSELNOR, ASODIRP, KATBALPOM, ADIOSMAC, Fray Domingo de Vico, UNIP, S.A., COACAP, ADAC	FEDECOVERA, FUNDALACHUA , UNIP	FEDECOVERA KAMPURA, Cacao Verapaces, UNIP, Encarnacion Pop <u>Transformadores:</u> La Grecia, Granada, Zurich, Chocolate Imperial, Dona Pancha, La Vienesa, Chocomuseo, Chocolates de Mixco, Fray Domindo de Vico, Itzel Chocolate de Peten	Financial services training: Proyecto Cambio(BCIE) BANRURAL, GENESIS EMPRESARIAL Transport of inputs and production: local and regional carriers

The diagrams in the Figure 59 below illustrates the corn, coffee and cocoa value chains and different stakeholders involved.

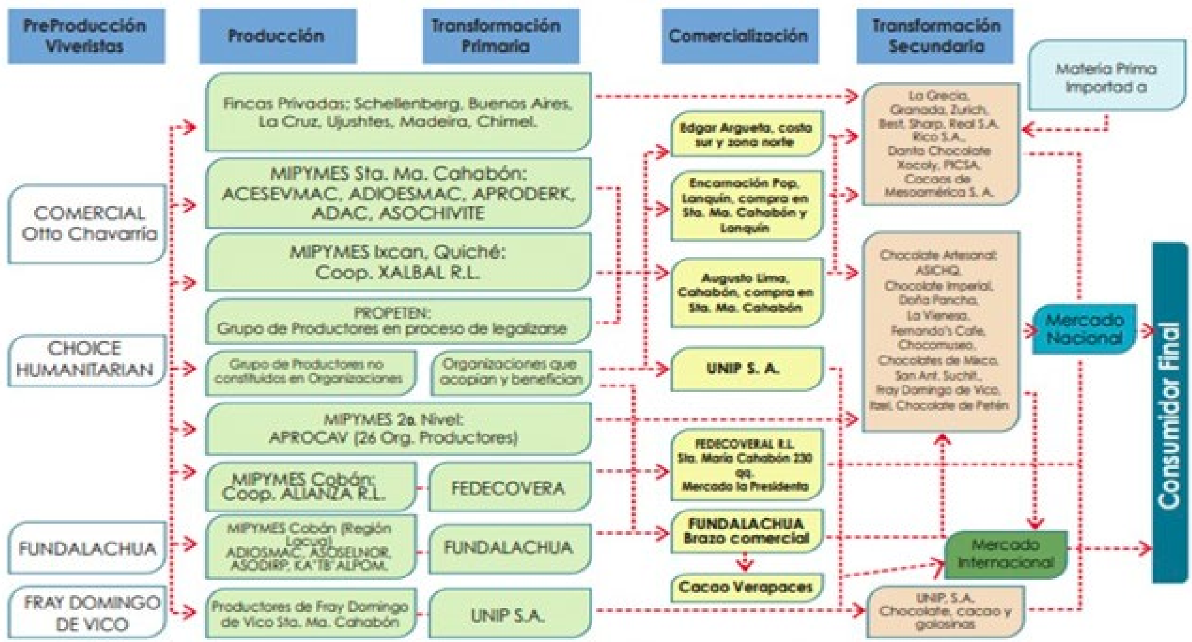
(a) Corn value chain



(b) Coffee value chain



(c) Cocoa value chain



Source: Author and MINECO (2015)[61]

Figure 59. Schematic maps of actors and their circuits of interrelation in the (a) corn; (b) coffee and (c) cocoa value chains in Guatemala.

D.6.5. Project Delivery Organizational Structure

Project Governance, execution and implementation

558. The following mechanisms for project execution, coordination and oversight have been agreed in close consultation with the Ministry of Environment and Natural Resources (MARN, the GCF NDA), the Ministry of Agriculture, Livestock and Food (MAGA) and the National Forestry Institute (INAB).

Governance arrangements

559. The project will be governed by the following entities:

[61] MINECO (2015). Analisis de la situacion actual de la cadena de cacao e identificacion de posibles acciones. Proyecto de fortalecimiento de la productividad de las MIPyMES

- **FAO, the Accredited Entity (AE),** will act as the Executing Entity (EE) for all the activities under the project and will be responsible for the GCF proceeds and for the overall quality assurance and oversight of the project.
- **MAGA and INAB** will be responsible to manage their co-financed funds but will not execute any GCF Proceeds. Both MAGA and INAB are mandated to coordinate and oversee the implementation of the project through the PSC.
- **The Project Steering Committee (PSC)** is the highest governance level, which is comprised by the MARN (represented by the Minister), and the co-executing agencies: MAGA (Represented by the Minister), and INAB (Represented by the Manager). MARN represents the Government in matters of climate change and is the Designated National Authority for the GCF. Furthermore, MARN coordinates the Inter-institutional Coordination Group (GCI), which is the mechanism where MARN, MAGA and INAB review the national agenda for climate change and conservation of natural resources. The NDA will chair the Project Board and FAO will act as the Secretariat. The main function of FAO, as secretary of the committee, will be, among others, to keep the documentary and logistical record for the operation of the PSC. The PSC aims at providing political and strategic orientation to the implementation of the project as well as ensuring sound inter-institutional coordination. The PSC will also ensure planned co-financing from government agencies is delivered in a timely manner.
- **The Technical Committee (TC)**, that will be responsible for the overall project coordination and for ensuring its strategic approach, coordination among the partners and consistency of the outputs with the strategic framework. The TC will be comprised of technical staff from MAGA and INAB and chaired by technical staff from the MARN. INAB has no discretion in deciding who are the beneficiaries of the incentives. INAB supervises and certifies the compliance with the activities of the Forest Management Plan. INAB will not execute any GCF proceeds. Therefore, a Subsidiary Agreement between FAO and INAB is not necessary, since FAO would already have an agreement with the Government of Guatemala, represented by the General Secretariat of Planning and the Ministry of Agriculture and INAB forms part of this agreement. FAO will act as the technical secretariat and provide support to the TC.

560. In order to implement the project, a Project Management Unit (PMU) will be established in Guatemala City, at the headquarters, campus or facilities of the Ministry of Agriculture, Livestock and Food (MAGA); and will coordinate and support project implementation and day-to-day activities during the project life-cycle, in close consultation with the governing structures of the project. FAO will contract the PMU in accordance with its policies and procedures. The day-to-day project monitoring and implementation responsibility rests on a recruited National Coordinator that will lead the PMU. S/he will be supported by a professional specialist in project operation, a financial specialist, thematic advisers (7), a monitoring and evaluation specialist and administration and operational staff.

561. At the local level, Territorial Operating Units will be established to serve as the key channel of communication between the PMU and local stakeholders and to assist with the implementation of stakeholder participation and engagement plan. They will comprise representatives of municipalities, local staff from MAGA and INAB, Civil Society Organizations (CSO), Non-Governmental Organizations (NGOs) and producer associations, and representatives of project beneficiaries, and projects staff such as the local technical staff, gender experts, among others. These Territorial Operating Units will be operating at the headquarters or facilities of MAGA or INAB, depending on availability.

562. The following chart presented in page 134, the general operation of the project will be under the coordination and responsibility of a National Consultant Project Coordinator whom three Head of operational centers will depend on, and who will be responsible for a Territorial Operating Unit each.

563. Each Head of operational centers (3) will be in charge of a Territorial Operating Unit (TOU) that will be integrated by the following staff (for each region): 1 Administrative Assistant, (6) Territorial forestry technicians, and (6) Territorial agroforestry technicians.

564. The governance and implementation structure of the project is shown below.

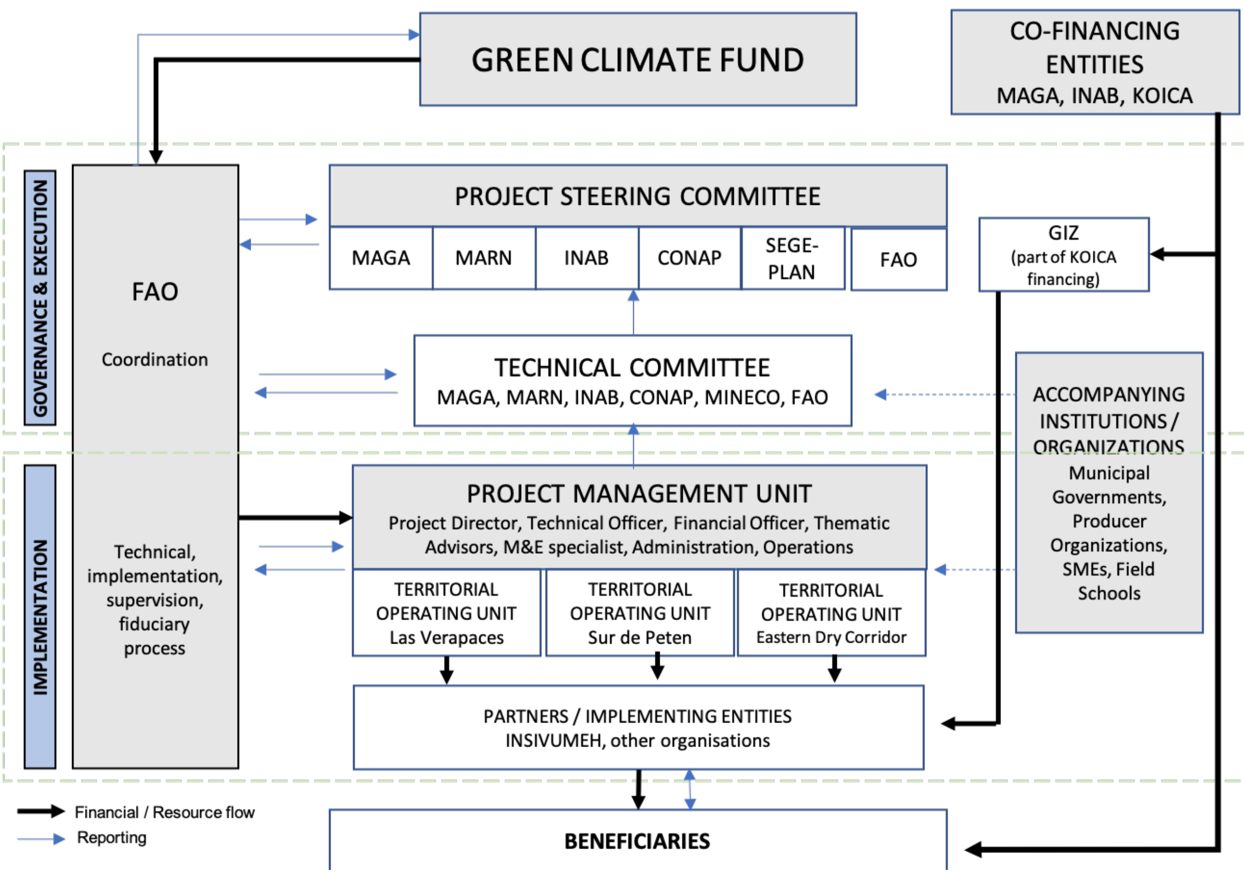


Figure 60. Roles and responsibilities of the key governance entities.

565. The table below presents a summary of the institutions involved in the implementation of the project activities:

Table 55: Projects activities by financing source and executing entity

Component	Output	Activity Title	Financing source	Executing Entity	EE engage a procured party	Beneficiaries	Major contractual arrangements
Component 1	Output 1.1	**Activity 1.1.1** Organize workshops for extension technicians and farmers regarding the importance of climate information and use in decision-making	KOICA	FAO		Extension Technicians / small farmers	NA
		Activity 1.1.2 Install 13 hydro-meteorological monitoring equipment for drought to inform climate resilient agricultural management strategies.	GCF	FAO	X	INSIVUMEH as a direct beneficiaries/ MARN/ Small farmers as indirect beneficiaries	Contracts for services (ITB, RFP) Contracts of personnel (CQS)
		Activity 1.1.3 Disseminate climate information and response adaptation measures using locally-relevant delivery mechanisms as virtual platforms, electronic means, telecommunication and visits of the extension workers.	GCF	FAO	X	INSIVUMEH / GCI Institutions (MARN MAGA/INAB/CONAP)/Small farmers	Purchase of equipment (ITB), Contracts of personnel (CQS), Travel (ITV)
		Activity 1.1.4 Implement 4 local agro-ecological centers for climate change adaptation for knowledge generation and sharing	KOICA	GIZ	X	The direct beneficiaries will be the MAGA´S Extension Technicians / and as Indirect beneficiaries are the small farmers	NA
	Output 1.2	**Activity 1.2.1:** Fund the implementation of the adaptation practices and gender-sensitive technology packages for staple crops, coffee and cocoa in 6,195 family farms.	GCF	FAO	X	Small farmers	Purchase of seeds, fertilizers, and plants (ITB), Contracts of personnel (CQS), Travel (ITV)

Component	Output	**Activity Title**	**Financing source**	**Executing Entity**	**EE engage a procured party**	**Beneficiaries**	**Major contractual arrangements**
		Activity 1.2.2 Implement at least 10 trainings to enhance the technical and organizational capacity of 6,195 farmers for climate-risk informed planning and implementation of agricultural adaptation measures at farm level	KOICA	Level 1:FAO; Level 2 MAGA / INAB; Level 3: MAGA		Technicians of MAGA and INAB, Small farmers/	NA
		Activity 1.2.3 Establish 28 women-led, farm-level seed nurseries for resilient crops and community forest nurseries	KOICA	FAO		Women small farmers	NA
		Activity 1.2.4 Extension workers provide technical assistance through regular consultation sessions and field visits to 6,195 small farmers.	MAGA	MAGA		Small farmers	NA
	Output 1.3	**Activity 1.3.1** Promote diversification of productive units in home gardens for 2,500 farm families and install 370 greenhouses micro-tunnel facilities for vegetables and poultry	GCF	FAO	X	Small farmers	Contracts for services, and Purchase of vehicles (ITB), Contracts of personnel (CQS), Travel (ITV)
		Activity 1.3.2 Organize training for 2,500 farmers to improve technical skills for enhancing coffee and cocoa value chains and to strengthen organizational capacities of producers' associations to access markets infrastructure	KOICA	FAO		Small farmers / Producers organizations /	NA
Component 2	Output 2.1	**Activity 2.1.1** Establish or strengthen the capacity of 14 Local Water Committees for climate risk-informed integrated water resource management and planning instruments related to public policy on climate change	GCF	FAO	X	Water committees	Purchase of office furniture and equipment (ITB) Contracts of personnel

Component	Output	Activity Title	Financing source	Executing Entity	EE engage a procured party	Beneficiaries	Major contractual arrangements
							(CQS), Travel (ITV)
		Activity 2.1.2 Provide technical assistance to Local Water Committees to develop and implement 14 climate risk-informed water management plans at micro-basin level which correspond to the project site.	GCF	FAO	X	Water committees	Procurement of services (ITB, RFP), Contracts of personnel (CQS), Travel (ITV)
	Output 2.2	**Activity 2.2.1** Technical support to 19,239 smallholder farmers (women in particular) to access forest incentives	KOICA	FAO		Small farmers	NA
		Activity 2.2.2 Training of 90 technicians from extension services, forest regents and INAB	GCF	FAO	X	Technicians from extension services, forest regents and INAB	Letters of Agreements, and procurement of services (ITB, RFP) Contracts of personnel (CQS), Travel (ITV)
		Activity 2.2.3 Restore 13,000 ha through reforestation and agroforestry	GCF	FAO	X	Small farmers	Contracts for services, and Purchase (ITB, RFP) Contracts of personnel (CQS), Travel (ITV)
		Activity 2.2.4 Evaluate forest management plans and certify their compliance to manage and allocate the necessary funds to reforest and manage 13,000 hectares of plantations and agroforestry systems	INAB	INAB		Small farmers	NA
	Output 2.3	**Activity 2.3.1** Provide trainings to improve technical capacity of 2,500 local officials and members of community organizations on the implementation and maintenance of micro-basin	GCF	FAO	X	Local officials and members of community organization/Community	Procurement of services (ITB), Contracts of personnel (CQS), Travel (ITV)

Component	Output	Activity Title	Financing source	Executing Entity	EE engage a procured party	Beneficiaries	Major contractual arrangements
		infrastructure					
		Activity 2.3.2 Install farm-level drip irrigation system for using harvested water on 250 ha of farm land	GCF	FAO	X	Small farmers	Contracts for services, and Purchase (ITB) Contracts of personnel (CQS), Travel (ITV)
Component 3	Output 3.1	**Activity 3.1.1** Provide training to 100 technicians from 28 municipal environmental units and other local government agencies on climate adaptation planning and climate resilient agricultural solutions	GCF	FAO	X	Technicians from 28 municipal environmental units and other local government agencies/ Gobernment Local /Technicians of Local producer organizations	Procurement of services (ITB) Contracts of personnel (CQS), Travel (ITV)
		Activity 3.1.2 Facilitate 4 meetings of 2 water management and climate change thematic roundtables including the participation of MAGA, MARN and other relevant actors to integrate agricultural resilience practices in the national action plan on adaptation to climate change.	GCF	FAO	X	Representatives from MAGA, MARN, INAB, CONAP, MINECO, SEGEPLAN, academia, private sector and civil society	Procurement of services (ITB), Contracts of personnel (CQS), Travel (ITV)
	Output 3.2	**Activity 3.2.1** Train and assist 90 staff members from INAB, MAGA and MARN on the management and dissemination of climate information.	GCF	FAO	X	Staff members from INAB, MAGA and MARN	Procurement of services (ITB, RFP), Contracts of personnel (CQS), Travel (ITV)

Component	Output	Activity Title	Financing source	Executing Entity	EE engage a procured party	Beneficiaries	Major contractual arrangements
		Activity 3.2.2, Train 100 experts at departmental and municipal level and agricultural extension workers and other staff from SNER on climate risk-informed agricultural adaptation strategies.	GCF	FAO	X	Agricultural Extension workers at departmental and municipal level	Procurement of services (ITB), Contracts of personnel (CQS), Travel (ITV)
		Activity 3.2.3 Train 300 community promoters on the use of climate information and planning instruments for agriculture adaptation strategies and strengthen the capacity of 80 CADERs	GCF	FAO	X	Community promoters at the CADERs	Procurement of services (ITB), Contracts of personnel (CQS), Travel (ITV)
Component 3 Total							
PMC	PMC	PMC Project Management Costs	GCF	FAO			
			KOICA	FAO			

*ITB: Invitation to Bid

Structure of flow of funds

566. FAO is the AE and will act as the Executing Entity (EE) as well. FAO is the AE to the GCF and, at the request of MARN, the NDA, will also act as Executing Entity (EE) for the GCF Proceeds, through the FAO-Guatemala Country Office. MAGA and INAB will not execute any GCF proceeds. These institutions will only be responsible to manage their co-financed funds (the in-kind contribution from MAGA and the PINPEP/PROBOSQUE incentives from INAB) in accordance with the annual work plan of the project as approved by the PSC but will not execute any GCF Proceeds. KOICA's co-financing of USD 7,000,000 will be executed through FAO (USD 5,000,000) and GIZ (USD 2,000,000). Therefore, GIZ will be co-executing agency for the project, in particular, GIZ will be responsible for the implementation of Activity 1.1.4.

567. FAO in its role of EE will manage the GCF funds, manage financial expenditures against budgets, execute payments, and provide technical and secretariat assistance to the PSC and TC. The GCF and FAO will enter into a FAA, under which FAO shall administer the relevant GCF Proceeds to be used for the financing of the project, in accordance with the FAA and AMA. Accountability on the use of financial resources will be facilitated through the review of annual and bi-annual project reports, as well as through audit and monitoring reports.

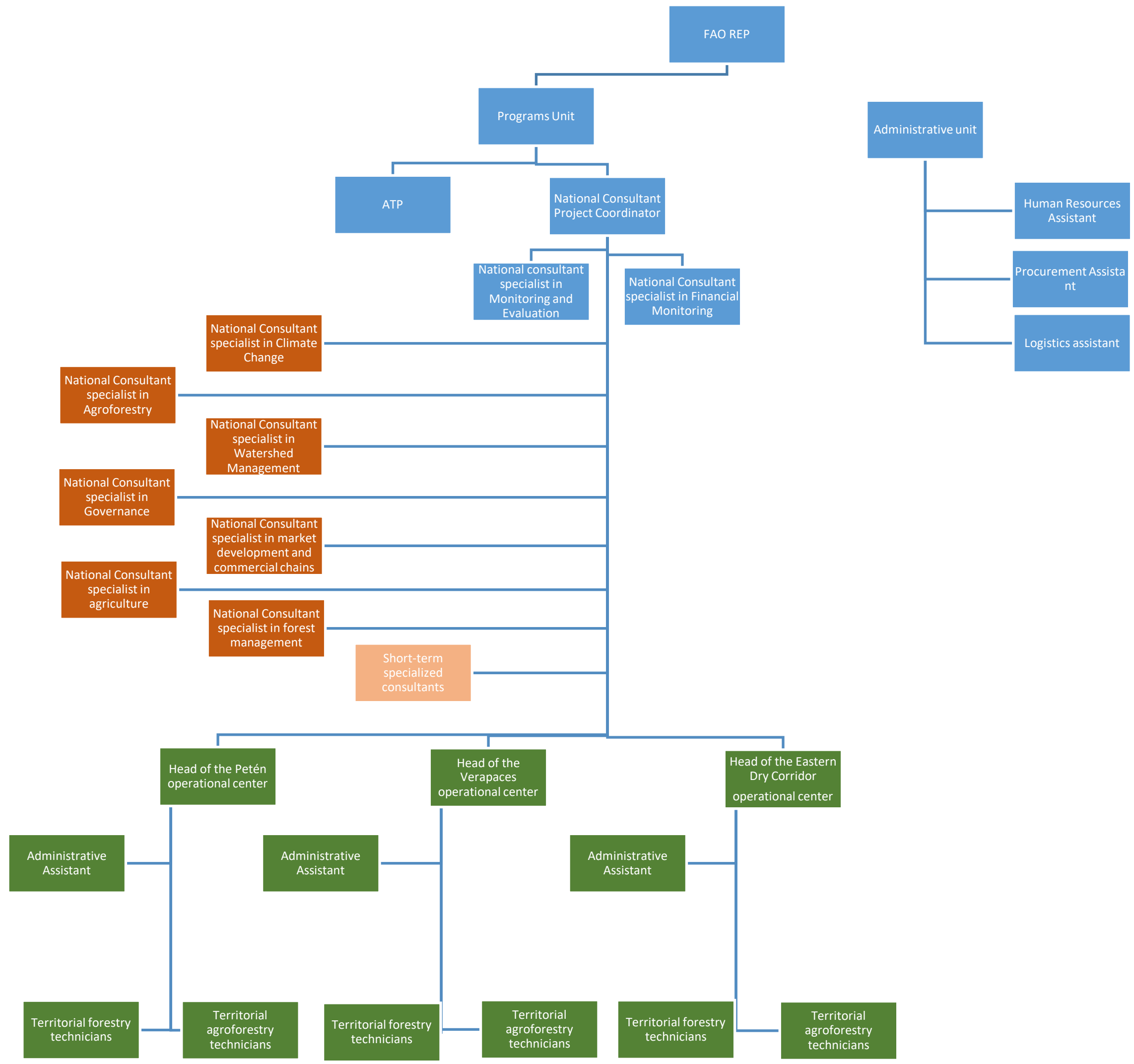
568. FAO in its role of AE shall sign a Project Agreement with SEGLEPLAN62 representing the Government of Guatemala, and MARN representing the GCF NDA. The Project agreement will be also co-signed by the governmental co-financiers and co-executing entities (MAGA and INAB). It will reflect the governance arrangements, govern the implementation of the project, be legally binding, detail the roles and responsibilities of FAO, MAGA and INAB, contain the relevant provisions for FAO's compliance with the requirements from the AMA and FAA, contain provisions on the applicability of the Convention on the Privileges and Immunities of the Specialized Agencies (the "the Specialized Agencies Convention") to FAO, including to the GCF Proceeds held by FAO. Every year the PMU will prepare the annual work plan and budget including a rolling procurement plan for the next 18 months. The TC will approve the plan and FAO will spend funds according to its covenants, rules and standards. A yearly report will be submitted to the GCF including the annual expenditure report as well as the yearly replenishment plan approved by the PSC. Funds from the co-financiers will be managed by MARN, MAGA and INAB respectively.

Project Management Unit

569. From the following chart, the general operation of the project will be under the coordination and responsibility of a National Consultant Project Coordinator whom three Head of operational centers will depend on, and who will be responsible for a Territorial Operating Unit each.

[62] Secretaria General de Planifica hydro-meteorologicalción (SEGEPLAN)

570. Each Head of operational centers (3) will be in charge of a Territorial Operating Unit (TOU) that will be integrated by the following staff (for each region): 1 Administrative Assistant, (6) Territorial forestry technicians, and (6) Territorial agroforestry technicians.



FAO REP
Programs Unit
Administrative unit
ATP
National Consultant Project Coordinator
Human Resources Assistant
Procurement Assista nt
Logistics assistant
National consultant specialist in Monitoring and Evaluation
National Consultant specialist in Financial Monitoring
National Consultant specialist in Climate Change
National Consultant specialist in Agroforestry
National Consultant specialist in Watershed Management
National Consultant specialist in Governance
National Consultant specialist in market development and commercial chains
National Consultant specialist in agriculture
National Consultant specialist in forest management
Short-term specialized consultants
Head of the Petén operational center
Head of the Verapaces operational center
Head of the Eastern Dry Corridor operational center
Administrative Assistant
Administrative Assistant
Administrative Assistant
Territorial forestry technicians
Territorial agroforestry technicians
Territorial forestry technicians
Territorial agroforestry technicians
Territorial forestry technicians
Territorial agroforestry technicians

571. A description of the responsibilities of the staff is described in the following matrix.

POSITION	RESPONSIBILITIES
National Consultant Project Coordinator	• Coordinate, supervise and ensure the implementation of project actions • Prepare technical inputs for the donor, coordinate the team of consultants, and liaise with the government institutions linked to the project • Prepare terms of reference for the companies / partner organizations / consultants required for the development of the project activities • Supervise and ensure that national and international companies / partner organizations / consultants deliver the products in a coordinated manner, within the deadlines established in their work plans, that their products are consistent with each other and that they meet the needs of the project.
ATP (External professional expert in project operation)	• Generate monitoring and operation manuals • Develop operational plans, biannual plans, investment plans, procurement plans • Develop Terms of Reference • Support the process of reviewing consultant reports, and institutional analysis.
National consultant specialist in Monitoring and Evaluation	• Follow up on the operation and maintenance of the project planning, monitoring and evaluation system • Review and adjust the annual operation plan, ensuring the contribution of activities to the scope of the products and the results, as well as the relevance of the unit of measure. • Keep up to date the implementation of the Project monitoring and evaluation system • Design or update instruments for measuring indicators • Consolidate and analyze the information and upload to the FAO monitoring system monthly, quarterly and semi-annual reports and prepare the requested reports for donors • Follow-up field activities as described in the Annual Operation Plans (POA) • Measure products and results´ indicators as established in the Logical Framework
National Consultant specialist in Financial Monitoring	• Follow up on the financial operation of the project • Keep track of finances with respect to payments and bank transfers of the return, suppliers of goods and services of the field projects of the FAO - Guatemala Representation. • Review payment requirements for FAO Guatemala projects and the Representation. • Review and reimburse the OPC and Petty Cash fund for each Project and the Representation • Enter payment requirements to the GRMS system. • Perform various procedures required by the official bank of the FAO Guatemala Representation. • Review the financial report of Letters Agreements of FAO Guatemala projects and the Representation. • Pay DSA for national and international consultants. • Ensure that the processes under their responsibility are framed in accordance with FAO manuals and regulations. • Support the preparation of the Periodic Budget Revision - PBR- of the Representation Office.
National Consultant specialist in Governance	• Operate institutional development and public policy actions for climate-resistant agriculture, as well as sustainable water management with national, regional and local actors • Prepare training programs and technical assistance to strengthen governance on issues related to climate change, agriculture and water at national, regional and local levels • Promote intersectoral dialogue spaces and organize the participation of actors at national, regional and local levels in terms of adaptation to climate change • Support the transfer of knowledge about climate-resistant agriculture, sustainable water management and climate change to national, regional and local
National Consultant specialist in Climate Change	• Operate the project's climate monitoring actions • Develop means for the systematization and socialization of climate information as well as its dissemination • Liaise with project partners that will support the management of climate information (FAO and the use of ASIS, MAGA and Anacafé with coffee and cocoa information) • Analyze climate information and develop written materials for its incorporation into agroforestry practices developed by the project
National Consultant specialist in agriculture	• Operate the planning, technical assistance and follow-up actions of the project products in agricultural practices in subsistence crops to promote climate resilience • Advise and supervise the implementation of climate-resistant subsistence farming practices • Provides training and technical assistance in management practices in subsistence crops to promote resilience to climate change • Monitor for compliance with products and results in terms of practices in subsistence crops • Prepare technical reports regarding the effect of the adaptation practices used
National Consultant specialist in forest management	• Operate the planning, technical assistance and follow-up actions of the project products in landscape restoration to promote climate resilience • Advise and supervise the implementation of management plans that will be entered into the forest incentives program • Provide training, training and technical assistance in restoration of agroforestry landscapes to promote resilience to climate change • Monitor for compliance with products and results in forest landscape restoration • Prepare technical reports related to the effect of adaptation practices based on landscape restoration
National Consultant specialist in Agroforestry	• Operate the planning, technical assistance and follow-up actions of the project products in agroforestry practices to promote climate resilience • Advise and supervise the implementation of climate-resilient agroforestry practices

	• Provide training and technical assistance in management practices of agroforestry systems to promote resilience to climate change • Monitor for compliance with products and results in agroforestry practices • Prepare technical reports regarding the effect of the adaptation practices used
National Consultant specialist in market development and commercial chains	• Operate the planning, technical assistance and follow-up actions of the project products in terms of market development and commercial chains • Prepare training programs (training of trainers) in market analysis and development, using guides and manuals • Assist producer organizations in the design of training programs in market analysis and development
National Consultant specialist in Watershed Management	• Operate the planning, technical assistance and follow-up actions of the project products in watershed management • Support and monitor the development of watershed management plans • Support the implementation of watershed management plans • Provide technical advice to local actors for the process of integrating watershed councils
Procurement Assistant	• Carry out the processes of acquisition of goods and services in compliance with the standards of the FAO manuals. Review the approved requisitions in the GRMS system and verify compliance with the respective annexes. Prepare comparative tables with a minimum of 3 quotes for purchases in the range of USD1,000.00 to USDGTQ5,000.00 • Follow up on suppliers to guarantee receipt of sent invitation to participate in purchase processes. • Officially notify about the award of goods and / or services to the participating suppliers, as well as to the project managers. • Ensure adequate delivery of goods or services. • Participate as secretary in the Local Purchasing Committee. • Issue of purchase Orders for each process either purchase based on 3 quotes or Tender, and follow up until approval. • Carry out the process to integrate into the GRMS Letters of Agreement under $ 25,000 and carry out the appropriate process for contracting the organizations providers of services for the Letters of Agreement over $ 25,000 for FAO Guatemala. • Update approved purchase orders; as well as the follow-up of expiration dates of letters of agreement for possible amendments. • Update the database of FAO suppliers.
Human Resources Assistant	• Support and participate in the selection and hiring processes of FAO staff. • Advise consultants on the filling out the official formats required for hiring personnel • Enter, extend or terminate GRMS personnel contracts. • Keep updated control of the Vacancy Ads posted on the TALEO platform. • Collaborate with staff in the management of claims to medical insurance. • Generate consultant's payment form according to the official payment calendar. • Manage the request for courtesy visas of the Representative and international staff of FAO in the Ministry of Foreign Affairs. • Control and administer staff performance evaluation. • Maintain, organize and control personnel records. • Update the information to the UNDSS automated system of recent staff for obtaining United Nations cards. • Prepare all procedures related to personnel (proof of income, monthly payment receipts, leave application, settlements, etc.) • Ensure that the processes under their responsibility are framed in accordance with FAO manuals and regulations.
Logistics assistant	• Support the management, organization and logistics processes of training events, workshops, tours and exchanges of experiences that FAO projects in Guatemala develop. • Assist and facilitate the management of national and international trips, which includes travel logistics, per diem, lodging reservations. • Responsible for the elaboration of Travel Authorizations -TA´s- in the GRMS system • Responsible for the purchase of air tickets for FAO Guatemala consultants and non-FAO staff invited to participate in national and international events. • Follow up on the payment of per diem for people traveling abroad, as well as international consultants who have official missions in our country. • Responsible for the management of national travel advances, verifying that it complies with the requirements according to FAO manuals and requirements. • Responsible for the verification and liquidation of national and international trips, preparing in a timely manner in the GRMS system the Local Travel Authorizations –LTA- and the Travel Expenses Claim –TEC- • Responsible for monitoring the settlement of events and training by presenting the lists of participants, reports of the event prepared by the person in charge of the event service provider contract, agenda and call, as supporting documentation to the Finance unit
Administrative Assistant (Operational centers)	• Support the messaging and contact local suppliers for various purchases. • Operate and keep records of the settlement of the petty cash. • Support the team in making payments of advances of funds and monitoring disbursement requests • Keep track of the fuel used by the Project. • Update the Project inventory. • Keep up-to-date input delivery records. • Support events logistics and the required delivery supplies
Head of the operational centers	• Coordinate the activities of the Regional Operational Center and provide technical assistance, training and support the project process to increase the resilience of project beneficiaries

	• Coordinate the technical and administrative activities of the project in the assigned municipalities • Lead and facilitate the strategic approach designed by the project to achieve the results • Support the linking of organized groups that execute productive projects with local markets to generate higher income • Facilitate and execute the project activities for the municipality together with the territorial counterparts (MAGA INAB, and Municipality) according to the Project Document and Annual Operation Plan • Coordinate with actors and projects in the municipality for the articulation of efforts aimed at improving the resilience of families
Territorial forestry technicians	• Responsible for the development of management plans and their entry into the forest incentives program • Support the relationship with local actors
Territorial agroforestry technicians	• Provide technical assistance in the field to individual producers and organized producer groups • Support the relationship with local actors

D.6.6. Project risks

572. The following table was prepared to analyze project risks. It shows risk categories, the impact level, the likelihood of occurrence and mitigation measures. A detailed analysis of the project's environmental and social impacts and mitigation measures is provided in Annex 6 of the Funding Proposal.

Table 56: Project Risks.

Selected Risk Factor 1		
Category	Probability	Impact
Governance	Medium	Low
Description		
Turnover of key project personnel and related technical and coordinating staff of implementing agencies could impact the pace of the project implementation and delay decision-making processes.		
Mitigation Measure(s)		
The risk that new officials will not support the project will be mitigated through information sessions to update them on the project actions and benefits to their constituencies. The development of micro-basin water management plans under Component 2 and inter-institutional arrangements under Component 3 will guide the work of new staff. The on-going capacity-building processes and the preparation of project reports and institutional reports and processes will also allow for knowledge transfer for new staff.		
Selected Risk Factor 2		
Category	Probability	Impact
Governance	Medium	Medium
Description		
Changes of central and local government leadership and in overarching policy priorities can lead to a lack of support for project activities.		
Mitigation Measure(s)		
The alignment of project activities with multiple overarching development policies, mainly the Framework Law for Climate Change and the National Action Plan for Climate Change, NDC, K'atun 2030, as well as Forest Law makes this a medium risk. While one or more government policies may change the project is likely to remain in alignment with at least some of these policies. Additionally, under Component 3 the project will help strengthen implementation and institutional arrangements that mitigate this risk and increase the likelihood that project activities in the territories will continue uninterrupted. The institutional arrangements strengthened throughout the project will facilitate political processes		

between the central government, local governments and the project. The implementation of agreements at the micro-basin level will enable the engagement with local government.		
Selected Risk Factor 3		
Category	Probability	Impact
Technical and operational	Medium	Low
Description		
Poor coordination / communication among stakeholders at the national and local level can lead to inefficiencies in the implementation and impact of the project.		
Mitigation Measure(s)		
The FAO will develop cooperation agreements with government agencies and the key stakeholders that will establish clear communication channels and procedures for project coordination with stakeholders involved in the project. The PMU team involves stakeholders from key institutions and is set to be maintained throughout the timeframe of the project in collaboration with the Territorial Operational Units. The PMU will ensure that communication and technical actions can continue. Under Component 3, institutional agreements will be established to share information between INAB and MAGA, which will improve the collection and dissemination of agro-climate information to farmers. Both agencies are full partners in the project, with roles and responsibilities to be clearly delineated at inception.		
Selected Risk Factor 4		
Category	Probability	Impact
Technical and operational	Medium	Medium
Description		
The institutions linked to the development of the project do not have the personnel and / or resources required to carry out the project activities.		
Mitigation Measure(s)		
Under component 3, clear institutional arrangements with MAGA and INAB will allow the project to use their institutional capacities and human resources across the targeted municipalities to reach the identified target communities. FAO has access to skills and experience across its international team and will play a strong role in monitoring the actions and goals proposed in the institutional agreements with the partners. FAO will assess partners' capacity, provide real-time monitoring and feedback, and where appropriate will provide technical support to ensure effective and efficient project delivery.		
Selected Risk Factor 5		
Category	Probability	Impact
Other	Low	Medium
Description		
Cultural barriers limit the participation of women, youth and ethnic groups.		
Mitigation Measure(s)		
The consultative process was carried out with the participation of women and indigenous groups to ensure that consultations were responsive to various gender needs and roles and cultural aspects such that project activities effectively respond to the unique needs of women and girls, men and boys, and promote equal opportunities to participate, and receive comparable social and economic benefits. Capacity building sessions, training and communication materials and technical assistance will be provided in local languages to ensure the engagement of indigenous families and that they benefit		

equally from the project and support its activities. The training processes will consider topics discussing the importance of the participation of all family members and ethnic groups in the decision-making spaces.		
Selected Risk Factor 6		
Category	Probability	Impact
Technical and operational	Medium	Low
Description		
Unfavorable changes in market prices of coffee, cacao and staple crops and in the prices of agricultural inputs.		
Mitigation Measure(s)		
Local farmers have limited ability to affect volatile global commodity prices. Instead this risk will be mitigated by reducing exposure. Many of the crops supported by the project are for local consumption, not for sale to wholesalers. For cash crops, the project will identify niche markets, develop differentiated products and partner with supply chain actors willing to pay fair prices. In addition, the project aims to enhance alternative sources of revenue and help farmers diversify incomes. In case of low prices of a crop that generates cash, the family will have other products for sale, which will help to offset the decrease in income.		
Selected Risk Factor 7		
Category	Probability	Impact
Other	Medium	Low
Description		
Extreme climate events and climate shocks could affect the successful implementation of project activities. For example, crop demonstrations could be hindered by drought and heatwaves.		
Mitigation Measure(s)		
Technical training sessions will help beneficiaries understand the impacts of climate change and the benefits of investing in climate resilient agriculture techniques. The monitoring and use of climate information will be promoted not only amongst project beneficiaries, but also project implementation teams, in order to ensure timely corrective and security actions, in case extreme events are forecasted to affect project activities. The use of demonstration plots will help farmers gauge the comparative benefits of climate resilient agricultural techniques, even in times of climate stress. While traditional crops varieties may outperform in normal years, the benefits of more resilient varieties will become more apparent during extreme events.		
Selected Risk Factor 8		
Category	Probability	Impact
Other	Medium	Medium
Description		
Security challenges could hinder the ability of the project team / extension agents to work with farmers.		
Mitigation Measure(s)		
Security risks are an ongoing challenge for extension services in Guatemala. The project will reduce the risk of security related disruptions through a combination of informal and formal measures. To the extent possible, project staff will be recruited locally. Project staff will receive detailed briefings prior to working in areas with known security challenges and receive training on how to react to potential security events. The project team will liaise with local leaders and seek their active endorsement when starting activities in a prioritized area. More broadly, project activities will promote family cohesion and reduce livelihood		

challenges that contribute to insecurity by directly involving vulnerable groups in project activities.

D.7. Exit strategy and sustainability

573. The project has been designed strategically to create the conditions to implement climate resilient agriculture solutions beyond the project period. Project sustainability (operational, financial, institutional, social, gender equality, environmental) will be ensured in the long run through the following features of the project:

D.7.1. Country ownership

574. FAO projects implemented in Guatemala have always ensured the active engagement of decision-makers from partner institutions. The proposed project objectives and activities are fully aligned with the national policies on climate change and food security (as described in Section D.5 of the Funding Proposal). National institutions have been closely involved in project planning and will participate fully during project implementation. The project will receive policy support and access to financial and in-kind resources from government programmes (MAGA and INAB). Engagement with INAB, which has committed to invest part of the forest incentive program PINPEP to the project's outputs, will allow for mainstreaming of climate resilient adaptation practices such as the proposed agroforestry systems (Output 2.2). Given that the incentive program has a perpetual lifespan, INAB’s engagement will help ensuring long-term delivery of project impacts. As the project has been designed and will be implemented within government program structures, project results will enhance current practices in PINPEP regarding smallholder farmers and especially women farmers and outcomes will be institutionalized. This will guarantee the commitment of the GoG to systematically drive investment in adaptation beyond project lifetime.

D.7.2. Engagement with local communities and institutions

575. The project was designed to create enabling conditions for the effective and sustained participation of private sector actors (i.e. beneficiary farmers under components 1 and 2 and the private sector actors in the agriculture value chain such as fertilizer and seed providers, the wholesalers who buy coffee and cacao from the farmers) and public sector actors involved in the climate change and development agenda. The project was formulated from the beginning in close consultation with and involvement of relevant government agencies, beneficiaries in farming communities and other stakeholders, in order to maximize buy-in and long-term ownership. The proposed activities were identified through a participatory approach engaging both women and men and based on community priorities (more details on the stakeholder consultations and stakeholder engagement plan in Annex 7 of the Funding Proposal). As described in the gender and indigenous assessments (Cf. Annexes 6 and 8 of the Funding Proposal), the project design ensured that the needs of women and vulnerable groups are prioritized in income generating and skills development activities.

576. Local organizational structures such as COCODEs and CADER as well as newly formed Local Water Committees will be used to achieve the buy-in and ownership amongst the

local communities. They will help to communicate the proposed adaptation measures to the target farmers in a culturally-relevant manner and in local languages. Additionally, farmers will be able to test and validate the proposed measures and to select a package of gender-sensitive agricultural adaptation measures that best fit their needs and conditions. This approach will help to ensure that the measures continue to be relevant and viable beyond the life of the project.

577. Finally, local financing will strengthen commitment and ownership in the implementation of the project and enable the local actors to sustain the investments beyond project duration. The project will leverage community co- investment into the proposed activities. The irrigation water solutions and farmer field trials of agricultural adaptation practices will be implemented with community co-investments in the form of labor and/or materials.

D.7.3. Capacity building for locally owned solutions on climate resilient agriculture and water resource management

578. Component 3 key objective is to strengthen the capacities of local institutions (such as the existing decentralized extension services for local farmers and producers, and the municipal forestry, water and gender offices and Local Water Committees) to plan for and implement climate-risk informed local water management solutions, adopt technologies and systems for climate resilient agricultural production, sustain climate resilience infrastructures and integrate climate information and advisories for water management ensuring their post-project financial viability. These local institutions are key to ongoing operations and maintenance of project infrastructure63.

579. Sustainability of operation and maintenance of acquired equipment will be guaranteed in the budgets of the beneficiary institutions. Maintenance of village irrigation systems will be supported by farmers' contributions, which are improved through project interventions on alternative income generation activities. Farmers will be asked to sign a MoU agreeing that the water infrastructure will be managed for food production on the site for at least 10 years (Output 2.3). Moreover, they will be encouraged to prepare a multi-year maintenance and financing plans at farm-level to monitor and plan to climate change. The Local Water Committees will also play a key role for the oversight and maintenance of the water supply infrastructures and will be trained to support their construction, operation and maintenance to ensure their proper management once the project is completed. Regarding the forest restoration, activities will be concentrated in the first years of the project, meaning that by the time project support for maintenance is withdrawn the trees will be sufficiently developed that their maintenance needs will be minimal.

D.7.4. Effective knowledge transfer and dissemination of information on benefits

580. Under Component 3, the project will strengthen knowledge management at the local and national levels and systematize and disseminate the results of economic

[63] Institutional arrangements will be defined to facilitate political processes between the central government, local governments and the project and will establish the roles and responsibilities of each stakeholder, in particular in relation to operations and maintenance of project infrastructure.

analyses of returns achievable from climate resilient investments, such as reductions in the need for spending on remedial and emergency actions in response to the impacts that climate change would have on health and food security. Knowledge and learning will be promoted through the participatory approach to be adopted to the generation and transfer of adaptation measures, including the use of CADER and the Community Centers for Adaptation, which will provide spaces for farmers to share experiences, test and validate alternatives, and innovate in order to develop sets of adaptation measures that are farmer-driven.

581. The uptake of climate services and alternative livelihood strategies by farmers will create conditions for investments by public and private sector actors. Farmers will see concrete benefits in a variety of ways, for example through better allocation of resources, increased productivity, and better access to markets. For instance, the project will provide the private sector with weather and climate information required to make informed decisions to increase productivity and make medium and longer-term investments. Also, measures that increase water use efficiency improve watershed management and are expected to have a demonstration effect – farmers who see a clear benefit will continue employing these measures. By delivering a tangible economic benefit to beneficiaries that adopt climate-resilient agriculture and efficient water management practices, the project will stimulate economic activity in Guatemala's rural areas even under conditions of climate change.

D.7.5. Replication, upscaling and sustainability of project results

582. The need to ensure sustainability, scaling up and replication have been incorporated into the project design. The scaling up and replication strategy seeks to promote a systematic approach by strengthening and adapting existing mechanisms such as alignment with national climate strategies, the agricultural extension services and the financial incentives for forestry and agroforestry:

583. At a national level, the project strengthens the enabling environment (Component 3) to effectively mainstream climate resilient practices in agricultural plans and strategies. Best practices from the project will be integrated as part of implementation mechanisms used by the NAP and NDC. This would be a key instrument for upscaling project results.

584. At provincial/local level, the project will strengthen technical and operational capacities of the extension services and technical staff from INAB at a national level to enable the replication of project best practices in other provinces in Guatemala. Thus, the project ensures that there is the needed capacity at local and provincial levels to promote the replication of the resilient agricultural practices through FFS and climate centers, beyond the project.

585. Table 57 below presents a summary of institutional, community and financial mechanisms to ensure replication, upscaling and sustainability of project results.

Table 57: Summary of institutional, community and financial mechanisms to ensure the replication, upscaling and sustainability of project results

<table>
<tr><th></th><th></th><th colspan="3">RELIVE adaptation measures</th></tr>
<tr><th></th><th></th><th>Agricultural adaptation packages for basic grains</th><th>Agricultural adaptation packages for coffee and cocoa</th><th>Micro-basin water management</th></tr>
<tr><th></th><th colspan="4">Local level</th></tr>
<tr><td rowspan="2">Replication and scaling-up</td><td>Institutional mechanisms</td><td colspan="2">Capacity building of extension services and demonstration sites: The RELIVE project will provide capacity building to the extension services and demonstration plots to ensure that there is the needed capacity at local and municipal levels to promote the replication of the resilient practices through Farmer Field Schools beyond the project. (Project Output
Replication: In order to ensure that generated knowledge and best practices from project interventions are shared and replicated effectively, the project will elaborate a portfolio with the agricultural adaptation practices to be distributed to extension services and promoted by them to farmers.
Scaling-up: The project will actively engage the agricultural extension services not only in the project site but also in other provinces by capacity development on resilient agricultural practices.</td><td>Development of management models for micro-basins: The RELIVE project will strengthen the capacity local communities to develop models for management of micro-basins through enhanced institutional structures such as the Local Water Committees (Project Output 2.1)
Replication: The management models for micro-basins will be further promoted by Community Councils of Urban and Rural Development (COCODE) and municipalities.</td></tr>
<tr><td>Financial mechanisms</td><td>Incentives through technology transfer for equitable benefits sharing: Technology transfer and vegetative material through the technique called “chain pass” (pase en cadena) is a kind of community social network, through which producers who have already obtained harvests of fruit seeds and banana seedlings are committed in solidarity to share or exchange these inputs and knowledge with other producers in the community or group of producers, in the same community or in other communities, in such a way that it becomes cheaper to obtain inputs for implementing adaptation practices, reducing the costs of the practices and therefore facilitating their replication and scalability. (Project Output 1.2)
<u>Replication:</u> New farmers interested in the adaptation practices will have the incentives provided by this mechanism to encourage them with access to</td><td>Production of vegetative material in community nurseries: this may be the case in coffee, cocoa. New vegetative material can be obtained from the seeds and vegetative parts of the cocoa and coffee plants acquired and established initially by the RELIVE project, through training and formation of specialized community nursery experts. In the case of cocoa, produce seeds and sticks for grafting. In the case of coffee, production of seeds and new seedlings through rooting techniques of cuttings. (Project Output 1.2 and Output 2.2)
<u>Replication</u>: New farmers interested in adopting the resilience practices will have access to affordable and quality inputs and know-how about the adaptation practices.</td><td></td></tr>
</table>

		affordable and quality inputs and know-how. ***Scaling-up:*** The community-led networks will join a wider provincial technology transfer network to promote a wider-range of inputs and knowledge.		
	Financial mechanisms	**Micro-enterprises for seed banks:** The establishment of women-led seed banks in the form of micro enterprises will aim to collect, store, exchange and locally sell seeds such as coffee, cocoa, tree seedlings and basic grain seeds. This will address the need of smallholder farmers to purchase improved and affordable seeds at a more appropriate scale and schedule. *(Project Output 1.2)* ***Replication:*** Demonstration of the effectiveness of the seed banks will encourage other communities / municipalities to create seed banks. ***Scaling-up:*** The established seedbanks by the project will form a regional network of seedbanks to allow for exchange of seeds.		
Sustainability	***Financial mechanisms***	**Mutual Contingency Community Fund:** FAO has experience in promoting such funds managed by a producer association that aims to support its members in case of emergency and to finance activities that can alleviate the problems of the most vulnerable families affected by unexpected events, such as drought, hurricanes, floods, earthquakes and other extreme events. They are targeted at households that do not have access to formal financing and insurance systems to protect their livelihoods. It is a sustainability complement to the association's livelihoods and savings and credit system. These funds can finance a variety of activities as long as they are approved by the association's board of directors. Activities may include the purchase of inputs for a new agricultural season when the harvest was lost, family and household expenses in emergency situations, productive and commercial activities that generate profit when the community lost sources of income, etc. *(Project Output 1.2)*		**Incentives for integrated and climate resilient micro-basin management:** The Local Water Committees will be responsible for the maintenance of the irrigation systems and oversee the water management activities in the micro-basin. These Committees will be registered as members of the Community Councils of Urban and Rural Development (COCODE), which belong to the National System of Development Councils of Guatemala. Once the Local Water Committees are registered with COCODE, they will be able to apply for funding from the regional budget thus ensuring financial sustainability of the irrigation systems. *(Project Output 2.2)*
	National level			
		Agricultural adaptation packages for basic grains	***Agricultural adaptation packages for coffee and cocoa***	***Micro-basin water management***
Replication and scaling-up	***Institutional mechanisms***	**Enhancing cooperation and collaboration for replication of knowledge and practices:** The project will seek collaboration with organizations that have the potential to promote upscaling such as farmer's associations (national/regional) as well as financial institutions such as CABEI. Opportunities will be explored to identify platforms to share best practices and lessons learnt. This can be either on online platforms or collaboration for the organization of farmer fairs (national/regional), where project beneficiaries may present success stories. Among such organizations are: Farmers Field Schools, Learning Centers for Rural Development (CADER),		

		Producer Groups, Cooperatives, producer organizations, community-based and peasant enterprises. The project, together with the participation of MAGA technicians, Territorial Technicians and Organization Leaders, will promote these organizational schemes, either by incorporating individual producers into existing associative schemes or by promoting the formation of other groups. *(Project Output 3.1 and Output 3.2)*	
	Policy mechanisms	**Promoting policy instruments to enhance rural businesses:** Promotion of Alliances for Inclusive Rural Businesses, with public policy instruments available at the Ministry of the Economy (Vice-Ministry of Small Businesses), MAGA (Directorate of Productive Development) and Ministry of Education (MINEDUC), especially with School Feeding Program.	
		Integrating portfolio of gender-sensitive agricultural adaptation packages in policy instruments: In Guatemala, the Climate Change Adaptation Program for the agro-forestry sector is managed jointly by MARN and MAGA. There are two legal instruments: - **The National Action Plan on Climate Change (PANCC)** is one of these policy instruments, which guides and prioritizes the actions to be implemented by the various sectors of the country for climate adaptation. - **National Council on Climate Change (CNCC)**, which is made up of different sectors of Guatemalan society and government and is chaired by the President of the Republic. ***Scaling-up:*** The RELIVE project is tightly aligned with these policy instruments and will promote a portfolio of the gender-sensitive agricultural adaptation packages and a catalogue of improved local seeds to be promoted by these policy instruments as best practices and used country-wide	

SECTION E. Economic and Financial Analysis.

586. Appendix 3 of the Funding Proposal shows the details of the RELIVE project economic and financial analysis, as well as the methodology used for estimating it. That is why in this section we will only make a brief description of the main results of said analysis.

587. In the aforementioned appendix, the marketable (agricultural production) and non-marketable benefits (the three ecosystem services considered) are aggregated to obtain the overall estimation of the economic value of the project, considering the total investment cost of US$66.7 million (US$29.8 million from Green Climate Fund, US$7 from KOIKA, US$5.7 million from MAGA and US$24.1 from INAB).

588.

589. A financial analysis was performed to evaluate the results of four adaptation packages in a midterm horizon: 10 years.

590. The results show that only Basic Crops presents a positive incremental net present value in a midterm analysis of 10 years horizon. If it the project lifespan is considered (20 years) all adaptation packages generates financial benefits to rural families that are higher than costs. The explanation of this situation is that adaptation packages presents incremental negative cash flows during first 4 years for cocoa, coffee and family gardens, but from then on cash flows are in all cases significantly superior to the without-adaptation option. This result is not unexpected since the benefits of the restoration of degraded landscape will be evident at a longer time period64.

591.

Table 58: Financial indicators per adaptation package and for operational center to add value

Adaptation Package	**Without project**		**With project**		**Net effect**		
	NPV (US$/ha)	Equivalent Annual Payment (US$/ha)	NPV (US$/ha)	Equivalent Annual Payment (US$/ha)	NPV (US$/ha)	Internal Rate of Return	Incremental Equivalent Annual Payment(US$/ha)
				10 years horizon			
Basic Crops	$ 243	$ 43.0	$ 256	$ 45.4	$ 14	12.4%	$ 2.4
Coffe	$ 4,272	$ 756.0	$ 3,212	$ 568.4	-$ 1,060	4.8%	-$ 187.6
Cocoa	$ 1,531	$ 270.9	$ 1,170.35	$ 207.1	-$ 360	8.3%	-$ 63.8
Family gardens	$ 759.39	$ 134.4	$ 676.63	$ 119.8	-$ 83	4.7%	-$ 14.6
				20 Years horizon			
Basic Crops	$ 239	$ 32.00	$ 1,175	$ 157.32	$ 936	22.4%	$ 125.32
Coffee	$ 5,421	$ 725.71	$ 6,375	$ 853.50	$ 954	15.2%	$ 127.79
Cocoa	$ 1,900	$ 254.32	$ 3,227	$ 431.97	$ 1,327	18.6%	$ 177.65
Family gardens	$ 988	$ 132.31	$ 1,096	$ 146.73	$ 108	16.3%	$ 14.42
Operational center to add value to coffee	-	-	-	-	$183,585	20.4%	$24,578
Operational center to add value to cocoa	-	-	-	-	$23,471	12.6%	$3,142

[64] This situation does not mean that family farmers will receive negative cash flows during the first years, due to incremental costs of the implementation of adaptation packages will be contributed by the project, not by families. While this is a financial cost, it is not paid by the farmer.

592. The support of the Green Climate Fund is critical to promote long term investments to enhance climate resilience of vulnerable farmers located in dry corridor, through the implementation of adaptive agroecosystem management to families that are facing high levels of poverty, limited technical assistance and lack of resources such as productive soil and water.

593. It is important to underline that, in a 20 years horizon, all adaptation packages are financially viable with IRR that ranges from 15% to 22%. This means that families will have new income generating opportunities, equivalent to US$14/ha and US$177/ha per year as a result of the adoption of the agronomical practices that also promotes restoration of the landscape and provision of ecosystem services. Also, both operational centers to add value to coffee and cocoa are financially viable.

594. Nevertheless, even though farmers will generate new revenues, the level of income is still very low in long term horizon. For a 10 years horizon, only Category II is financially viable due to the fact that the effects of proposed adaptive agroecosystem management gradually will be taking place over time, and in a long term analysis it will be reflected the full revenue stream of benefits. The negative returns over a 10 years horizon underline the need for grant financing to encourage climate-resilient investments. This shows that it needs time to bring farmers to a level in which they are financially sustainable and have returns greater than the cost of capital. This is a condition to enhance the sustainability of results and the exit strategy of the project.

595. Without this intervention that allows long term investments, family farmers will continue to live under vulnerable conditions to climate change and the flow of public goods to society (carbon capture, water flow regulation, erosion control) will be reduced.

596. A sensitivity analysis was performed for each adaptation package and for the center to add value to coffee and cocoa, to evaluate how financial indicators changes with a variations of key variables:

- Reductions in expected flows of benefits from agriculture
- Delay in benefit generation due to lags in project implementation
- Increment in investment costs

Table 59: Sensitivity analysis for the financial indicators

Variable	Variation	Basic crops		Coffee		Cocoa		Family gardens		Processed Coffee		Processed Cocoa	
		Total net present value US$	Internal Rate of Return	Total net present value US$	Internal Rate of Return	Total net present value US$	Internal Rate of Return	Total net present value US$	Internal Rate of Return	Total net present value US$	Internal Rate of Return	Total net present value US$	Internal Rate of Return
Reduction in benefits	-5%	$378	16.0%	$31	12.1%	$784	15.9%	($97)	8.2%	($233,961)	4.6%	$122,471	17.6%
	-10%	($180)	10.2%	($893)	8.9%	$242	13.2%	($303)	0.2%	($491,392)	-11.5%	$61,358	14.8%
	-15%	($738)	4.7%	($1,817)	5.5%	($300)	10.5%	($508)	-10.5%	($748,823)	.	$244	12.0%
Delay in benefit generation	1 year	($423)	9.5%	($1,344)	8.6%	($25)	11.9%	($387)	4.4%	($616,229)	1.4%	$37,481	13.3%
	2 years	($1,635)	4.5%	($3,370)	4.8%	($1,226)	8.1%	($830)	-0.3%	($1,187,390)	-4.0%	($92,969)	9.4%
	3 years	($2,718)	1.3%	($5,206)	1.9%	($2,305)	5.2%	($1,226)	-3.3%	($1,697,355)	-7.7%	($209,442)	6.7%
Increment	10%	$757	19.3%	$794	14.6%	$1,213	17.8%	$52	13.8%	($50,200)	10.8%	$135,188	17.5%

in investment costs	20%	$578	17.0%	$633	14.0%	$1,098	17.0%	($4)	11.9%	($123,871)	9.2%	$86,791	15.2%
	30%	$400	15.1%	$473	13.4%	$984	16.3%	($60)	10.3%	($197,542)	7.9%	$38,394	13.3%

597. For a 20 years horizon, the incremental economic benefit for the entire project is estimated in US$28.2 million, with an internal rate of return of 50.0%. With an investment of US$66.7 million, it is expected to create economic benefits in excess to the opportunity cost of capital (12%), and produce a bonus of US$28.2 million. This means an economic net present value per benefited hectare of US$987, and an economic net present value per beneficiary of US$217. For a 10 years horizon, the incremental economic net present value is US$10.9 million, with an internal rate of return of 45.5%.

598. It is important to highlight the importance of co-benefits in the economic evaluation, since the value of the restoration of the ecosystem services of erosion control, water provision and carbon sequestration represents 58% of total economic benefits.

599. It should be noted that RELIVE will contribute to strengthening the resilience of other ecosystem services that have not been considered: biodiversity conservation, genetic resources conservation, medicinal resources and recreation. Nor was possible to quantify important social benefits that have a direct impact on the well-being of families, such as the impact of food production on family health and the foregone time to fetch water. None of these important benefits was possible to quantify in the economic analysis due to lack of information.

600. A sensitivity analysis was also performed, to evaluate how the economic indicators of the overall project changes with a variations of key variables:

- Reductions in expected flows of benefits from marketable and not marketable benefits.
- Delay in benefit generation due to lags in project implementation
- Increment in investment costs

601. The table below shows that the net present value of overall project still presents positive economic indicator even when exist reduction of 15% of expected benefits, there is a delay in benefit generation of 3 years, or overruns appears (up to 15%). This reveals the robustness of RELIVE.

602.

Table 60: Sensitivity analysis for the economic indicators

Variable	Variation	Total net present value US$ million	Economic Internal Rate of Return
Reduction in benefits	-5%	$26.4	47.8%
	-10%	$24.6	45.7%
	-15%	$22.9	43.5%
Delay in benefit generation	1 year	$23.4	38.0%
	2 years	$19.1	31.4%
	3 years	$15.4	26.9%
Increment in	5%	$26.1	40.2%

	10%	$24.0	34.0%
	15%	$21.9	29.5%

603. The analysis shows that the RELIVE is a robust project and creates economic value for society considering the productive, ecological and climate impacts. The economic analysis considered benefits from agriculture production and only three ecological services: erosion control, water provision and carbon sequestration. It was not possible to account for a number of other economic effects. Including: i) other ecosystem services, such as genetic resources conservation, medicinal resources and recreation; ii) the important impact of food production on family health; and iii) the benefits of foregone time to fetch water. Thus, this analysis underestimate the real economic impact for society, and shall be considered as the inferior limit of the economic benefits.

Efficiency and effectiveness

604. The total Project cost is USD 66.7 millions, comprising USD 36.8 millions of co-financing (USD 24.1 million in the form of financial incentives under the INAB/PINPEP and PROBOSQUE programs, 5.7 million in the form of in-kind contribution from MAGA and USD 7 million in the form of grants from KOICA) and USD 29.8 millions of GCF funding in the form of grants. This corresponds to a co-financing ratio of 1:1.1.

605. The GCF support in the form of grant is a key element to reduce market barriers that are currently affecting vulnerable farmers (See Section B.2 for more details on the market barriers):

- The project will serve to decrease information asymmetries, by demonstration and dissemination to other farmers and public institutions for which the set of environmentally-friendly and climate resilient agricultural practices constitute a practical and viable alternative for adaptive capacity, strengthening food security and increasing production. This is a key element of the project, as it is expected to be replicated in other areas of the country.
- The project will support smallholder farmers with the elaboration of the technical studies requested to access the forest incentives under PINPEP.
- The project will provide access of smallholders to public services, such as extension, technical assistance, innovation and knowledge. Also, with the project it is expected that farmers will have access to quality inputs, such as quality seeds.
- The project will give value to non-market ecosystem services through the restoration of degraded areas. The project will create positive environmental externalities for services that don't have markets, such as erosion prevention.
- GCF grant support will provide the minimum concessional funding necessary to make the project viable. Concessional GCF support will address several market needs including food security, and the need for small-scale farmers to access information, knowledge, and technology to address the challenges of climate change.

606. The effectiveness of the proposed adaptation solutions is based on evidence and has been validated in a number of FAO projects at varying scale in the Central American region and worldwide (See section A5 of Feasibility Study). This project builds on those lessons of cost-effectiveness and efficiency of delivery. The project will build synergies with other projects in the same geographical location and working on same issues as water resource development and management, forest management and climate resilience to maximize effectiveness (please see Section B4).

607. Costs of the infrastructure investments have been estimated using comparable benchmarks from other projects. The micro-infrastructure for water harvesting can support varying number of farm-level irrigation systems. On average the cost of the construction and the implementation of the micro-infrastructure and the irrigation systems, is about in USD 5,000 (more details in Section C.6 of the feasibility study). Average costs for implementation of adaptation practices (agroforestry, USD 2,000) and construction of community seed nurseries (USD 4,000), infrastructure for the processing of coffee (USD 1,500) and cocoa (USD 83,000) have been derived from the benchmarks of other projects discussed in Section A4 of Feasibility Study.

608. Finally, community participation in the implementation and operational stages will ensure cost-effectives of the investments. Previous experience shows that in some instances (e.g. for river basin protection) labor is usually volunteered. 65 The micro-basing water management plans will be managed by the community, thereby reducing the operation and maintenance costs for the governance in the long term. Similarly, the community contribution to the management of hydro-meteorological stations can make the maintenance cost-effective because this will reduce the inputs (travel, salaries and accommodation) from the project.

Application of best practices

609. This project includes the uptake of agricultural management and ecosystem restoration measures to improve climate resilience of smallholder farmers. All of the proposed measures have been extensively tested through other FAO projects and research studies in comparable conditions in Guatemala and elsewhere in the region (See section A.5 of the feasibility study). The gender-sensitive agricultural adaptation packages promoted in Output 1.2 (see table 3) as well as the diversification of the productive systems in Output 1.3 were developed based on lessons learned from experiences in Latin America and the Caribbean on solutions for climate resilient agriculture for food security[66]. The resilient agricultural practices in Output 1.2 were further tailored through a preliminary option analysis conducted by CATIE and described in detail in Section C.6 of the Feasibility Study. The project will also build on the lessons learned and best practices developed through the IDB project "Recovery of the Natural

[66] AECID, 2018. Lecciones Aprendidas sobre *sobre agricultura resiliente al cambio climático para contribuir a la seguridad alimentaria y al derecho a la alimentación en América Latina y el Caribe. URL: http://www.aecid.es/Centro-Documentacion/Documentos/Publicaciones%20AECID/Agricultura_resiliente.pdf*

Capital of the Dry Corridor and Climate Adaptation of its Population" and the project "Adaptation to Climate Change in the Dry Corridor of Guatemala" implemented in the same targeted project area.

610. RELIVE seeks to strengthen the farmer ownership of the agricultural resilient practices by encouraging them to cover for O&M costs of the equipment and productive infrastructure. This approach was used by the project "Reducción de Vulnerabilidades para Contribuir al Desarrollo Rural en cinco Municipios de las Cuencas de los Ríos Coatán y Alto Suchiate en el Departamento de San Marcos" implemented from 2010 to 2014 by. Lessons learned from this project have been incorporated in two on-going projects: "Practicas resilientes" and "Mesoamerica sin hambre". In these two projects, smallholder farmers were provided with macro-tunnels facilities and rainwater collection bins for drip irrigation. RELIVE draws on lessons learned from these projects aiming to replicate sustainability aspects that are at the same time accompanied by extension and capacity building activities (workshops and trainings) to strengthen local technical capacities and allow producers to be able to operate and maintain the equipment not only during the life of the project but also after the project finishes

SECTION F. References

- Abdulai, I. V. (2017). Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun. Glob Chang Biol, 24(1), 273-286. doi:10.1111/gcb.13885
- ADEC. (2016). Análisis de la Cadena Productiva del Café de Guatemala. Guatemala: ADEC.
- Adjaloo, M., & Oduro, W. (2013). Insect assemblage and the pollination system of cocoa (Theobroma cacao L). Journal of Applied Biosciences, 62, 4582-4594.
- AECID. (2018). Lecciones Aprendidas sobre Agricultura Resiliente al Cambio Climático para Contribuir a la Seguridad Alimentaria y al Derecho a la Alimentación en América Latina y el Caribe. Madrid.
- Alfaro, G., & Gómez, R. (2019). Antecedentes y Contexto del Cambio Climático en Guatemala. Obtenido de https://sgccc.org.gt/wp-content/uploads/2019/05/1.-1erRepCCGuaCap1.pdf
- Allen, C., B. D., & McDowell, N. (2015). On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. Ecosphere, 8(129), 6.
- Álvarez. (2010). Influencia de la cobertura de bosque nativo en la generación de escorrentía en el sur de Chile: estudio comparativo de microcuencas (Tesis de Maestría). Santiago de Chile: Universidad de Chile. Obtenido de http://repositorio.uchile.cl/handle/2250/102485
- Anderson, T., Anchukaitis, T., Griffin, D., Pons, D., & . Taylor, M. (s.f.). Climate sensitivity and potential vulnerability of Guatemalan fir (Abies guatemalensis) forests in Totonicapán, Guatemala" in Journal of Latin American.
- Anzueto, F. (2016). EL cambio climático, la variabilidad climática y sus efectos en la caficultura. El Cafetal, 44, 4-5.
- Avelino, J. C. (2015). The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. Food Security, 7(2), 303-321. doi:10.1007/s12571-015-0446-9
- Baca, M., Läderach, P., Haggar, J., Schroth, G., & Ovalle, O. (2014). An integrated framework for assessing vulnerability to climate change and developing adaptation strategies for coffee growing families in Mesoamerica. PloS One, 9(2).
- Bhattacharya, T., & Coats, S. (2020). Atlantic-Pacific gradients drive last millennium hydroclimate variability in Mesoamerica. Geophysical Research Letters, 47, e2020GL088061. https://doi.org/10.1029/2020GL088061
- Banco Mundial. (2017). Recuperado el 1 de 11 de 2017, de Datos. Gasto (% del PIB): https://datos.bancomundial.org/indicador/GC.XPN.TOTL.GD.ZS

- Baumeister, E. (2010). Pequeños Productores de Granos Básico en América Central. Cuantificación, caracterización, nivel de ingresos, pobreza y perfiles demográficos, socioeconómicos y ocupacionales. FAO.
- Beer, J., Muschler, R., Kass, D., & Somarriba, E. (1998). Shade management in coffee and cacao platations. Agroforestry Systems, 139-164.
- Bellenger, H., Guilyardi, E., Leloup, J. et al. ENSO representation in climate models: from CMIP3 to CMIP5. Clim Dyn 42, 1999–2018 (2014). https://doi.org/10.1007/s00382-013-1783-z
- Beteta, H. (21 de Julio de 2014). La Economía del cambio climático en Guatemala: Opciones de respuesta. Guatemala, Guatemala. Obtenido de http://cambioclimaticogt.org/wp-content/uploads/2014/09/Econom%C3%ADa_y_CC_Hugo-Beteta_CEPAL1.pdf
- Betts, R., P, C., M, C., P, H., C, H., & Jones, C. (2004). The role of ecosystem–atmosphere interactions in simulated Amazonian precipitation decrease and forest dieback under global climate warming. Theor Appl Climatol, 78, 157–175.
- Bouroncle, C., Imbach, P., Läderach, P., Rodríguez, B., Medellín, C., Fung, E., . . . Donatti, C. (2015). La agricultura de Guatemala y el cambio climático: ¿Dónde están las prioridades para la adaptación? CGIAR. Obtenido de https://www.conservation.org/publications/Documents/La-Agriculture-de-Guatemala-y-el-Cambio-Climatico.pdf
- Bouroncle, C., Medellín, C., & Winograd, M. (2018). CTC.org. Recuperado el 2019 de Mayo de 13, de https://www.ctc-n.org/technical-assistance/projects/strengthening-technical-capacities-implementation-guatemalan-online
- Bruijnzeel, L. (1988). (De) Foresttion and dry season flow in the tropics: a closer look. Journal of Tropical Forest Science, 229 - 243.
- Bureau, P. R. (2016). World Population Data Sheet. Washington, DC: Population Reference Bureau .
- Calvo, J., & Gutiérrez, I. (2010). Fortalecimiento de los grupos locales para la gobernanza ambiental: un análisis a partir de los capitales de la comunidad. . Recursos Naturales y Ambiente no.56-57 , 130-137.
- Camacho, N. (2013). Manual de buenas prácticas para el manejo de cuencas hidrográficas. USAID.
- Carr, M., & Lockwood, G. (2011). The water relations and irrigation requirements of cocoa (Theobroma Cacao L.): a review. Experimental Agriculture, 47(04), 653-676. doi:10.1017/s0014479711000421
- Carreño, G. (2015). Arboles dispersos en fincas. Esfuerzos mínimos para estimar la riqueza de árboles en fincas. ICRAF-CATIE.

- Carvajal, R. (2015). Estudio de viabilidad de cosecha de agua de lluvia en Reserva Conchal para su utilización en riego del campo de golf. San José: UCA.
- CATIE. (2013). Programa Agroambiental Mesoamericano (MAP). Turrialba: CATIE.
- CATIE. (2018a). Identificación Selección y Descripción de Medidas de Adaptación al Cambio Climático que Permitan Aumentar la Resiliencia de Personas Vulnerables en Guatemala. Parte 2: Descripción de las medidas de adaptación. Informe final. Guatemala: CATIE.
- CENTA. (2017). Variedad sintética de maíz amarillo para granos con tolerancia a humedad limitada. Centro Nacional de Tecnología Agropecuaria y Forestal. La Libertad.
- Centro de Estudios Ambientales y Biodiversidad (CEAB), UVG. (2016). Línea base de deforestación evitada en la región Sub-nacional REDD+ Sarstún-Motagua. Guatemala: Universidad del Valle de Guatemala.
- CEPAL. (1999). Guatemala: Evaluación del Daño Causado por el Huracán MITCH, 1998. México, D.F., México: CEPAL.
- CEPAL. (2005). Efectos en Guatemala de las lluvias torrenciales y la tormenta tropical Stan, octubre de 2005. México D.F., México: CEPAL.
- CEPAL. (2018). La economía del Cambio Climático. Documento técnico. Santiago de Chile: Naciones Unidas.
- Cerda, R., Deheuvels, O., Calvache, D., Niehaus, L., Saenz, Y., Kent, J., . . . & Somarriba, E. (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. Agroforestry Systems, 88(6), 957-981. doi:10.1007/s10457-014-9691-8
- CGIAR . (11 de Octubre de 2018). CGIAR Challenge Program on Water and Food. Obtenido de Rainwater Management for Climate Smart Agriculture: https://waterandfood.org/2011/12/21/rainwater-management-for-climate-smart-agriculture/
- Chiquimula. (2011). Consejo Departamental de Desarrollo del Departamento de Chiquimula. Guatemala: Consejo Departamental de Desarrollo del Departamento de Chiquimula. Obtenido de https://www.segeplan.gob.gt/nportal/index.php/biblioteca-documental/file/50-pdd-chiquimula
- Chocooj, M., & Morales, S. (2017). Situación nacional de la roya de café y recomendaciones para su manejo. Boletín Técnico CEDICAFE. Guatemala: ANACAFE.
- CIAT, C. I. (2012). Escenarios del Impacto del Clima Futuro en Áreas de Cultivo de Café en Guatemala. Informe Final. Cali, Colombia y Managua, Nicaragua: CIAT.
- CIMMMYT. (1999). Desarrollo, mantenimiento y multiplicación de semillas de variedades de polinización libre. México D.F.: Programa de maíz.

- Clará, R. (2013). Guía técnica para la producción artesanal de semilla de variedades de polinización libre de sorgo en América Central. INTSORMIL Scientific Publications.
- CNCC, & SEGEPLAN. (2016). Plan de Acción Nacional de Cambio Climático (PANCC). Recuperado el 10 de Marzo de 2018, de http://sgccc.org.gt/wp-content/uploads/2016/10/Plan-de-Accio%CC%81n-Nacional-de-Cambio-Clima%CC%81tico-ver-oct-2016-aprobado-1.pdf
- CONADUR. (2014). Plan Nacional de Desarrollo K'atun: Nuestra Guatemala 2032. Consejo Nacional de Desarrollo Urbano y Rural, Guatemala, SEGEPLAN.
- Confalonieri, R., Donatelli, M., Bregaglio, S., & Tubiello, F. y. (2012). Agroecological Zones Simulator (AZS): A component based, open-access, transparent platform for climate change – crop productivity impact assessment in Latin America. International Environmental Modelling and Software Society, 1-8.
- Consejo de Desarrollo Departamental de Alta Verapaz. (2011). Plan de desarrollo departamental de Alta Verapaz. Guatemala: Consejo de Desarrollo Departamental de Alta Verapaz. Obtenido de file:///C:/Users/Martinezmi.FIELD/Downloads/PDD_16%20(1).pdf
- Consejo Departamental de Desarrollo Departamental de Baja Verapaz. (2010). Plan de Desarrollo Departamental PDD de Baja Verapaz. Guatemala: Consejo Departamental de Desarrollo Departamental de Baja Verapaz. Obtenido de https://www.segeplan.gob.gt/nportal/index.php/biblioteca-documental/category/49-planes-desarrollo-departamental
- Cook, Edward R et al. “Tree-Ring Reconstructed Summer Temperature Anomalies for Temperate East Asia Since 800 C.E.” *Climate dynamics* 41.11-12 (2012): 2957–2972. Web.
- Cox, P., Betts, R., Collins, M. H., Huntingford, C., & Jones, C. (2004). Amazonian forest dieback under climate-carbon cycle projectsions for the twenty-first century. Theor Appl Climatol, 78, 137–156.
- Cox, P., R, B., Jones, C., Spal, I. S., & Totterdell, I. (2000). Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature, 408, 184-187.
- Cutter, S., Emrich, C., & T., M. D. (2013). Integrating social vulnerability into federal flood risk management planning. of Flood Risk Management, 6(4), 332-344.
- de Sousa, K., van Zonneveld, M., Imbach, P., Casanoves, F., Kindt, R., & Ordonez, J. (2017). Suitability of key Central American agroforestry species under future climates: an Atlas. Turrialba: ICRAF.
- Depsky., N., Pons,.D.(2020). Droughts Are Projected to Worsen in Central America’s Dry Corridor Throughout 21st Century: A Multiple Climate Model Assessment . Submitted to ERL 2020.

- Eckstein, D., Künzel, V., & Schäfer, L. (2018). GLOBAL CLIMATE RISK INDEX 2018. Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2016 and 1997 to 2016. Bonn: Germanwatch e.V. Obtenido de https://germanwatch.org/en/download/2043
- EM-DAT. (2017). EM-DAT. The International Disaster Database. Centre for Research on the Epidemiology of Disasters -CRED-. Obtenido de https://www.emdat.be/emdat_db/
- Espinosa, A., Gómez, N., Sierra, M., Betanzao, E., Caballero, F., B., C., . . . Cano, O. (2003). Tecnología y producción de semillas de híbridos y variedades sobresalientes del maíz de calidad proteínica (QPM) en México. Agronomía Mesoamericana.
- FAO. (2000). Manual de Captación y Aprovechamiento del Agua de Lluvia: Experiencias en América Latina. Santiago de Chile: FAO. Obtenido de http://www.fao.org/tempref/docrep/fao/010/ai128s/ai128s00.pdf
- FAO. (2013). La Resiliencia de los medios de vida - Programa Reducción del riesgo de desastres para la Seguridad Alimentaria y Nutricional. Roma: FAO. Obtenido de http://www.fao.org/3/a-i3270s.pdf
- FAO. (2017). El sistema agroforestal Kuxur Rum contra las amenazas naturales en Guatemala. Obtenido de http://www.fao.org/3/a-i6814s.pdf
- FAO. (2018a). Libro de consulta sobre la agricultura climáticamente inteligente, resumen de la segunda edición. Roma: FAO.
- FAO. (3 de Marzo de 2018). Food and Agriculture Organization of the United Nations. Obtenido de FAOSTAT: http://www.fao.org/faostat/en/#data/QC
- FAO; PMA. (S/f). Informe especial Misión FAO/PMA de Evaluación de Cosecha y Seguridad Alimentaria en Guatemala. Guatemala. Obtenido de http://www.fao.org/docrep/012/ak344s/ak344s00.htm
- FAP. (2009). Una Huerta para Todos. FAO. Obtenido de https://coin.fao.org/coin-static/cms/media/1/12956304968670/cartilla_una_huerta_para_todos.pdf
- FEWS NET. (8 de Octubre de 2015). FEWS NET FAMINE EARLY WARNING SYSTEMS NETWORK. Obtenido de Continuing El Niño drives increased food insecurity across many regions: http://www.fews.net/ global/alert/october-8-2015
- Foster, P. (2001). The potential negative impacts of global climate change on tropical montane cluod forest. Earth science reviews(75), 73-106.
- García, J. (2012). Sistema de captación y aprovechamiento pluvial para un ecobarrio de la CD de México. México: UNAM.
- Garibaldi, L., Steffan-Dewenter, I., Winfree, R., Aizen, M., Bommarco, R., Cunningham, S., & Klein, A. (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science, 339(6127), 1608–1611.

- GCI. (2017). Estrategia Nacional para el Abordaje de la Deforestación y Degradación de los Bosques en Guatemala (ENDDBG). Guatemala.
- Giorgi, F. (2006). Climate change hot-spots. Geophys Res Lett(33), 1-4.
- Guha-Sapir, D., Below, R., & Hoyois, P. (2017). EM-DAT: The CRED/OFDA International Disaster Database – www.emdat.be –. Bruselas, Bélgica: Université Catholique de Louvain.
- Guzman, V. (2016). Diagnóstico de la Cadena de Cacao. Guatemala: MARN-PNUD-Proyecto Paisajes Productivos Resilientes.
- GWP. (2017). La situación de los recursos hídricos en Centroamérica: hacia una gestión integrada. Tegucigalpa, Honduras: Global Water Partnership (GWP).
- Hannah L, D. C. (2017). Regional modeling of climate change impacts on smallholder agriculture and ecosystems in Central America. Climatic Change, 141(1), 29–45.
- Hanson, R., Flint, L., Flint, A., Dettinger, M., Faunt, C., Cayan, D., & Schmid, W. (2012). A method for physically based model analysis of conjunctive use in response to potential climate changes. Water Resour Res, 48(2).
- Harvey, C. A.-E. (2014). Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. Conservation Letters, 7(2), 77-90. doi:10.1111/conl.12066
- Harris, Ian et al. "Version 4 of the CRU TS Monthly High-Resolution Gridded Multivariate Climate Dataset." *Scientific data* 7.1 (2020): 109–18. Web.
- Hidalgo, H., & Alfaro, E. (2015). Skill of CMIP5 climate models in reproducing 20th century basic climate features in Central America. International Journal of Climatology, 35(12), 3397-3421.
- Hijmans, R., Cameron, S., Parra, J., Jones, P., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. International journal of climatology, 25(15), 1965-1978.
- IARNA-URL. (2011). Cambio climático y biodiversidad. Elementos para analizar sus interacciones en Guatemala con un enfoque ecosistémico. Guatemala: IARNA-URL.
- IARNA-URL. (2012). Perfil Ambiental de Guatemala 2010-2012. Vulnerabilidad local y creciente construcción de riesgo. Guatemala: IARNA-URL.
- ICTA. (2015). Recomendaciones técnicas para el cultivo del maíz en el oriente de Guatemala. Guatemala. Obtenido de http://www.icta.gob.gt/publicaciones%202015/Documentos%20pag.%20web%202da%20etapa/Granos%20Basicos/Maiz/Manuales/2013/Aspectos%20generales%20y%20guia%20para%20el%20manejo%20del%20maiz.pdf
- ICTA. (2018). ICTA B15ACP+ZINC Maíz blanco fortificado: Variedad de maíz con alta calidad de proteína y más contenido de zinc. Guatemala.

- IFOAM. (2014). Agricultura Familiar Agroecológica en América Latina, en un contexto de cambio climático. Lima.
- IICA. (2013). Post-harvest Losses in Latin America and the Caribbean: Challenges and Opportunities for Collaboration. Washington, DC. Obtenido de http://www.iica.int/Esp/Programas/SeguridadAlimentaria/Documentos Seguridad Alimentaria/Report on Post-Harvest Losses in Latin America and the Caribbean 9-20-2013.pdf
- IICA. (2014). Agregación de Valor a productos de origen agropecuario. San José: IICA. Obtenido de https://www.iica.int/sites/default/files/publications/files/2015/B3639e.pdf
- Imbach, P., Molina, L., Locatelli, B., Roupsard, O., Mahé, G., Neilson, R., . . . Ciais, P. (2012). Modeling potential equilibrium states of vegetation and terrestrial water cycle ofMesoamerica under climate change scenarios. Hydrometeor, 13(2), 665–680.
- Imbach P, Chou SC, Lyra A, Rodrigues D, Rodriguez D, Latinovic D, et al. (2018) Future climate change scenarios in Central America at high spatial resolution. PLoS ONE 13(4): e0193570. https://doi.org/10.1371/journal.pone.0193570
- INAB, CONAP, & UVG. (2006). Dinámica de la Cobertura Forestal de Guatemala durante los años 1991, 1996 y 2001 y Mapa de Cobertura Forestal 2001. Guatemala.
- INCAP. (2017). Cambio climático y nutrición. Análisis y propuestas metodológicas para evaluar el impacto y respuesta en Centroamérica y República Dominicana. Instituto de Nutrición de Centroamérica y Panamá. Sistema de Integración Centroamericana (SICA).
- INE (2019). XII Censo Nacional de Poblacion y VII de Vivienda. Guatemala.
- INE. (2002). Censos Nacionales XI de Población y VI de habitación 2002. Guatemala: Instituto Nacional de Estadística (INE). Obtenido de https://www.ine.gob.gt/sistema/uploads/2014/02/20/jZqeGe1H9WdUDngYXkWt3GIhUUQCukcg.pdf
- INE. (2003). Características de la población y de los avitantes censados. Guatemala: Instituto Nacional de Estadística (INE).
- INE. (2016). Encuesta Nacional de Condiciones de Vida. 2014. Tomo I. Guatemala: Instituto Nacional de Estadística (INE).
- INE. (s/f). Población Total por Municipio. Recuperado el 13 de Mayo de 2019, de http://www.oj.gob.gt/estadisticaj/reportes/poblacion-total-por-municipio(1).pdf
- INE-ENEI. (2019). Encuesta Nacional de Empleo e Ingresos I-2019. Guatemala.
- INSIVUMEH. (2002). Mejoramiento de la Capacidad Técnica para Mitigar los Efectos de Futuros Eventos de la Variabilidad Climática (El Niño). Estudio Técnico. Guatemala: Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH).

- INSIVUMEH. (2018). Variabilidad y Cambio Climático en Guatemala. Guatemala: Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología (INSIVUMEH).
- IPCC. (2013). Summary for Policymakers. En T. D.-K. Stocker (Ed.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA.
- Jha, S.; Bacon, C.; Philpott, S.; Méndez, E.; Läderach, P.; Rice, R. (2014). Shade Coffee: Update on a Disappearing Refuge for Biodiversity. BioScience, 64(5), 416-428. doi:10.1093/biosci/biu038
- JICA. (2015). Guía práctica para cosechar el agua de lluvia. Proyecto de Desarrollo Rural Integral Sostenible en la Provincia de Chimborazo. Ecuador: JICA.
- Jiménez, J., & Sepúlveda, C. (2015). Sistemas silvopastoriles y buenas prácticas para la ganadería sostenible en Oaxaca. (M. F. México, Ed.) Recuperado el 25 de junio de 2018, de Monitoreo Forestal: http://www.monitoreoforestal.gob.mx/repositoriodigital/items/show/542
- Jones, P., Harpham, C., Harris, I., Goodess, C., B. A., Centella-Artola, A., Baur, T. (2016). Longterm trends in precipitation and temperature across the Caribbean. International Journal of Climatology, 36(9), 3314–33.
- Karmalkar, A., Bradley, R., & Díaz, H. (2011). Climate change in Central America and Mexico: regional climate model validation and climate change projections. Climate Dynamics, 37, 605-629.
- Klein, A., Vaissiere, B, Cane, J., Steffan-Dewenter, I., Cunningham, S.,Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. Proc R Soc Lond B Biol Sci, 274(1608), 303–313.
- Knutti, R., & Sedláček, J. (2013). Robustness and uncertainties in the new CMIP5 climate model projections. Nature Climate Change, 3(4), 369-373.
- Läderach, P., Haggar, J., Lau, C., Eitzinger, A., Ovalle, O., Baca, M, Lundy, M. (2013). Mesoamerican coffee: building a climate change adaptation strategy. CIAT Policy brief n.2. Cali, Colombia: CIAT.
- Laderach, P., Lundy, M., Jarvis, A., Ramirez, J., Portilla, E. P., Schepp, K., & Eitzinger, A. (2011). Predicted Impact of Climate Change on Coffee Supply Chains. The Economic, Social and Political Elements of Climate Change, 703-723.
- Leandro-Muñoz, M. E.-M. (2017). Effects of microclimatic variables on the symptoms and signs onset of Moniliophthora roreri, causal agent of Moniliophthora pod rot in cacao. PloS one, 12(10). doi:10.1371/journal.pone.0184638
- León, J., & Arroyo, N. (2011). Producción, tecnología y comercialización del arroz en Costa Rica 1950-2005. San José: SIEDIN.

- Lyra, A., Imbach, P., Rodriguez, D., Chou, S., Georgiou, S., & Garofolo, L. (2017). Projections of climate change impacts on central America tropical rainforest. Cimate Change, 14(1), 93-105.
- MAGA, CATIE, Embajada de Noruega. (S.F.). Marco Metodológico para la implementación de sistemas locales de extensión. Guatemala.
- MAGA. (2013). El nuevo Sistema Nacional de Extensión Rural (SNER): un aporte para el desarrollo socioeconómico de las familias campesinas . Guatemala: MAGA.
- MAGA. (2013). El Nuevo Sistema Nacional de Extensión Rural SNER. Guatemala: MAGA.
- MAGA. (2014). Informe sobre roya del café. Guatemala: MAGA. Obtenido de https://www.maga.gob.gt/wp-content/uploads/img/roya/acceso_informacion-roya_del_cafe.pdf
- MAGA. (2014). Sistema de Monitoreo de Cultivos. Boletín No. 8. Guatemala: MAGA.
- MAGA. (2015). Plan Operativo Anual POA 2016 y Plan Multianual 2016-2018. Guatemala: MAGA.
- MAGA. (2016). Estrategia Nacional de la Agrocadena de Cacao –ENAC– en Guatemala. Plan estratégico de la agrocadena de cacao en Guatemala. 2016-2025 -PEDAC-. Guatemala: MAGA.
- MAGA. (2016). Plan Estratégico de la Agrocadena de Cacao de Guatemala 2016-2025. Guatemala.
- MAGA. (2016). Programa de Agricultura Familiar para el Fortalecimiento de la Economía Campesina 2016-2020. Guatemala: MAGA.
- MAGA. (2017). Informe Situación del Frijol a Diciembre 2017. Guatemala.
- MAGA. (2017). Programa de Agricultura Familiar para el Fortalecimiento de la Economía Campesina. Guatemala, Guatemala, Guatemala: Gobierno de Guatemala.
- MAGA. (2018). Informe de Situación de Maíz Blanco. Guatemala: MAGA.
- Magrin, G. O., & Travasso, M. I. (2015). Adaptación al cambio climático en América Latina y el Caribe. Santiago de Chile: CEPAL.
- Magrin, G., Gay García, C., Cruz Choque, D., Giménez, J., Moreno, A., Nagy, G., Villamizar, A. (2007). Latin America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (O. C. M.L Parry, Ed.) Cambridge, UK,: Cambridge University Press.
- Magrin, G., Marengo, J., Boulanger, J., Buckeridge, M., Castellanos, E., Poveda, G., Vicuña, S. (2014). América Central y del Sur. En V. C. Barros, Cambio climático 2014: Impactos, adaptación y vulnerabilidad. Parte B: Aspectos regionales. Contribución del Grupo de trabajo II al Quinto Informe de Evaluación del Grupo

Intergubernamental de Expertos sobre el Cambio Climático (págs. 1499-1566). Cambridge, Reino Unido y Nueva York, NY, Estados Unidos de América: Cambridge University Press.

- Malhi, Y., Aragao, L., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., & al., e. (2009). Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. Proceeding of the National Academy of Sciences of United States of America (PNAS), 106(49), 20610-20615.
- Mapplecroft. (2014). Indice de vulnerabilidad y adaptatción al cambio climático en la región de América Latina y Caribe. Banco de Desarrollo de América Latina. Corporación Andina de Fomento.
- Marengo, J. A. (2015). Regional differences in aridity/drought conditions over Northeast Brazil: present state and future projections. Climatic change, 129(1-2), 103-115.
- MARN. (2007). Programa de Acción Nacional de Lucha Contra la Desertificación y Sequía en Guatemala. Guatemala: MARN.
- MARN. (2015). Segunda Comunicación Nacional Sobre Cambio Climático. Guatemala: MARN.
- MARN. (2016). Diagnóstico de la Cadena de Café "Identificación de Cadenas Ecoproductivas y su Potencial Acceso a Mercados, en la Zona del Proyecto PPRCC". Guatemala.
- MARN. (2016). Informe ambiental del Estado de Guatemala. Guatemala: Ministerio de Ambiente y Recursos Naturales de Guatemala (MARN).
- MARN. (2016). Posición de país COP 22, Guatemala, un país pluricultural, megadiverso y particularmente vulnerable, contribuye a los esfuerzos mundiales de lucha contra el cambio climático. Boletín. Guatemala: MARN.
- MARN. (2017). Informe Ambiental del Estado 2016. Ministerio de Ambiente y Recursos Naturales, Guatemala.
- MARN-URL/IARNA-PNUMA. (2009). Informe Ambiental del Estado - GEO. Guatemala: MARN.
- Martínez Tuna, M. (2017). Metodologías para apoyar la estimación de costos en la implementación del Plan Nacional de Adaptación y Mitigación al Cambio Climático en Guatemala. Santiago de Chile: CEPAL.
- Martínez-Rodríguez, M., Viguera, B., Donatti, C., Harvey, C., & F., A. (2017). Cómo enfrentar el cambio climático desde la agricultura: prácticas de adaptación basadas en ecosistemas (AbE). Turrialba.
- McLachlan, J., Hellmanmaga, J., & .Schwartz, M. (2007). A framework for debate of assisted migration in an era of climate change. Biology Conservation, 21(2), 197-202.

- MEERHOFF, E. (2008). Análisis de los impactos causados por el fenómeno meteorológico El Niño 1997-1998 a escala regional y por países. UNESCO.
- Mendieta, M., & Rocha, L. (2007). Sistemas agroforestales. Managua: Universidad Nacional Agraria.
- Mendoza, J. R., Sabillón, L., Martinez, W., Campabadal, C., Hallen-Adams, H. E., & Bianchini, A. (2017). Traditional maize post-harvest management practices amongst smallholder farmers in Guatemala. Journal of Stored Products Research 71, 14-21.
- Mora, J., Ramirez, D., Ordaz, J., & A. Acosta y Serna, B. (2010). Guatemala: efectos del cambio climático sobre la agricultura. México D.F., México: CEPAL.
- Moser, G. L. (2010). of cocoa trees (Theobroma cacao) to a 13-month desiccation period in Sulawesi, Indonesia. Agroforestry Systems, 79(2), 171-187. doi:10.1007/s10457-010-9303-1
- Neelin, J., Münnich, M., Su, H., Meyerson, J., & Holloway, C. (2006). Tropical drying trends in global warming models and observations. Proceedings of the National Academy of Sciences , 103, 6110–6115.
- OCDE; CEPAL; CIAT; BID. (2017). Estadísticas tributarias en América Latina y el Caribe 2017. París: OCDE.
- Oglesby, R. (2016). A High-Resolution Modeling Strategy to Assess Impacts of Climate Change for Mesoamerica and the Caribbean. American Journal of Climate Change, 5(2), 202-228.
- Oglesby, R., & Rowe, C. (2014). Impactos climáticos para Guatemala: resultados preliminares de los modelos climáticos regionales y globales IPCC AR5. Ministerio de Ambiente y Recursos Naturales. Guatemala
- OPS. (2007). Manual sobre las cinco claves para la inocuidad de los alimentos. WHO. Obtenido de https://www.who.int/foodsafety/publications/consumer/manual_keys_es.pdf
- Orozco Aguilar, L., Deheuvels, O., Villalobos, M., & Somarriba, E. (2007). l sector cacao en Centroamérica: Estado de desarrollo en el año 2007. Serie Técnica. Informe Técnico no 401. Turrialba, Costa Rica: CATIE.
- Ovalle-Rivera, O., Laderach, P., Bunn, C., Obersteiner, M., & Schroth, G. (2015). Projected shifts in Coffea arabica suitability among major global producing regions due to climate change. PLoS One, 10(4).
- Phillips-Mora, W., & Cerda, R. (2011). Enfermedades del cacao en Centroamérica. Turrialba: CATIE.
- Phillips-Mora, W., Ortiz, C., & Aime, M. (9 de 10 de 2006). Fifty years of frosty pod rot in Central America: Chronology of its spread and impact from Panama to Mexico. (C. P. (COPAL)/CATIE, Ed.) Proceedings 15th International Cocoa Reserch Conference. , I, 1039-1047.

- Pizarro, R., Abarza, A., Morales, C., Calderón, R., Tapia, J., García, P., & Córdova, M. (2015). Manual de diseño y construcción de sistemas de aguas lluvias en zonas rurales de Chile. PHILAC-UNESCO.
- PMA, P. M., & FAO, O. d. (2010). Informe especial misión PMA/FAO, Evaluación de Cocecha y Seguridad Alimentaria en Guatemala.
- PNUD. (2009). Desarrollo de Capacidades: Texto Básico del PNUD. New York: PNUD.
- PNUD. (2015). Cosecha de agua de lluvia para enfrentar la escasez de agua en áreas de secano. Chile: PNUD.
- Pons, D., & Brincker, J. (2017). Aumento de la resiliencia climática de las familias rurales a través de restauracion de los sistémas hidrológicos estratégicos en Guatemala. Guatemala: Centro de Estudios Ambientales y de Biodiversidad. Universidad del Valle de Guatemala.
- Pons, D., Brincker, J., & Castellanos, E. (2018). Asegurando la resiliencia ante el CC en los paisajes Mayas de Petén, Verapaces y el Corredor Seco. Producto 1. Documento de análisis de los efectos del Cambio climático a nivel nacional y local. Documento de consultoría. Guatemala.
- Pons, D., Taylor, M., Griffin, D., Castellanos, E., & Anchukaitis, K. (2017). On the production of climate information in the high mountain forests of Guatemala. Annals of the American Association of Geographers. Special Edition on Mountains, 107(2), 323-335.
- Posada, K. (2012). Impacto del Sistema Agroforestal Kuxur Rum en la sostenibilidad de los medios de vida de las familias rurales en Camotán y Jocotán, Guatemala. Turrialba: CATIE.
- Prinz, D. (1996). Water Harvesting: Past and Future. In: Pereira, L. S. (ed.), Sustainability of Irrigated Agriculture. NATO Advanced Research Workshop, Vimeiro, (págs. 21--26). Balkema.
- Ramirez-Villegas, J. &. (2010). Downscaling global circulation model outputs: the delta method decision and policy analysis Working Paper No. 1. Cali, Colombia: International Center for Tropical Agriculture (CIAT).
- Región VII-ANACAFE. (2015). Anacafé-14, la variedad de café de Guatemala resistente a la roya. El Cafetal, 4-5.
- República, C. d. (1996). Decreto No. 101-96. Ley Forestal. Guatemala.
- República, C. d. (2002). Decreto No. 11-2002. Ley de los Consejos de Desarrollo Urbano y Rural. Guatemala.
- República, C. d. (2013). Decreto 7-2013. Ley Marco para Regular la Reducción de la Vulnerabilidad, la Adaptación Obligatoria ante los Efectos del Cambio Climático y la Mitigación de Gases de Efecto Invernadero. Guatemala.

- Ricketts, T. (2004). Tropical forest fragments enhance pollinator activity in nearby coffee crops. Conserv Biol, 1262–1271.
- Rodríguez, C., Barrueco, F., García, F., & Subramaniam, P. (1984). La fijación de nitrógeno atmosférico: una biotecnología en la producción agraria. Salamanca: Instituto de Recursos Naturales y Agrobiología.
- Romero, W. (2013). La Agricultura Familiar en Guatemala. Informe del Proyecto Análisis de la Pobreza y de la Desigualdad en América Latina Rural. Serie de Documentos de trabajo. Documento Nº 148. Grupo de Trabajo: Desarrollo con Cohesión Territorial. Santiago de Chile: Rimisp.
- Romero, W. (2014). La Agricultura Familiar en Guatemala. Serie de documentos de trabajo No 148. Grupo de trabajo: Desarrollo con Cohesión Territorial para el Desarrollo, Santiago, Chile.
- Ruiz, H., R.P., G. G., & Gutiérrez., I. (2018). Huertos Familiares: Agrobiodiversidad y su aporte en la seguridad alimentaria en territorios rurales de Guatemala. Agroecología 9 (1 y 2), 85-88.
- Sáenz-Romero, C., Guzmán, R., & Rehfeldt, G. (2006). Altitudinal genetic variation among Pinus oocarpa populations in Michoacán, Mexico. Implications for seed zoning, conservation, tree breeding and global warming. Forest Ecology and Management, 226, 340–350.
- SAGARPA. (2016). Regla para la calificación de semillas de maíz (Zea mays L.). Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. México.
- Schmidt, A., Eitzinger, A., Sonder, K., & Sain, y. G. (2012). Tortillas on the Roaster: Central American Maize-Bean Systems and the Changing Climate. Full technical report . Catholic Relief Services.
- Scholze, M., K. W., A. N., & Prentice, I. (2006). A climate change risk analysis for world ecosystems. Proc Natl Acad Sci U S A, 103, 13116–13120.
- Schroth, G., Jeusset, A., Gomes, A. d., Florence, C. T., Coelho, N. A., Faria, D., & & Läderach, P. (2014). Climate friendliness of cocoa agroforests is compatible with productivity increase. Mitigation and Adaptation Strategies for Global Change. doi:10.1007/s11027-014-9570-7
- SEGEPLAN. (2006). Estrategia para la Gestión Integrada de los Recursos Hídricos de Guatemala. Diagnóstico. Guatemala: Secretaría de Planificación y Programación de la Presidencia (SEGEPLAN).
- SEGEPLAN. (2011ch). Plan de Desarrollo Departamental - Departamento de Chiquimula. SEGEPLAN.
- SEGEPLAN. (2011z). Consejo de Desarrollo Departamental de Zacapa. Guatemala: Consejo de Desarrollo Departamental de Zacapa. Obtenido de https://www.segeplan.gob.gt/nportal/index.php/biblioteca-documental/category/49-planes-desarrollo-departamental

- SEGEPLAN. (2013). Diagnóstico Territorial de Petén. Guatemala: Secretaría de Planificación y Programación de la Presidencia (Segeplan). Obtenido de http://www.segeplan.gob.gt/downloads/PDI%20Pet%C3%A9n%202032%20Diagn%C3%B3stico.pdf
- SESAN, MAGA, OXFAM, ACF, PMA. (2013). Impacto de la Canícula Prolongada en la población de infra y subsistencia del Corredor Seco de Guatemala. Guatemala: SESAN, MAGA, OXFAM, ACF, PMA.
- SESAN. (2014). Informe de daños ocasionados por la canícula prolongada 2014 (en línea). Guatemala: SESAN (Secretaria de Seguridad Alimentaria y Nutricional, Guatemala). Obtenido de http://sintet.net/index.php?option=com_sobi2&sobi2Task=sobi2Details&catid=1&sobi2Id=1149&Itemid=
- SESAN. (2017). Plan de Respuesta para La Atención del Hambre Estacional. SESAN_Hambre-estacional-2017. Guatemala: SESAN (Secretaria de Seguridad Alimentaria y Nutricional, Guatemala). Obtenido de http://www.sesan.gob.gt/wordpress/wp-content/uploads/2017/07/PRONOSTICO-SAN-DIC-17-A-FEB-2018-ACTUALIZACION.pdf
- SGCCC-CEAB/UVG. (2017). Presentación sobre “Cambio climático en Guatemala: Impacto en el agua y la agricultura”. Sistema Guatemalteco de Ciencias del Cambio Climático, Centro de Estudios Ambientales y Biodiversidad de la. Guatemala, 23 de febrero 2017.
- SGCCC-CEAB/UVG. (23 de febrero de 2017). Presentación sobre “Cambio climático en Guatemala: Impacto en el agua y la agricultura”. Sistema Guatemalteco de Ciencias del Cambio Climático, Centro de Estudios Ambientales y Biodiversidad de la Universidad del Valle de Guatemala (CEAB/UVG). Guatemala, Guatemala, Guatemala.
- SIFGUA. (2017). Incendios forestales en Guatemala. Guatemala: SIFGUA.
- SIINSAN. (2019). Situación de la Seguridad Alimentaria y Nutricional (SAN). Recuperado el 13 de Mayo de 2019, de http://www.siinsan.gob.gt/siinsan/situacion-san/
- Sistema Guatemalteco de Ciencias del Cambio Climático, S. (s.f.). Sistema Guatemalteco de Ciencias del Cambio Climático (SGCCC). Recuperado el 12 de Mayo de 2019, de https://sgccc.org.gt/informacion-general/
- Somarriba, E. (2002). Estimación visual de la sombra en cacaotales y cafetales. Agroforestería en las Américas, 86-94.
- Somarriba, E. (2013). Oferta mundial de tecnologías de producción de cacao prioritarias para elevar los rendimientos, mejorar la calidad del cacao y asegurar la sostenibilidad y seguridad alimentaria de las familias cacaoteras de Centroamérica. Informe Final Consultoría. Costa Rica: RUTA-UNOPS.

- Somarriba, E., Beer, J., & & Muschler, R. (2001a). Research methods for multistrata agroforestry systems with coffee and cacao: recommendations from two decades of research at CATIE. Agroforestry Systems 53, 195-203.
- Somarriba, E., Valdivia, R. O., Vasquez, W., & & Galloway, G. (2001b). Survival, growth, timber productivity and site index of Cordia alliodora in forestry and agroforestry systems. Agroforestry Systems, 51 , 111-118.
- Suchini, J., Taleno, S., & Soto, G. (2017). Manual para el establecimiento y manejo agroecológico de patios y huertos comunitarios. Turrialba: CATIE.
- Taleno, S., & Villanueva., C. (2016). La finca y el patio soñados: Guía de diseño y planificación. Turrialba: CATIE.
- Tapia, S. (2014). Situación actual de la cadena de valor de cacao en Guatemala. Proyecto Gestión del Conocimiento de la de cadena de valor del cacao en Centroamérica. VECO Mesoamérica.
- Touchan, Ramzi et al. "Climate Controls on Tree Growth in the Western Mediterranean." *The Holocene* 27.10 (2017): 1429–1442. Web.
- Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. Geographical review, 38(1), 55-94.
- Toledo-Hernández, M. W. (2017). Neglected pollinators: Can enhanced pollination services improve cocoa yields? A review. Agriculture, Ecosystems & Environment, 247, 137-148. doi:10.1016/j.agee.2017.05.021
- Torselli, C., Morataya, M., & Coyoy, E. (2016). Informe País de Financiamiento para Cambio Climático.
- Tscharntke, T. C. (2011). Multifunctional shade-tree management in tropical agroforestry landscapes - a review. Journal of Applied Ecology, 48(3), 619-629. doi:10.1111/j.1365-2664.2010.01939.x
- UNOCHA, (. N. (28 de Febrero de 2016). Humanitarian needs overview: Central America. Obtenido de https://www.humanitarianresponse.info/en/system/files/documents/files/2016-hno-centralamerica-7jan.pdf
- USAID. (2017). Compendio de Prácticas Ancestrales del Sistema Milpa. Proyecto Nexos Locales.
- Vaast, P., & Somarriba, E. (2014). Trade-offs between crop intensification and ecosystem services: the role of agroforestry in cocoa cultivation. Agroforestry Systems, 88(6), 947-956. doi:10.1007/s10457-014-9762-x
- Vallejo D., R. D., & Chuela B., R. Z. (2008). Manual de protección de semilla de maíz. Estudio de caso. Guadalajara: INIFP, CIRPAC.
- van Etten, J. d. (En impresión). Crop variety management for climate adaptation supported by citizen science.

- Verweij, P., & Winograd, M. (2018). Informe Técnico sobre Desarrollo y Uso de Plataformas de Información sobre Cambio Climático y/o Ambiental para la Toma de Decisiones. Documento de trabajo 4. Fortaleciendo el Sistema Nacional de Información para Cambio Climático (SNICC). Recuperado el 6 de Mayo de 2019, de https://www.ctc-n.org/technical-assistance/projects/strengthening-technical-capacities-implementation-guatemalan-online
- Vecchi GA, Wittenberg AT (2010) El Niño and our future climate: where do we stand? Wiley interdisciplinary reviews. Clim Change 1:260–270. doi:10.1002/wcc.33
- Villanueva, C. (2014). Huertos familiares y su relación con los saberes agrícolas tradicionales, seguridad alimentaria y conservación de la agro diversidad : el caso de la Aldea Seluc, San Agustín Lanquín, Alta Verapaz, Guatemala. Turrialba: CATIE.
- Villanueva, E., Oliva, A., Rosales, M., Moscoso, C., Torres, A., & Gonzalez, E. (2015). Manual de producción y manejo de aves de patio. Turrialba: CATIE.
- Villarreina Acuña, R., Cerda Bustillos, R., Echeverría, J., Padilla, D., Suchini, J., Posada, E., Mercado, L. (2016). Priorización de inversiones en Agricultura Climáticamente Inteligente (ACI): Prácticas agropecuarias de huertos caseros, granos básicos, sistemas agroforestales y pasturas priorizadas en el territorio Trifinio.
- Virginio-Filho, E. d., & Astorga, C. (2015). Prevención y control de la roya del café. Manual de buenas prácticas para técnicos y facilitadores. Turrialba.
- Wang, J., Yang, B., Ljungqvist, F. C. & Zhao, Y. The relationship between the Atlantic Multidecadal Oscillation and temperature variability in China during the last millennium. J. Quaternary Sci. 28, 653–658, https://doi.org/10.1002/jqs.2658 (2013).
- White, A., C. M., & Friend, A. (1999). Climate change impacts on ecosystems and the terrestrial carbon sink: a new assessment. Global environmental change(9), S21-S30.
- Zuidema, P. L. (2005). A physiological production model for cocoa (Theobroma cacao): model presentation, validation and application. Agricultural Systems, 84, 195-225. doi:10.1016/j.agsy.2004.06.015

SECTION G. Supplementary Material

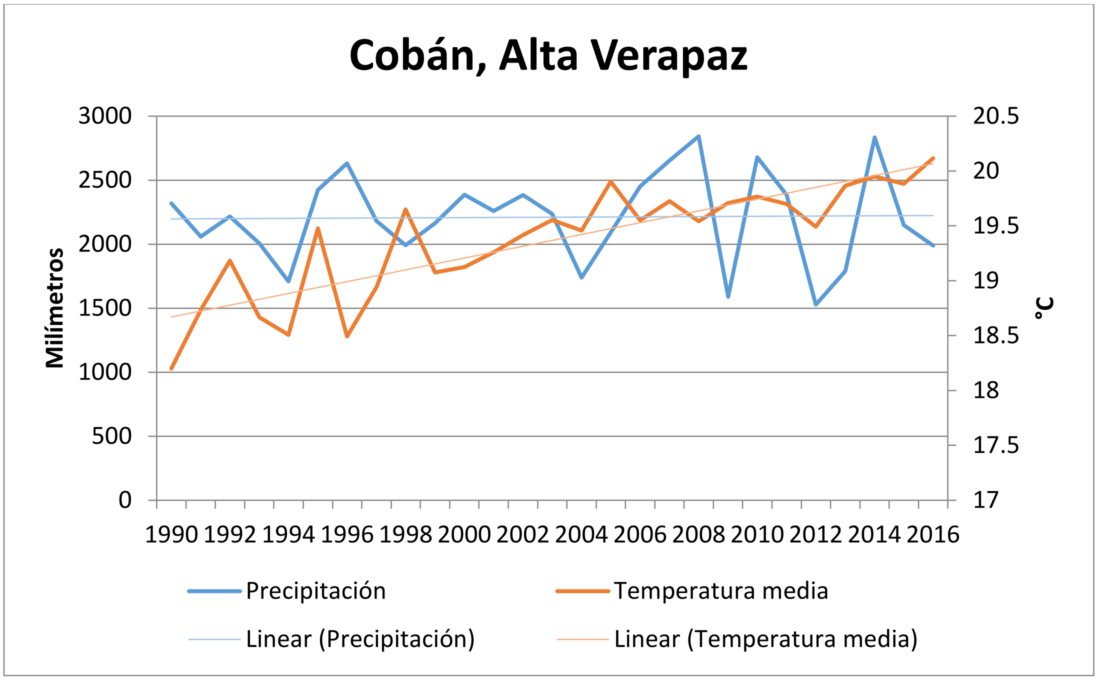
G.1. Supplementary Material 1. Damage caused by the 2014 prolonged midsummer drought in departments prioritized by FAO and UVG.

Departamento	Municipios	Comunidades	Total de familias en las comunidades evaluadas
Alta Verapaz	1	53	12332
Baja Verapaz	8	126	34187
Chimaltenango	5	147	17978
Chiquimula	11	422	61929
El progreso	8	208	56388
Escuintla	11	70	15978
Guatemala	10	104	43075
Huehuetenango	12	221	49463
Izabal	3	10	816
Jalapa	5	115	21116
Jutiapa	17	557	98533
Peten	10	36	7466
Quetzaltenango	5	32	5311
Quiche	20	364	45728
Retalhuleu	3	107	20812
Sacatepéquez	16	42	20724
San marcos	10	206	33059
Santa rosa	14	513	65604
Sololá	18	177	57307
Suchitepéquez	7	106	19118
Totonicapán	8	116	50823
Zacapa	6	82	17172
TOTAL	**208**	**3814**	**754,919**

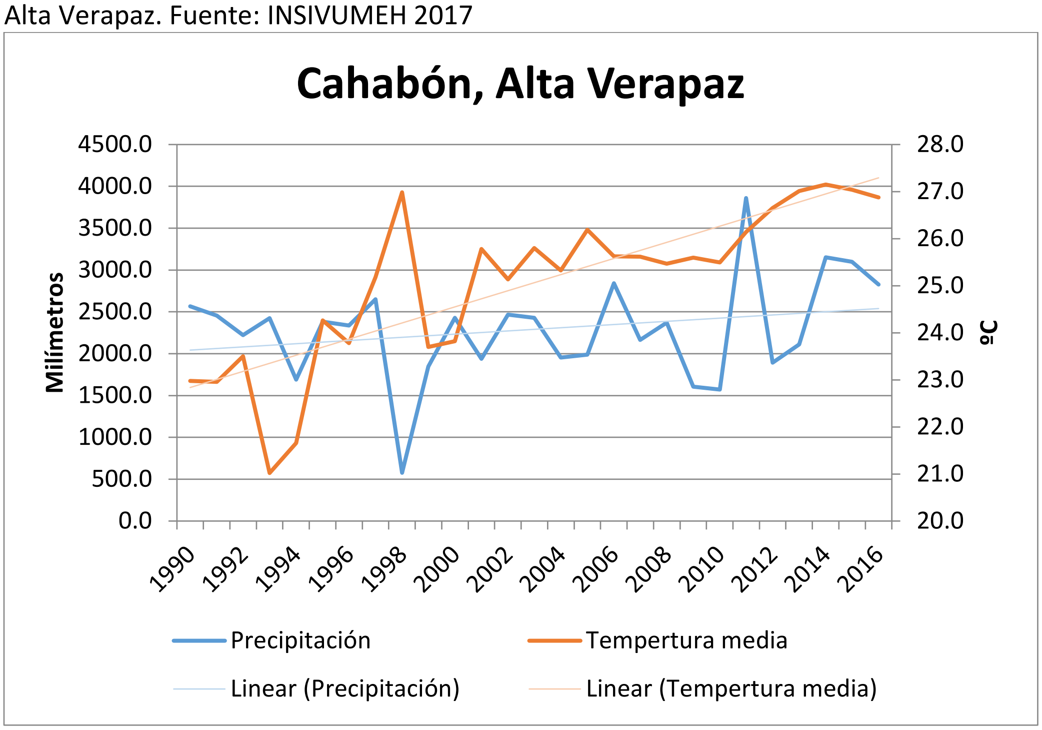
Source: SESAN 2014.

G.2.Supplementary material 2. Micro-watersheds prioritized for the implementation of RELIVE

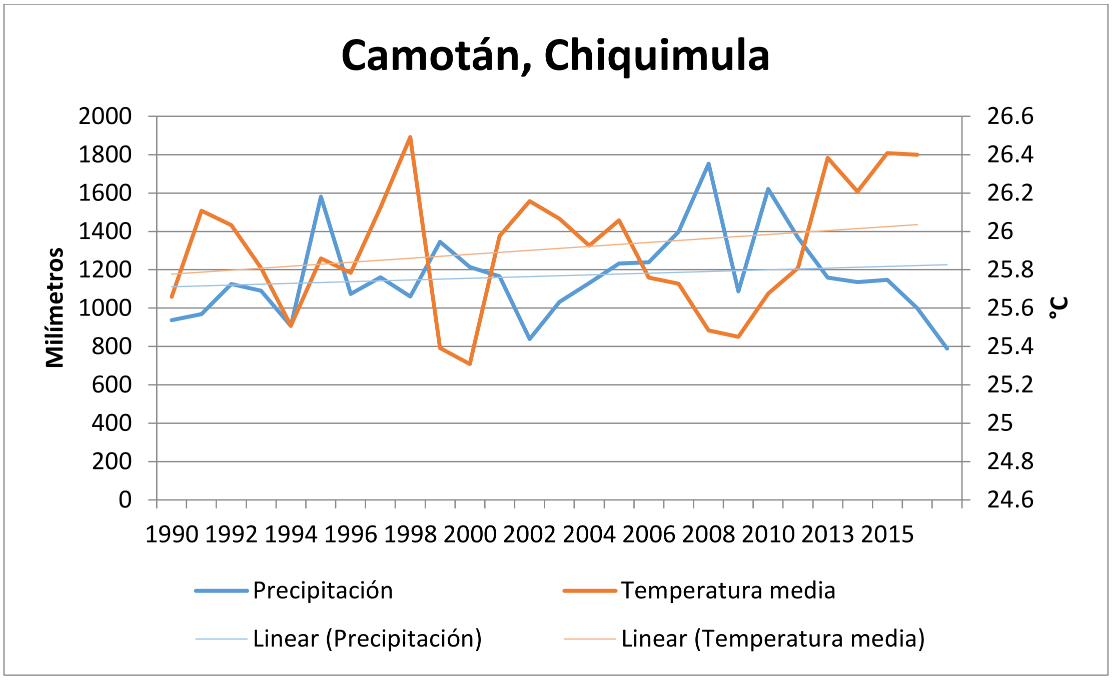
No.	Estación	Registro (años)
1	Puerto Barrios, Izabal	43
2	Camotán, Chiquimula	43
3	Asunción Mita, Jutiapa	43
4	San Jerónimo, Baja Verapaz	43
5	INSIVUMEH, Guatemala	43
6	San Martín Jilotepeque, Chimaltenango	43
7	Chuitinamit, Sacapulas, El Quiché	43
8	Nebaj, El Quiché	43
9	Huehuetenango	43
10	Camantulul, Santa Lucia Cotz., Escuintla	43
11	Quezada, Jutiapa	43
12	Cobán, Alta Verapaz	42
13	La Unión, Zacapa	42
14	La Ceibita, Monjas, Jalapa	42
15	Pasabien, Zacapa	42
16	Labor Ovalle, Quetzaltenango	42
17	Esquipulas	41
18	La Fragua, Estanzuela, Zacapa	41
19	Sabana Grande	41
20	Flores aeropuerto, Flores, Petén	40
21	Las Vegas, Livingston, Izabal	40
22	Potrero Carrillo, Jalapa	40
23	San Pedro Ayampuc, Guatemala	40
24	Suiza Contenta, San Lucas Sacatepéquez, Sacatepéquez	40
25	San Marcos	40
26	Todos Santos, Huehuetenango	40
27	San José Aeropuerto, Puerto San José, Escuintla	40
28	Santa María Cahabón, Cahabón, Alta Verapaz	39
29	Santa Cruz Balanyá, Chimaltenango	39
30	Santiago Atitlán, Sololá	39
31	Chinique	39
32	Montufar, Jutiapa	38
33	San Agustín Chixoy, Chisec, Alta Verapaz	36
34	Retalhuleu Aeropuerto	34
35	Cubulco, Alta Verapaz	33
36	Alameda ICTA, Chimaltenago	33
37	Quiché Chixoy, Chicamán, Quiché	30



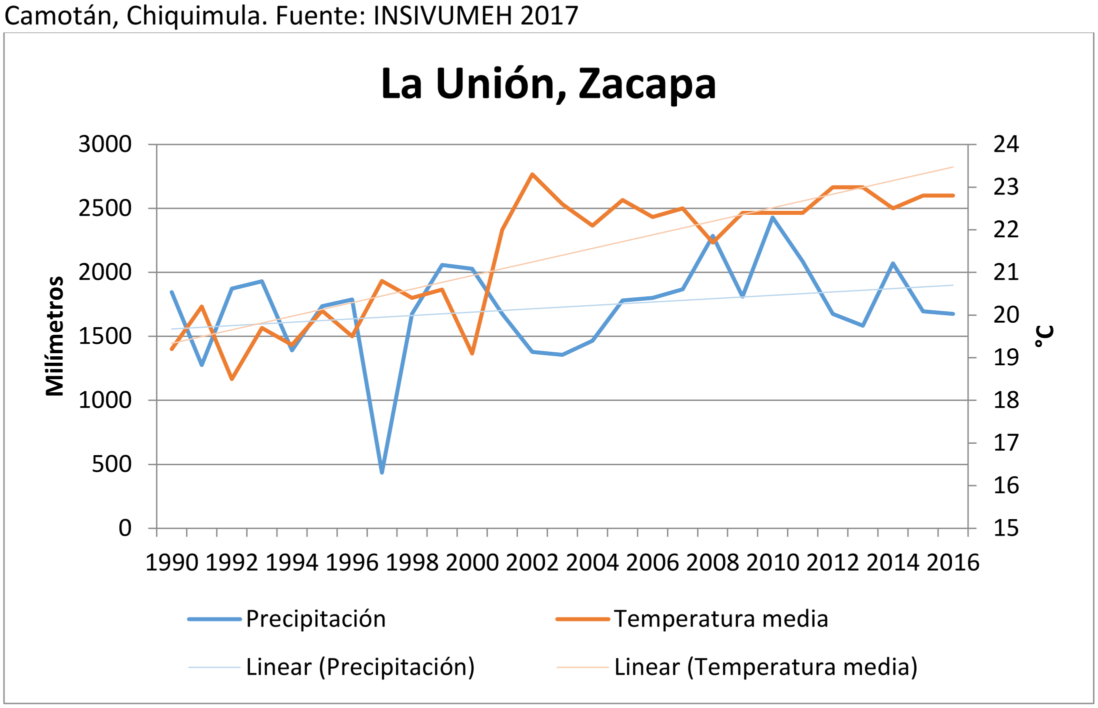
Tendencias históricas de temperatura promedio anual y precipitación promedio anual. Estación Cobán, Alta Verapaz. Fuente: INSIVUMEH 2017



Tendencias históricas de temperatura promedio anual y precipitación promedio anual. Estación Cahabón, Alta Verapaz. Fuente: INSIVUMEH 2017

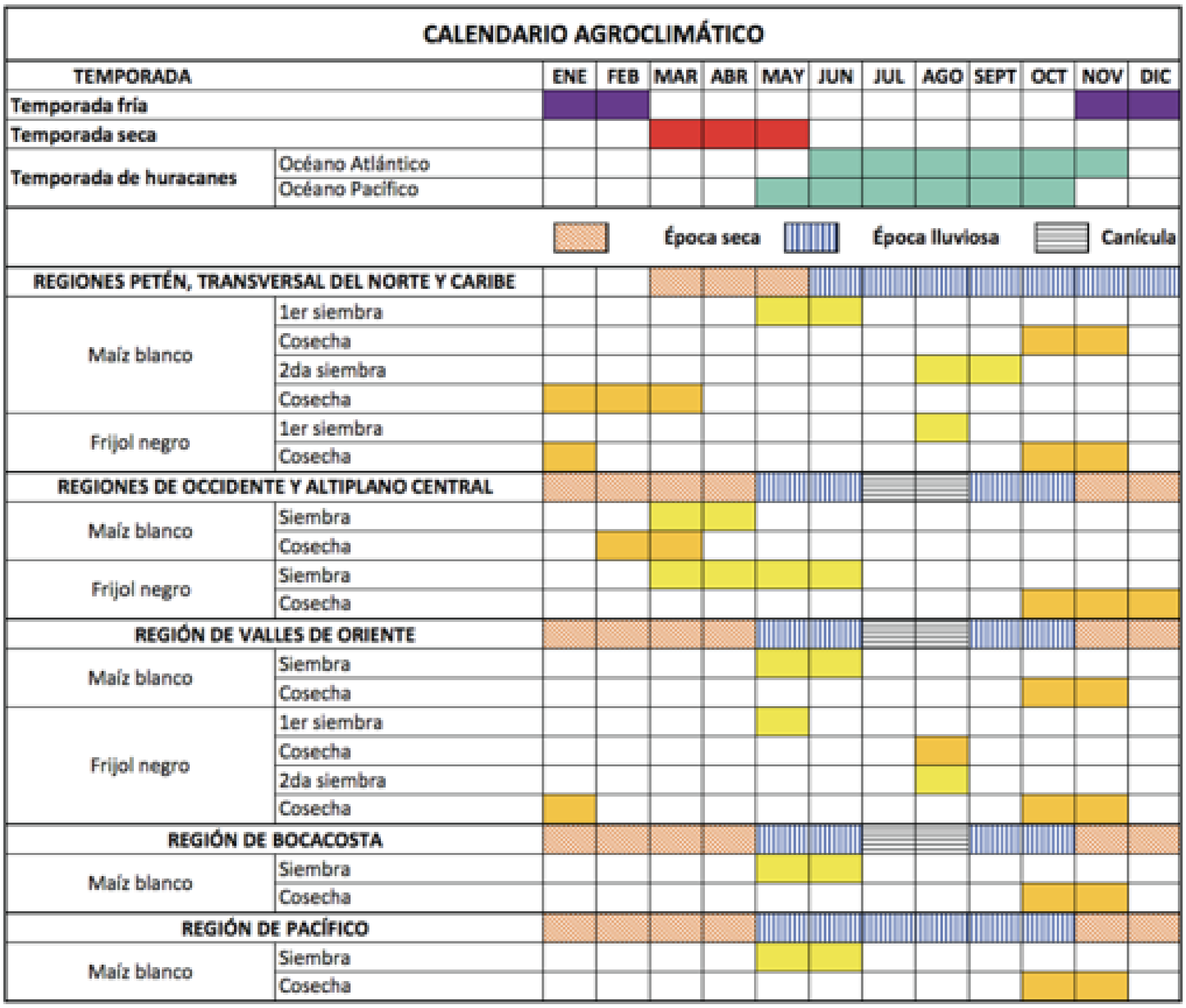


Tendencias históricas de temperatura promedio anual y precipitación promedio anual. Estación Camotán, Chiquimula. Fuente: INSIVUMEH 2017



Tendencias históricas de temperatura promedio anual y precipitación promedio anual. Estación La Unión, Zacapa. Fuente: INSIVUMEH 2017

G.1.Supplementary Material 3 Agroclimatic Calendar



Fuente: elaborado con información de INSIVUMEH, FAO, NOAA y MAGA

G.2.Supplementary Material 4 Seasonal calendars of the Four Regions of the country *

Calendario Estacional de la Región Norte del país

Mes	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Estaciones	lluviosa	seca			lluviosa			canícula	lluviosa			
Cultivo de maíz			cosecha 2a		siembra 1ra				cosecha 1a		siembra 2da	
Cultivo de frijol		cosecha 1ra			siembra 2da			cosecha 2da		siembra 1ra		
Periodo de escacez de alimentos					Periodo de escacez de alimentos							

Calendario Estacional de la Región Sur del país

Mes	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Estaciones	seca				lluviosa		canícula		lluviosa		seca	
Cultivo de maíz		cosecha 2a			siembra 1ra				siembra 2da cosecha 1a			
Cultivo de frijol					siembra			cosecha				
Periodo de escacez de alimentos					Periodo de escacez de alimentos							

Calendario Estacional de la Región Oriente del país

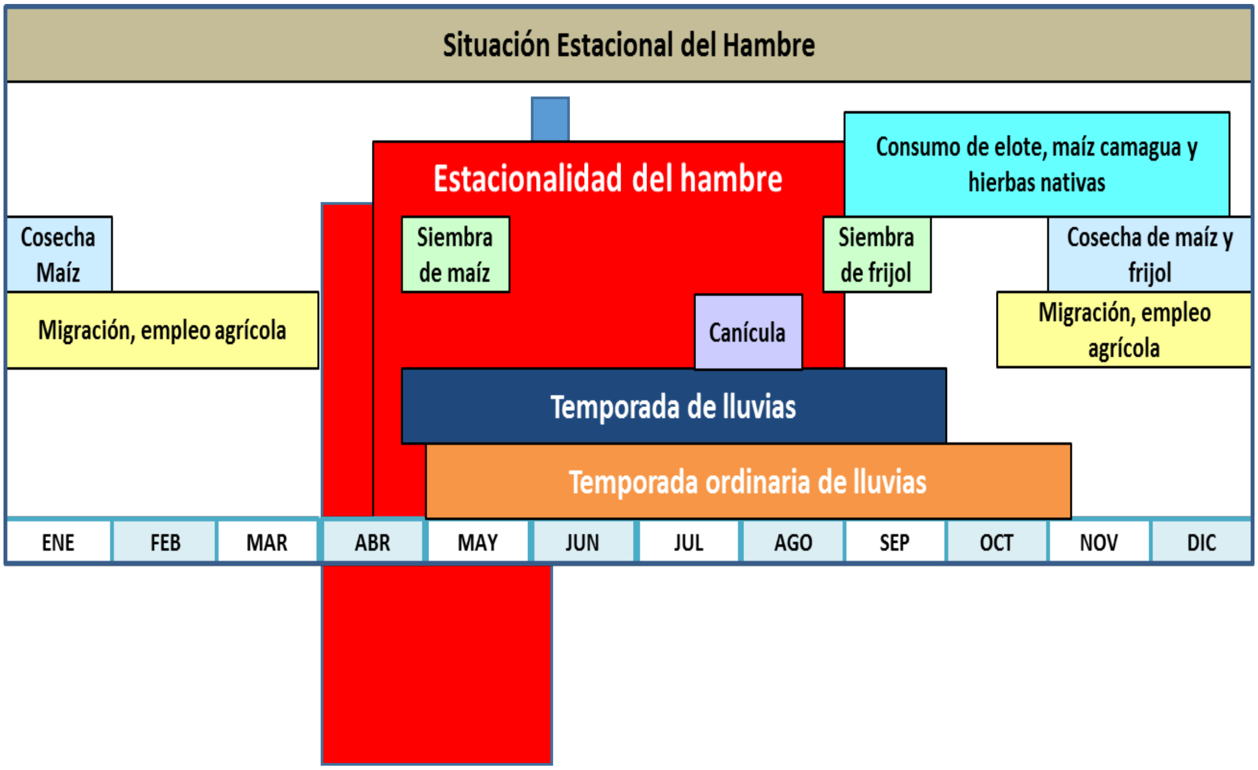
	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Estaciones	seca				lluviosa		canícula	lluviosa			seca	
Cultivo de maíz					siembra				cosecha			
Cultivo de Frijol					siembra 1ra			cosecha 1a	siembra 2da			cosecha 2a
Sorgo	cosecha					siembra						
Periodo de escacez de alimentos					Periodo de escacez de alimentos							

*= **Elaboración**: Gustavo García/FAO/2014

Calendario Estacional de la Región Occidente del país

Mes	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
Estaciones	seca				lluviosa		canícula	lluviosa			seca	
Cultivo de maíz		siembra									cosecha	
Cultivo de frijol		siembra									cosecha	
Periodo de escacez de alimentos					Periodo de escacez de alimentos							

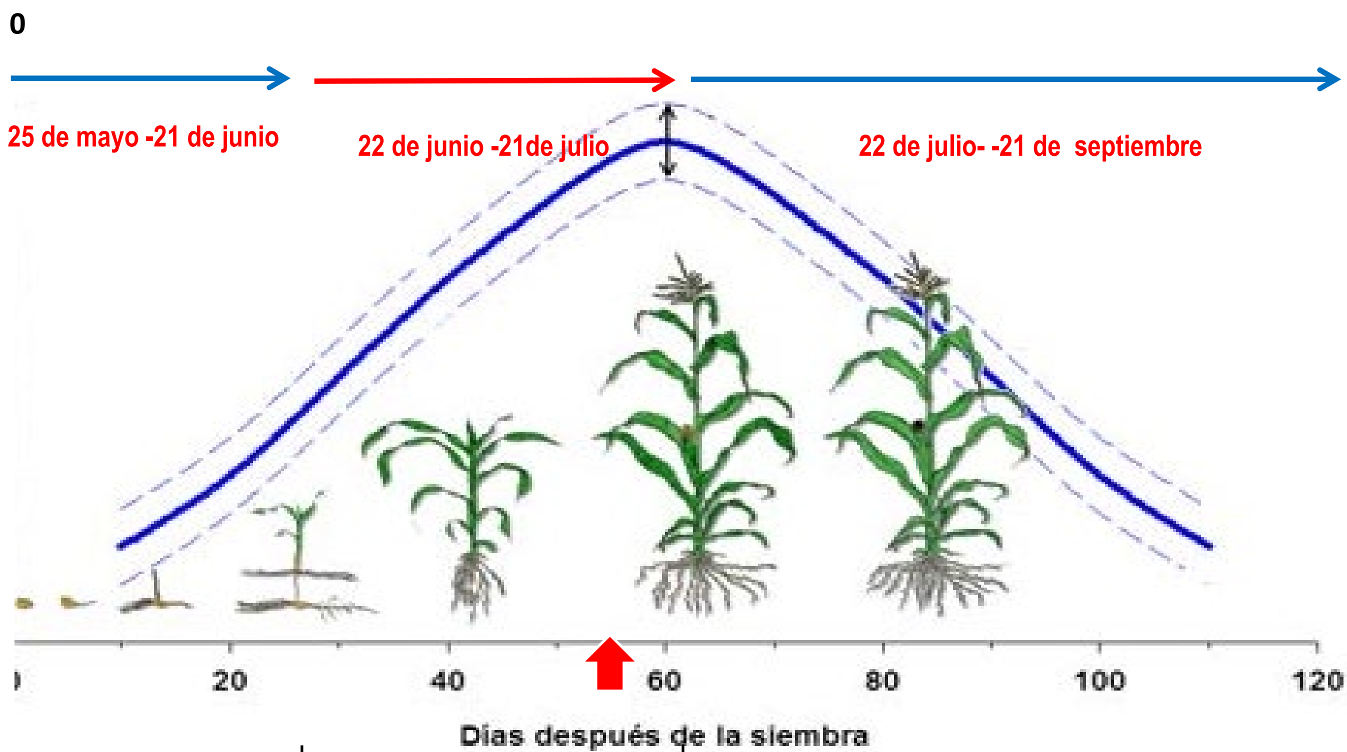
CALENDARIO ESTACIONAL DE SESAN



Fuente: Adaptado de medios de vida, FEWS NET, 2007

Requerimiento hídrico del cultivo de maíz para el área del Corredor Seco de Guatemala*

Fase en que la planta necesita más agua,
generalmente en estas fechas ocurre la canícula**



	Fase Vegetativa 0-- 28 días	Fase Pre y Floración 29 - 60 días	Fase Reproductiva 61 -120 días	
Requerimiento de agua	300 mm	200 mm	200 mm	Total de agua requerida 700 mm
% de pérdida si el cultivo no cuenta con el agua requerida	25% pérdida	50% pérdida	25% pérdida	
Lluvia año 2015	79.6 mm	26.66 mm		
			Pendiente	Total lluvia: Pendiente

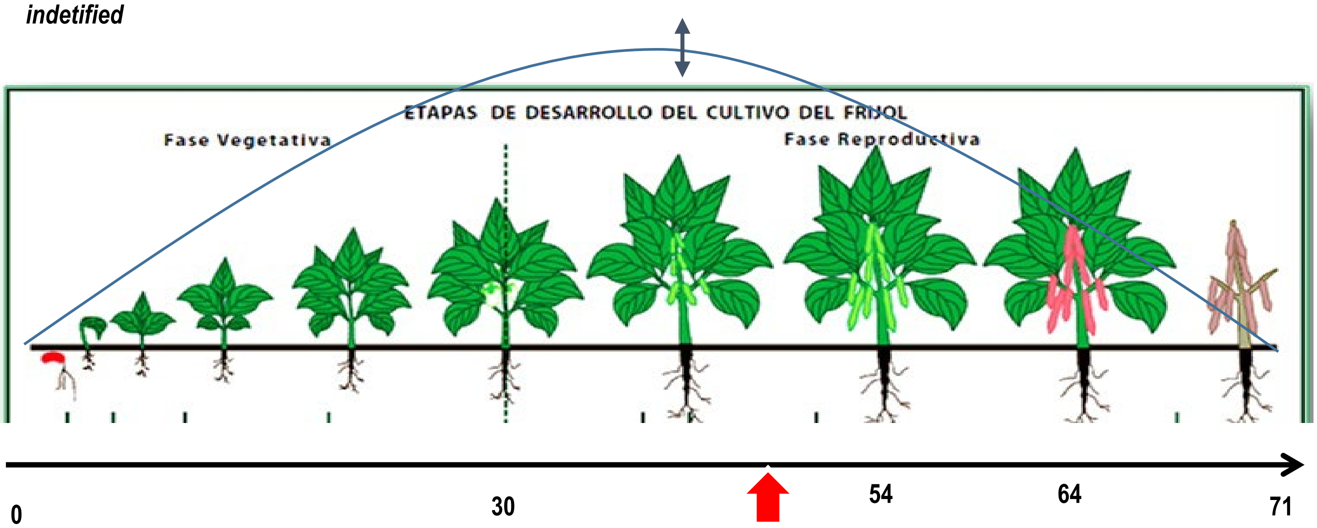
* **Elaboración**: Gustavo García/FAO/2015**,** utilizando la gráfica del Instituto de Investigación de Panamá (IDIAP) presentada en el Foro sobre adaptación del maíz y frijol al cambio climático, Proyecto SICTA del IICA/Cooperación Suiza, Nicaragua. La tabla con las fases fenológicas y requerimiento hídrico del cultivo es información del Instituto de Ciencia y Tecnología Agrícola –ICTA- y estudios de FAO. **Se utilizó como referencia el ciclo de cultivo de la variedad de maíz ICTA B7.**

****Canícula:** periodo de verano que se presenta en la época lluviosa, generalmente se da entre la primera semana de julio y la tercera semana de agosto

Requerimiento hídrico del cultivo de frijol negro para el área del Corredor Seco de Guatemala*

Fase en que la planta necesita más agua,
generalmente en estas fechas inicia la canícula**

indetified



Días después de la siembra

	25 de mayo -24 de junio	24 de junio -19 de julio	19 de julio - 5 de agosto	
	Fase Vegetativa e inicio de la floración 0--30días	Floración e inicio de la fructif. 29 - 54 días	Fructificación 55 -71 días	
Requerimiento de agua	180 mm	120 mm	100 mm	Total de agua requerida 400 mm
% de pérdida si el cultivo no cuenta con el agua requerida	20% pérdida	40% pérdida	40% pérdida	
Lluvia año 2015	79.6 mm	26.66 mm	Total lluvia	Pendiente

* **Elaboración**: Gustavo García/FAO/2015, utilizando la gráfica del Manual de manejo del cultivo de frijol en Bolivia/BOLTAGRO/Santa Cruz de la Sierra, Bolivia. La tabla con las fases fenológicas y requerimiento hídrico del cultivo es información del Instituto de Ciencia y Tecnología Agrícola –ICTA- y estudios de FAO. **Se utilizó como referencia el ciclo de cultivo de la variedad de frijol negro ICTA Ligero.**

****Canícula:** periodo de verano que se presenta en la época lluviosa, generalmente comprende el periodo entre la primera semana de julio y la segunda