Pragmatic economic valuation of adaptation risk and responses across scales in Nicaragua

Working Paper No. 210

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Abstract

Nicaragua is particularly vulnerable to climate change due to its geographic, social, economic and environmental conditions. Increased temperature, fluctuation of precipitation patterns, and sea-level rise pose significant impacts for agricultural productivity, water resources availability and the risk of extreme disaster. Consequently, some crops may lose their suitability in current growing areas. This study provides a vulnerability assessment based on the results for exposure, sensitivity and adaptive capacity, and includes present and projected future climatic conditions and hazards, crop suitability analyses and socio-economic assessments at a district scale. In addition, a case study is presented in three municipalities: Waslala, Rancho Grande and El Cuá, focusing on coffee and cocoa systems, which are essential to the Nicaraguan rural economy, where there has been a significant reduction in climate suitability. The case study shows opportunities, economic trade-offs and barriers of the adoption of climate-smart agriculture (CSA) practices for adaptation to progressive climate change.

Keywords

Adaptation to climate change; adoption opportunities and barriers; climate-smart agriculture; cost-benefit analysis; crop suitability; Nicaragua; socio-economic analysis; vulnerability assessment.

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Acronyms

ASAP	Adaptation for Smallholders Agriculture Program
CBA	cost benefit analysis
CC	climate change
CCAFS	climate change, agriculture and food security
CIAT	International Center for Tropical Agriculture
CSA	climate-smart agriculture
DAPA	decision and policy analysis
FAO	Food and Agriculture Organization of the United Nations
GCM	global circulation models
GDP	gross domestic product
GHCN	Global Historical Climatology Network
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
NICADAPTA	Adapting to Market and Climate Change project
NITLAPAN	Research and Development Institute of the Nicaragua's Central America University
RCP	Representative concentration pathways

1. Introduction

The Republic of Nicaragua is in Central America, bordered by Honduras to the North, Costa Rica to the South, the Caribbean Sea to the East and the Pacific Ocean to the West. It has an approximate surface area of 130 373.47 km^2. According to the National Population Census VIII (INIDE 2006) in 2005, Nicaragua had a population of 5 142 098.

The World Bank and CIAT's latest Nicaraguan country profile on climate-smart agriculture (CSA) highlights the importance of tackling the current and future challenges of climate change for Nicaragua's agricultural and livestock sectors. Together, these sectors represent 17 percent of gross domestic product (GDP) and 77 percent of the nation's exports, providing for 32 percent of the domestic job market. Specifically, these two sectors provide the main source of rural employment, where poverty is highly prevalent, with 50.1 percent of rural households living under the poverty line (INIDE 2016). Additionally, 20 percent of small landholding agriculturists are undernourished according to both the World Bank and CIAT studies (World Bank and CIAT 2015).

Figure 1: Map of Nicaragua

Note: The maps included in this report are not intended to represent the legal boundaries of the Republic of Nicaragua.

Given the nature of climate change, predictions indicate the possibility of far-reaching effects on the agricultural and livestock sectors. Scientific forecasting anticipates a gradual increase in the mean and extreme temperatures, ultimately reaching an increase of 2 °C by 2050, as well as a slight decrease in precipitation levels (Bouroncle et al 2014). These changes in climactic trends are expected to be accompanied by an increase in the frequency and intensity of extreme weather events such as hurricanes. On a more local scale, climate change is predicted to have a heavier impact on rural municipalities, with 78 percent losing the required climate suitability necessary for their primary crops (Bouroncle et al 2014). Additionally, the cropping calendars and agricultural habits of farmers are affected by alterations in precipitation patterns and increases in temperature, which bring about favourable conditions for the spread of pests and diseases amongst crops (Nelson et al 2009), threatening the food security of 52 percent of the rural population.

To lead change, IFAD is continuously supporting smallholder farmers through its portfolio of economic rural development projects, with a distinctive focus on poverty reduction and climate change adaptation in Nicaragua. As part of that effort, the Adaptation for Smallholder Agriculture (ASAP) program has developed the Adapting to Market and Climate Change project (NICADAPTA). This project's main aim is to support the coffee sector, which will be the most severely affected by climate change, protecting against market price volatility, and developing the potential of the cacao sector. This is a 5-year project with a total budget of USD 37 million, which is designed to benefit about 100 000 individuals.

Within this context, the International Center for Tropical Agriculture (CIAT), through its Decision and Policy Analysis (DAPA) research area has implemented a project known as "Pragmatic economic valuation of adaptation risk and responses across scales", with the objectives of: (1) assessing the vulnerability of crops spatially and economically;
(2) highlighting and prioritizing the climate-smart agricultural (CSA) practices by considering the costs and benefits of the practices and characteristics of users to better understand the opportunities for and barriers to adoption. The project was funded by IFAD/CCAFS Learning Alliance, contributing to its overall aim of enabling agricultural development policymakers and practitioners to make science-based decisions in the context of climate change, leading to greater positive impacts on target populations. The project was carried out in three countries where IFAD's ASAP implementation is most advanced: Nicaragua, Uganda and Vietnam.
This working paper presents results of the project in Nicaragua, divided into two chapters: a vulnerability assessment; and challenges, opportunities and trade-offs of CSA adoption with case studies in El Cuá, Rancho Grande, and Waslala.

Chapter 1: Vulnerability assessment

Summary

We used a geo-spatial approach to create an index of agricultural vulnerabilities, with three factors to define vulnerability: exposure, sensitivity and adaptive capacity (Fritzsche et al 2014). Together these factors provide new insights into spatial vulnerability that can support evidence-based decision-making towards more resilience to climate change and variability in Nicaragua. We chose five crops that are important for food security and national economy. We used the global circulation models (GCMs) for future conditions and WorldClim as the baseline for describing the climate. Then these data sets and crop climate parameters were applied in a species distribution model to estimate climatic suitability to grow a crop in a specific area. We also used socio-economic indicators to estimate adaptive capacity. The combination of these factors allowed us to create an index of vulnerability for each crop and to estimate an overall vulnerability score.

The results revealed four different zones with elevated levels of vulnerability:

Zone 1: Wiwili de Nueva Segovia.
Zone 2: Siuna and Bonanza.
Zone 3: Rancho Grande, Matiguas, Muy Muy and Boaco.
Zone 4: Acoyapa, Villa Sandino, El Almendro and El Castillo.

All the zones presented different impacts of climatic related risks and climate change on crops. The crops might lose suitability e.g. with coffee and beans (primera and postrera) or gain suitability e.g. with cocoa and maize. The model estimates the gain or loss in climatic suitability at the municipality level; the additional variables determining vulnerability are also processed at this scale.

I. Agricultural sector in Nicaragua

Agriculture is a key sector in the Nicaraguan economy. On average, the agricultural sector (including agriculture, forestry, and fisheries) contributes about 17 percent to the gross domestic product (GDP) (See Table 1), compared to other sectors such as trade (14 percent) and manufacturing (13 percent) (BCN 2014). The average value of agricultural exports for the period 2009–2013 was USD 1 409 million, representing 77 percent of total exports (CETREX 2014). An estimated 349 000 jobs were generated by primary production in agriculture (FAOSTAT 2015). Agricultural work, including ranching, forestry, hunting, and fishing, constituting 32 percent of the national job market and most of the rural labour efforts (World Bank 2015).

Most of the poor (approximately 65 percent) and the extreme poor (80 percent) live in Nicaragua's rural areas and their main livelihood is agriculture, based on a combination of vegetable, livestock, and poultry systems and the provision of labour to larger farmers (World Bank and IFAD 2015).

Table 1: Gross domestic product (GDP) at current prices by economic sector by year, items and economic sector. GDP calculate base 2006

Year	USD million	Structure (percent)			
		Agriculture, forestry and fishing	Industry	Service (commerce, hotels and restaurants)	Net taxes on products
2011	9,898.6	17.4	17	12.7	9.4
2012	10,645.5	16.5	16.3	12.6	9.7
2013	11,255.6	15.3	17.5	12.6	9.5

Source: Central Bank of Nicaragua (BCN 2014).

1. Crop selection for the study

The last agricultural census in Nicaragua uses the term agricultural exploitation to define the sum of surface areas of all the plots in a farm. From a total of 262 546 agricultural exploitations in the country, 181 046 of them grow at least one basic grain, of which the most common are: maize (166 567), beans (137 879) and rainfed rice (23 578). Furthermore, 104 334 agricultural exploitations grow at least one perennial crop (INIDE 2012).

The production systems that are important for Nicaragua's economy are: coffee (mainly produced by smallholders in agroforestry systems), sugarcane, cattle (meat and dairy), peanut, tobacco and banana, as they constitute the bulk of export revenues. Basic grains, such as maize, rice, sorghum and beans, which are primarily cultivated by small-scale farmers, are part of the basic diet and important for ensuring national food security (World Bank and CIAT 2015).

For the vulnerability analysis, we prioritized five crops, three from basic grains (beans, rainfed rice and maize) and two from perennial crops (coffee and cocoa). These two last crops are important for the household and the national economy, and for their contribution to the environment as they are grown in agroforestry systems.

Currently IFAD and the Government of Nicaragua are promoting these two crops as a strategy to cope with the effects of climate change in the country. The beneficiaries of the project are small farmers with less than 14 ha who grow coffee and cocoa, and families of indigenous and people of Afro-descent living in communities with current or potential participation in selected coffee and cocoa value chains. The goal is to directly engage 40 000 families.

II. Rationale and elements of vulnerability

Nicaragua is ranked as one of the ten countries that are most vulnerable to climate change and climate variability in the world (Germanwatch 2016). Progressive climate change will lead to increased temperatures and altering precipitation patterns, resulting in rising sea levels, a higher probability of floods and droughts, and more intense tropical cyclones (Coumou and Rahmstorf 2012).

A better spatial understanding of agricultural vulnerabilities, especially among poor, rural households, to climate change and variability is fundamental to building more resilient communities and farming systems in Nicaragua. This research contributes to a spatial analysis of the three factors that define vulnerability (see Figure 2) – exposure, sensitivity and adaptive capacity (Fritzsche et al 2014). Together, these features provide new insights on spatial vulnerability that can support evidence-based decision-making towards more resilience to climate change and variability in Nicaragua.

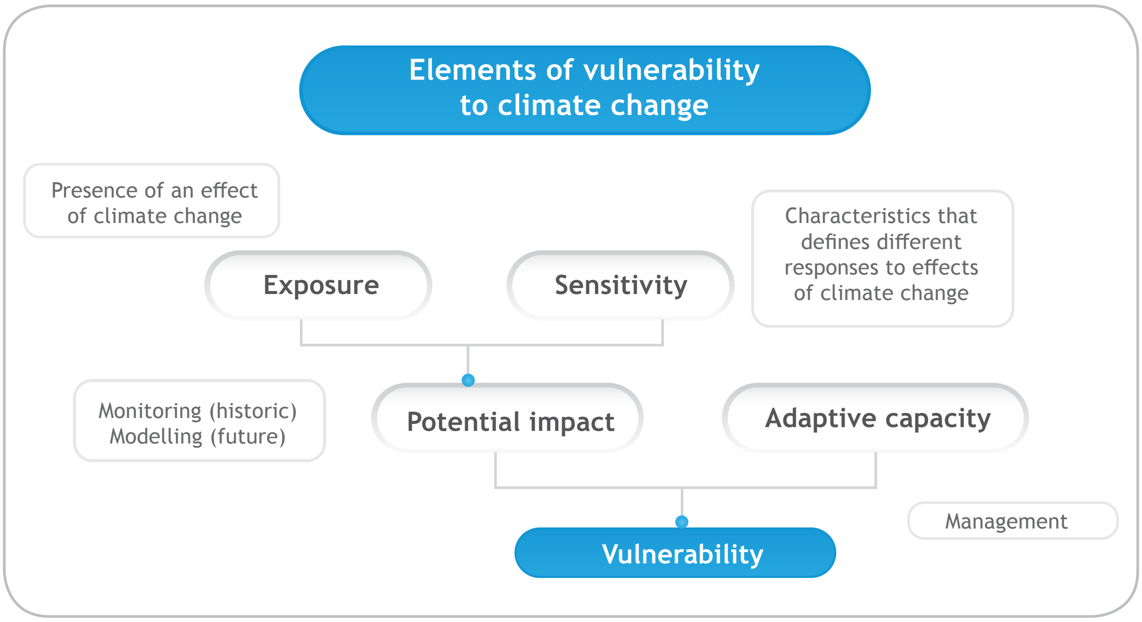


Figure 2: Framework outlining the main components of vulnerability with the necessary components required to assess impacts of climate change on agriculture and rural livelihoods

Source: Adapted from Marshal et al (2010).

The distinction between exposure, sensitivity and adaptive capacity is complex and multi-faceted. Fritzsche et al (2014) recommends that: "only those factors which are directly determined by climatic factors (such as 'water availability from precipitation') are understood as exposure. The others are 'intermediate impacts''.

However, Smit and Wandel (2006) assert that exposure and sensitivity are complexly interconnected and not fixed entities. Thus, our definitions of exposure, sensitivity and adaptive capacity are based on accepted definitions as well as on the adopted approach.

We used the combination of components of vulnerability for each of the indicators previously described. The process is shown in Figure 2 and the inputs in each component are shown in Figure 3.

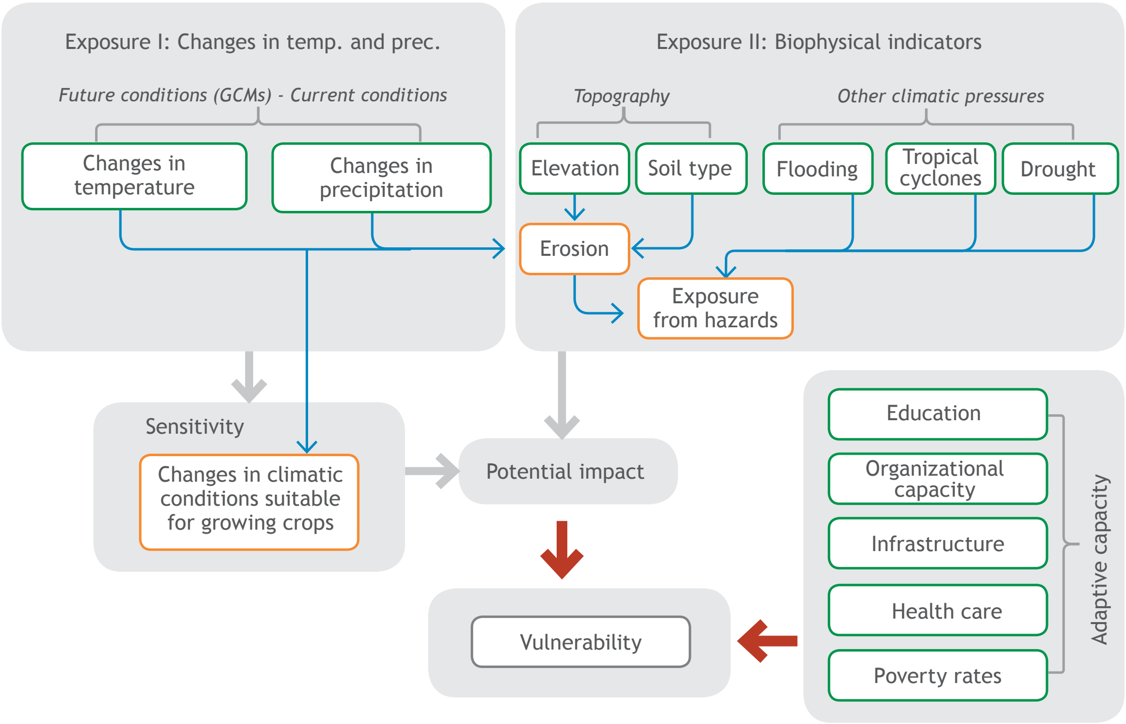


Figure 3. Indicators used to estimate the vulnerability

Source: Own elaboration based on Marshal et al (2010).

The steps in the process can be briefly described as follows:

1. Use the GCM for future conditions and WorldClim for current conditions to describe changes in temperature and precipitation.
2. Use these data sets and crop climactic parameters in crop niche distribution models to estimate climatic suitability to grow a crop in a specific area. Subtract the results for current conditions from future conditions to obtain the change.

3. Use biophysical indicators to estimate climatic related risks index.
4. Use socio-economic indicators to calculate the adaptive capacity.
5. Use the change for each crop, related risk from biophysical indicator and adaptive capacity to estimate the vulnerability of each crop.
6. Use the vulnerability for all crops, the harvested area per crop and the harvested area for all crops to estimate the overall vulnerability, described in Equation 1, for the five crops selected in this study.

$$x = \ Exposure_{\ i} + \ Sensitivity_{\ i} + Adaptive\ capacity X' = \frac{x - \min(x)}{\max(x) - \min(x)} Overall\ Vulnerability = \left(\sum_{i=1}^{5} \left(\frac{Harvested\ Area_{\ i}}{Harvested\ Area\ Total} \right) * (X'') \right) * \left(100 - \left(\left[N_{crops} \right] * 10 \right) \right) iHarvested\ Area_{\ i} Harvested\ Area\ Total X'' N_{crops}$$

1. Biophysical indicators used to assess exposure and sensitivity

1.1. Exposure

Data to estimate changes in temperature and precipitation

Current climate: the study is based on the WorldClim (Hijmans et al 2005) database. WorldClim is a high-resolution set of global climatic layers compiled from climate data measured at weather stations from various sources at global, regional, national and local levels, such as the Global Historical Climatology Network (GHCN) and FAO, with records dating from 1950 to 2000. The layers were generated by interpolating monthly averages of climatic data at a spatial resolution of 30 arc-seconds (~ 1 km^2 at the equator) using the thin-plate spline algorithm (Hutchinson 1995). The final product offers global climate surfaces for total monthly rainfall and maximum, mean and minimum monthly temperature, and is available to download from www.worldclim.org

Future climate: To anticipate future climate change, we need to project how greenhouse gases will change over the coming decades. For this the IPCC (Intergovernmental Panel on Climate Change) has developed emission scenarios to represent alternatives for what may occur in the future. These have been widely used in the analysis of climate change, its impacts and options for mitigation. In the Fifth Assessment Report (IPCC 2013) – AR5 – defined four new emission scenarios, called RCP ‘Representative Concentration Pathways’ developed to be representative of future emissions and concentration scenarios published in the existing literature. These are important developments in climate research and provide a potential foundation for further research and assessment, including emissions mitigation and impact analysis (Wayne 2013). Emission scenarios – SRES – used in the AR4 did not contemplate the effects of possible policy or international agreements aimed to mitigate emissions, representing potential socio-economic developments unrestricted emissions. By contrast, some of the new RCP can incorporate the effects of policies to limit climate change for the twenty-first century. Regarding the uncertainties associated with GCMs, the range of scenarios RCP is larger compared to the previous reporting scenarios (Knutti and Sedláček 2012).

The data is formatted in an annual time scale and we calculated three 30-year periods to represent a short-, mid- and long-term projection of climate (2040–2069 representing 2050 decadal time). The future period selected for this study is 2050s, corresponding to a horizon of medium term. The selected scenario is the RCP8.5 that is characterized by increasing greenhouse gas emissions over time. Although the new RCPs provide a different means of assessing climate change to the previous scenarios (IPCC Special Report on Emissions Scenarios 2000), the RCP 8. 5 also referred to as business as usual, represents a situation assuming high population growth, relatively low GDP growth, and modest rates of technological change and energy efficiency. This leads to significant energy demands and consequent emissions of greenhouse gases. In this scenario, no climate change policies are implemented (Riahi et al 2007). The spatial resolution of GCMs is too coarse to analyse the direct impacts on farmers' production. We therefore downscaled the outputs of each GCM based on the sum of interpolated anomalies to the 2.5 arc-minutes resolution of the monthly climate surfaces of baseline generated before. This method produced a smoothed, interpolated surface of changes in climates forecast derived from the GCMs, which was then applied to the baseline climate of WorldClim (Ramírez-Villegas and Jarvis 2010). A list of the used GCMs can be found in Annex 1. The changes in precipitation and temperature were estimated by subtracting current to future climate, using the downscaled data sets.

Other climate risks

Flooding

We used an estimate of flood frequency developed by UNEP (2009) in collaboration with the USGS, EROS Data Center and the Dartmouth Flood Observatory 2008. This is based on three sources: 1) GIS modelling using a statistical estimation of peak-flow magnitude and a hydrological model using HydroSHEDS data set and the Manning equation to estimate river stage for the calculated discharge value; 2) Observed flood from 1999 to 2007, obtained from the Dartmouth Flood Observatory (DFO); and 3) The frequency was set using the frequency from UNEP/GRID-Europe PREVIEW flood data set (UNEP 2009). The data is available at a global scale and a resolution of 0.0083 degrees or roughly 1 km^2 resolution at the equator. Categorizing the data into weekly intervals enabled the calculation of the number of weeks a year that an area is affected by flood. The data was extracted for Nicaragua and analysed at the national scale.

Tropical cyclones

The data for tropical cyclones is available from UNEP (2014) as part of the Global Risk Data platform, which includes spatial data that is downloadable for many natural hazards. Spatial data is available on the frequency of events at the global scale and at a resolution of 0.0173 degrees (roughly 2 km^2) at the equator. The data set estimates the tropical cyclone frequency of Saffir-Simpson Category 5 (UNEP 2014) from 1970 to 2009.

Aridity index

The CGIAR-CSI Global Aridity Index (Global-Aridity) and Global Potential Evapo-Transpiration (Global-PET) geo-spatial data sets were produced by Antonio Trabucco, currently at the Forest Ecology and Management Research Group, K.U. Leuven, with the support of the International Water Management Institute (IWMI), and the International Centre for Integrated Mountain Development (ICIMOD), and are provided online by the CGIAR-CSI and the International Center for Tropical Agriculture (CIAT). The Global-Aridity and Global-PET data sets are provided for non-commercial use in standard ESRI grid geospatial format, at 30 arc seconds or ~ 1 km at the equator, to support studies contributing to sustainable development, biodiversity and environmental conservation, poverty alleviation, and adaption to climate change globally, particularly in developing countries. The methods used to derive these data sets, and the data dictionary are described briefly below, and discussed further in Trabucco et al (2008), Zomer et al (2007) and Zomer et al (2008).

Aridity is usually expressed as a generalized function of precipitation, temperature and potential evapo-transpiration (PET). An Aridity Index (UNEP 1997) can be used to quantify precipitation availability over atmospheric water demand.

Global mapping of mean Aridity Index from the 1950-2000 period at 30’ spatial resolution is calculated as:

Aridity Index (AI) = MAP/MAE [2]

where:

MAP = mean annual precipitation

MAE = mean annual potential evapo-transpiration

Table 2. Values and respective classes for aridity index

Aridity index value	Climate class
< 0.03	Hyper arid
0.03 - 0.2	Arid
0.2 - 0.5	Semi-arid
0.5 - 0.65	Dry sub-humid
> 0.65	Humid

The values have been rescaled between 0 and 1 and inverted so that 1 to 0 represent a range of drought risk.

Soil erosion

We used the erosion map published by MAG (2010), which describes soil erosion caused by water. This map was generated based on a qualitative evaluation during a survey of soils. The various levels of erosion are referred to the effect on the arable layer of soil that is form by a mix of materials of A and B horizons.

1.2. Sensitivity

Sensitivity is understood as the change in the climatic suitability of an area to grow a crop. We estimated this change by subtracting the current climatic suitability from the future suitability. For current and future climate data, we used the data described in Section 1.1 and the maximum entropy (Maxent) model, a statistical niche model that incorporates crop–environment interactions through a machine-learning approach based on the current climatic conditions in cocoa growing areas (Phillips and Dudik 2008). Maxent is a general-purpose method for making predictions or inferences from incomplete information. Like logistic regression, Maxent weighs each environmental variable by a constant. The probability distribution is the sum of each weighted variable divided by a scaling constant to ensure that the probability value ranges from 0 to 1. The algorithm starts with a uniform probability distribution and iteratively alters one weight at a time to maximize the likelihood of reaching the optimum probability distribution. Maxent is generally considered to be among the most accurate models for this task (Elith and Graham 2009). This approach has previously been used to model relative climatic suitability of cocoa in West Africa (Läderach et al 2013; Schroth et al 2015) and for elsewhere for other tree crops including coffee (Schroth et al 2009; Baca et al 2014).

The idea is to estimate a target probability distribution by finding the probability distribution of maximum entropy, subject to a set of constraints that represent the incomplete information about the target distribution. The information available about the target distribution often presents itself as a set of real-valued variables, called ‘features’, and the constraints are that the expected value of each feature should match its empirical average – “average value for a set of sample points taken from the target distribution” (Phillips et al 2006). Like logistic regression, MAXENT weighs each environmental variable by a constant.

Regarding the data used as evidence points, we used the potential distribution of crop based on the zoning crops maps published by MAG (2010). Using GIS, both maps were converted to

GRID format and then into points; these points were used for training the model along with the bioclimatic variables.

Within the WorldClim database (Hijmans et al 2005), there are bioclimatic variables derived from monthly temperature and rainfall values to generate more biologically meaningful variables, which are often used in ecological niche modelling (e.g. BIOCLIM, GARP). The bioclimatic variables represent annual trends (e.g. mean annual temperature, annual precipitation), seasonality (e.g. annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g. temperature of the coldest and warmest month, and precipitation of the wettest and driest quarters).

The derived bio-climatic variables are:

Bio1 = Annual mean temperature
Bio2 = Mean diurnal range (Mean of monthly (max temp - min temp))
Bio3 = Isothermality (Bio2/Bio7) (* 100)
Bio4 = Temperature seasonality (standard deviation *100)
Bio5 = Maximum temperature of warmest month
Bio6 = Minimum temperature of coldest month
Bio7 = Temperature annual range (Bio5–Bi06)
Bio8 = Mean temperature of wettest quarter
Bio9 = Mean temperature of driest quarter
Bio10 = Mean temperature of warmest quarter
Bio11 = Mean temperature of coldest quarter
Bio12 = Annual precipitation
Bio13 = Precipitation of wettest month
Bio14 = Precipitation of driest month
Bio15 = Precipitation seasonality (coefficient of variation)
Bio16 = Precipitation of wettest quarter
Bio17 = Precipitation of driest quarter
Bio18 = Precipitation of warmest quarter
Bio19 = Precipitation of coldest quarter

Based on the results from the models for future changes in the climatic suitability, we used an index to group and include the positive and negative impacts (See Table 5) on final vulnerability.

Table 3: Description, changes in percentage and the sensitivity index used as one of the factors to estimate vulnerability

	Changes (percent)	Sensitivity Index
Negative	-50 to -100	1
	-25 to -49	0.5
	-5 to -24	0.25
No change - no crop presence (5 selected crops)	-5 to 5	0
Positive	5 to 24	-0.25
	26 to 49	-0.5
	50 to 100	-1

To assess the potential impacts of current and future climatic related risks for each crop, we used a combination of change in climatic suitability to grow crops (sensitivity) and biophysical indicators.

2. Socio-economic indicators to assess adaptive capacity

To estimate adaptive capacity, we used the data generated by Bouroncle et al (2017). In this study, the adaptive capacity was mapped as a function of three conditions: satisfaction of basic needs, resources for innovation and resources for transforming innovation into actions. A series of indicators was compiled (see Table 4), which were constrained by availability of information. Then indicators were normalized with values linearly to a 0–1 interval based on their minimum and maximum values in each municipality to avoid biases due to wide variations of socio-economic development (Alfaro et al 2015).

Table 4. List of criteria with weights and indicators used

Adaptive capacity condition	Criteria (weight)	Indicator
Satisfaction of basic needs	Safe drinking water (0.33)	Rural households with access to safe drinking water
	Public health (0.27)	Primary health care units per 1 000 people
	Education (0.20)	Rural school-age population (aged 7-17) that attends school
	Housing (0.13)	Rural dwellings built with long-lasting materials
	Equity (0.07)	Rural Gender Parity Index
Resources for innovation	Land (0.50)	Entitled agricultural production units
	Technical assistance (0.33)	Agricultural production units that received technical assistance
	Infrastructure (0.17)	Road density
Resources for action	Financial resources (0.66)	Rural economically active population employed in non-agricultural activities
		Agricultural production units that received a loan
	Labour force (0.34)	Rural demographic dependency ratio

Source: Bouroncle et al (2017).

III. Results

Climatic suitability of crop-growing areas

Maps have been created, one for each of the respective crops (Figure 4), that reveal on the left the current suitability, with their counterparts on the right indicating suitability changes. Crops with increasing suitability are shown in green and those losing suitability in red. The colour beige indicates areas that are expected to remain close to current conditions.

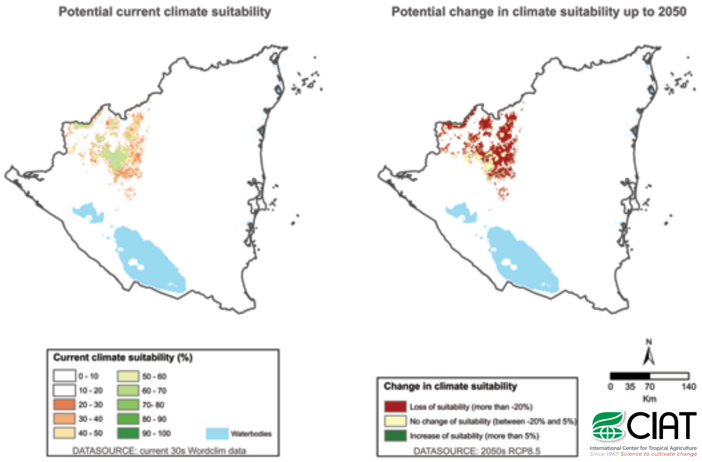
According to the model, based on changes in temperature and precipitation (Annex 3) and evidence points, we estimated the change in climatic suitability of each crop. These results show that there are different impacts across crops and regions (see Figure 5). Coffee (a) might lose suitability in current areas due to an increase in the minimum temperature in the coldest month and in the annual mean temperature. Meanwhile cocoa (b) might gain suitability in the Central and Caribbean areas as these areas become hotter and remain humid enough for the crop. Beans in primera and postrera cycles (c) might lose suitability mostly because of the increase in temperature and reduction in total annual precipitation, while some highlands in the centre and North of the country might remain suitable. For beans in apante cycle (d), as the variation in monthly total precipitation increases for the Central and Northern regions, the suitable areas shift to the Caribbean region. Rain-fed rice (e) might lose suitability in most of the current growing areas due to an increase in the temperature annual range and a decrease in the total annual precipitation. Although some areas in Jalapa Valley and the North-eastern municipalities in RAAN are suitable or become more suitable. In the case of maize (f), the areas in the Pacific region might lose suitability to grow this crop, but most other areas in the country stay at the same level of suitability.

Adaptive capacity

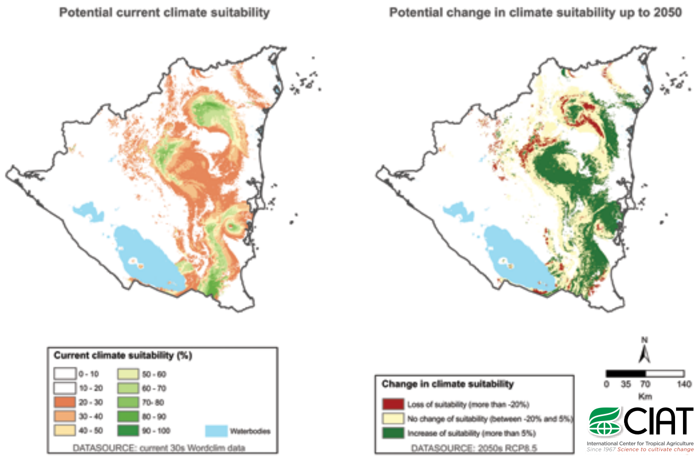
The result of using the socio-economic indicators to assess the adaptive capacity index (Bouroncle et al 2017) is shown in Figure 5. Here we map the four most important variables (See Annex 4) to define this index.

Based on the data collected, most agricultural services are found in the Pacific and North regions of the country. The Central and Caribbean regions have less access to these services. The municipality with the lowest adaptive capacity San Juan del Norte – is therefore the most remote. According to the index, most of the municipalities of RAAN, RAAS, Matagalpa, Jinotega, Boaco, Chontales and Rio San Juan have a low adaptive capacity.

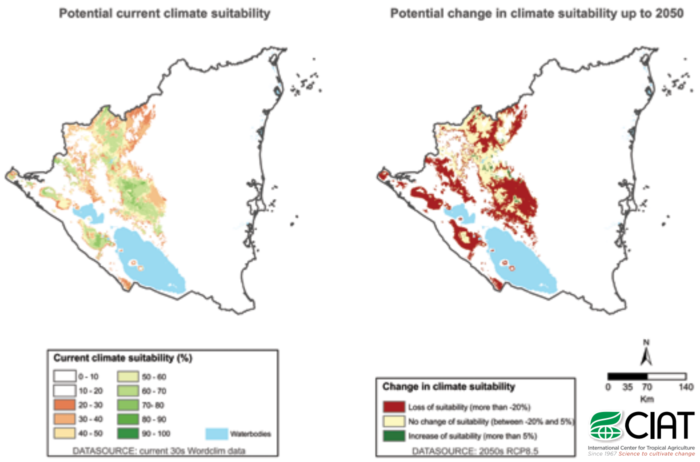
a Climate sensitive for coffee



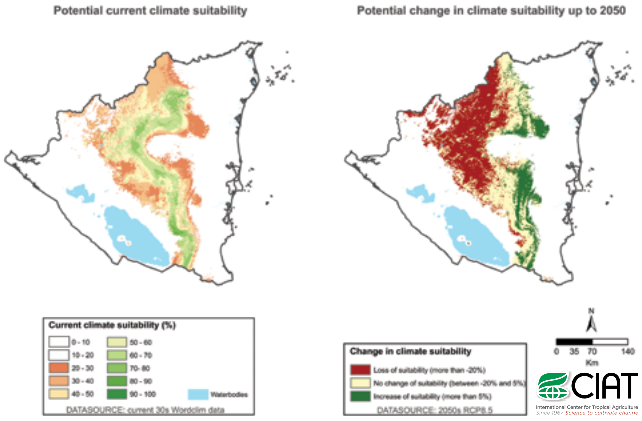
b Climate sensitive for cocoa



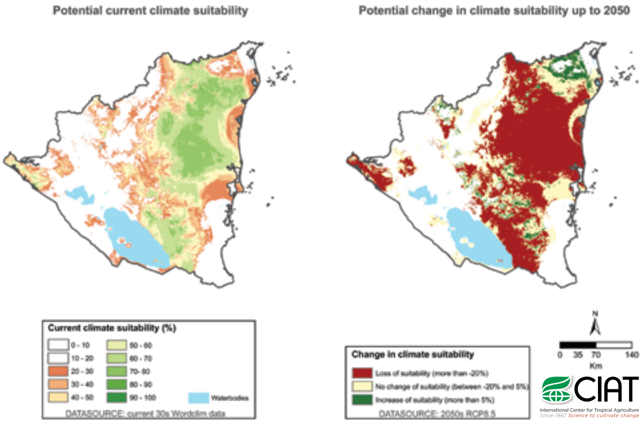
c Climate sensitive for bean postrera



d Climate sensitive for bean apante



e Climate sensitive for rice



f Climate sensitive for maize

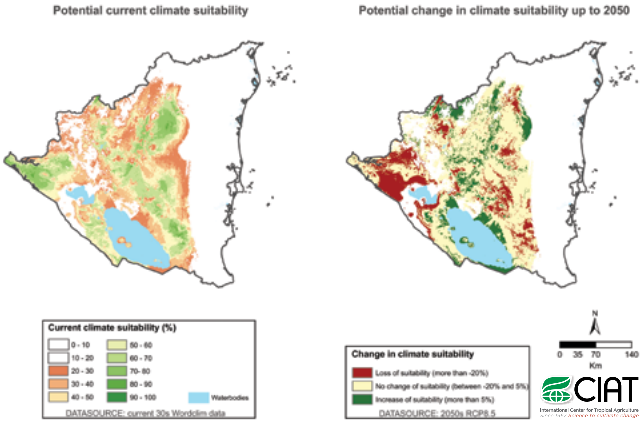


Figure 4: Results for each crop at current (left) and potential change in climate suitability by 2050s conditions (right), considering the impact of temperature and precipitation only

Source: Global Carbon Project (2016).

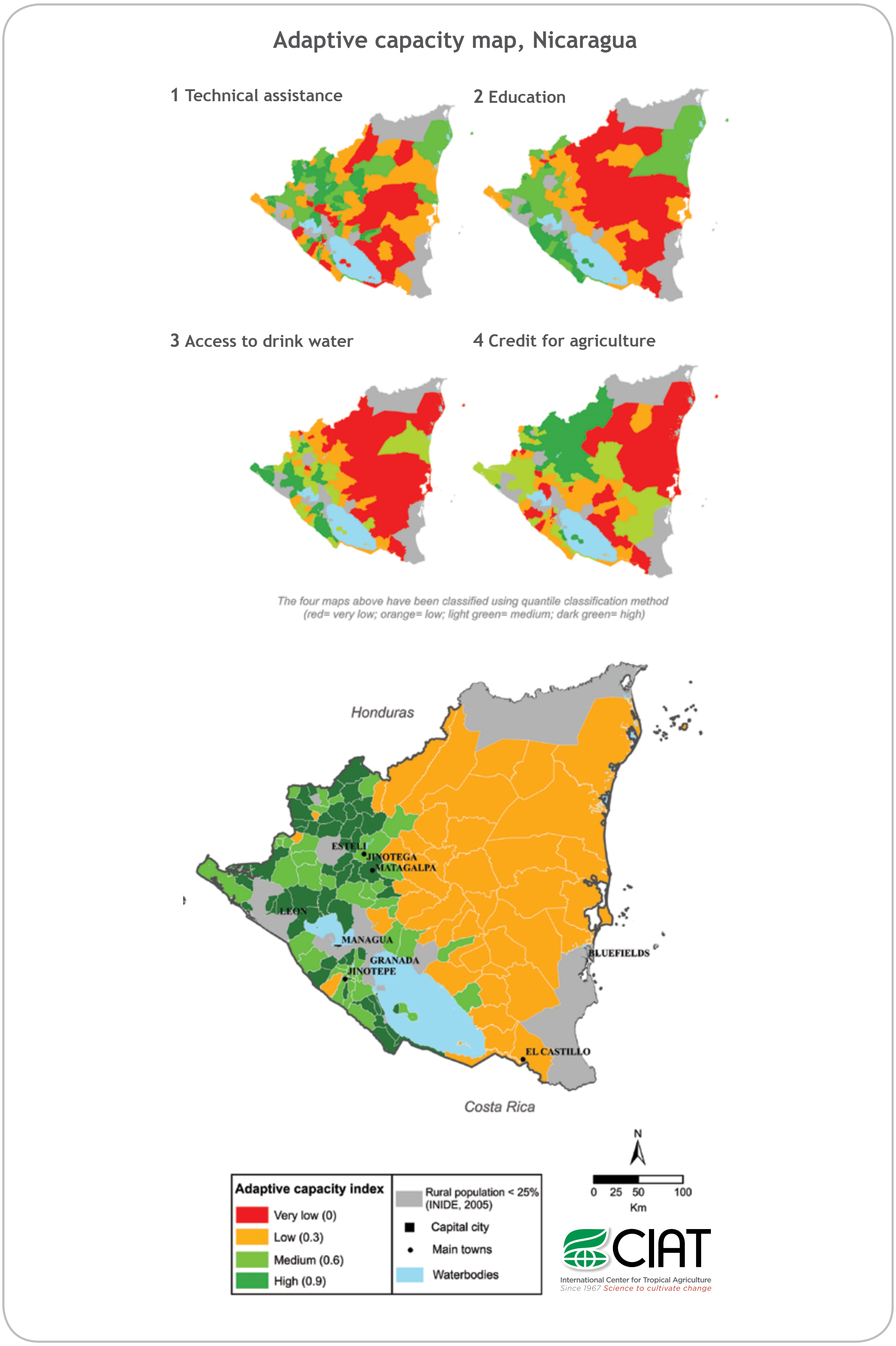


Figure 5. Adaptive capacity based on selected socio-economic indicators

Source: Own elaboration.

Overall vulnerability scores for crop production

Using the results from biophysical indicators to estimate soil erosion and other impacts (see Annex 5), and the results from adaptive capacity combined with the results for changes in suitability, we estimated the vulnerability for each crop. This gave us five different classes of vulnerability when we considered the impacts of climate change, climate related risks and adaptive capacity (see Figure 6).

Based on the methodology proposed and the crops selected, the final overall index showed us a total of 12 municipalities that had high vulnerability to climate change. These 12 municipalities were classed as having low adaptive capacity, but certain impacts can allow them to be ranked as the most vulnerable in the country.

Zone 1. Wiwili de Nueva Segovia: exposed to drought and flooding and might lose suitability for beans (primera and postrera cycles) and coffee but might gain suitability for maize.

Zone 2. Siuna and Bonanza: exposed to tropical cyclones, might lose suitability for rice, but gain suitability for beans (apante) and cocoa.

Zone 3. Rancho Grande, Matiguas, Muy Muy and Boaco: some areas were affected by drought, soil erosion and floods. These areas might lose suitability for growing beans in primera, postrera and apante cycles. Matiguás and Rancho Grande might lose suitability for growing coffee. Some areas might gain suitability for growing maize.

Zone 4. Acoyapa, Villa Sandino, El Almendro and El Castillo: some areas were often affected by tropical cyclones and floods. For El Almendro, the suitability for bean (apante) growing areas generally remained the same. There might be an increase in suitability for growing cocoa in Villa Sandino and El Castillo. There might be an increase of climatic suitability for growing maize in Acoyapa.

Limitations of the study

Other significant crops related to key agricultural systems in Nicaragua were not included in the study because of an absence of data for those crops. Despite this, the methodology was open to include new crops or new socio-economic data for adaptive capacity so that the vulnerability for those crops or systems could be estimated.

This study included current natural risks and climate change. It didn’t include climate variability. MaxEnt model used climatic variables only and did not include soil variables.

This study considered the major biophysical exposure variables – flooding, tropical cyclones, soil erosion and aridity index – as a proxy for drought.

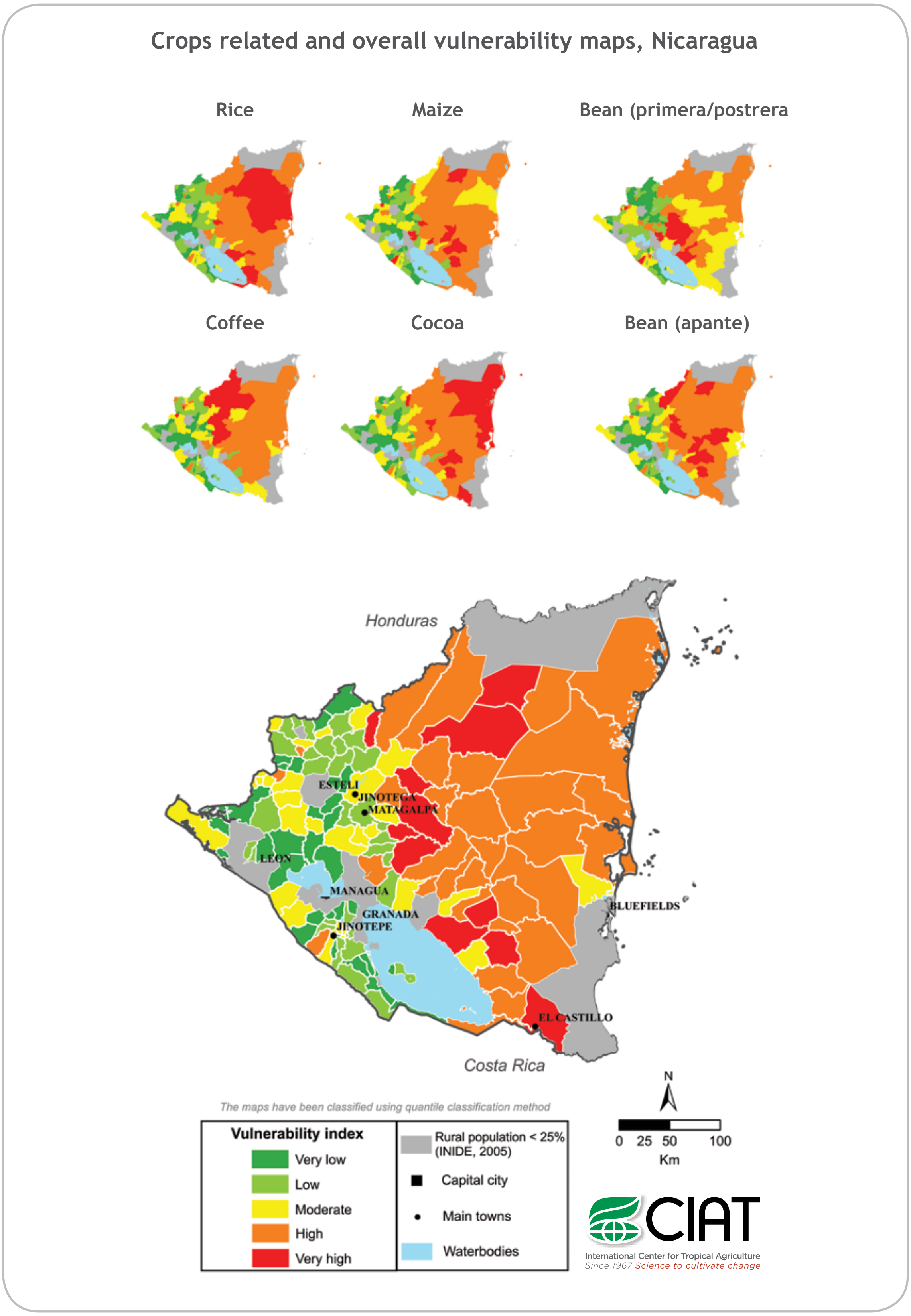


Figure 6. Overall vulnerability score for the six selected crops (top) and the overall vulnerability (bottom) for the agricultural system (combined vulnerability of the six crops)

Source: Own elaboration.

IV. Conclusions

1. According to the socio-economic indicators used in this study, which were based on the availability of data, most of Nicaragua's municipalities demonstrated low adaptive capacity. Most of these were in the Central and Caribbean regions.
2. **Zone 1.** Wiwili de Nueva Segovia: as these areas were exposed to both drought and flooding, CSA practices and technologies on water harvesting and drainage should be promoted in this zone. Along with these practices, improved bean varieties that resist heat should be used, and coffee farms should be diversified into coffee–fruits–Musaceaes–wood systems.
3. **Zone 2.** Siuna and Bonanza: exposure to tropical cyclones might result in a loss of suitability for growing rice, but a gain in suitability for growing beans (apante) and cocoa. Techniques for the sustainable use of water for rain-fed rice should be promoted in this zone, as well as agro-forestry systems, such as Quesungual, for beans–maize–trees (fruits–wood).
4. **Zone 3.** Rancho Grande, Matiguas, Muy Muy and Boaco: Soil conservation and water harvesting, and drainage practices should be encouraged in this zone in order to cope with drought soil erosion and flooding. Most of these areas are already diversifying their coffee farms into coffee–cocoa systems, or are testing new plots for cocoa. This is also an important zone for commercial production of red beans, so we should focus on securing production in the first two cycles using improved varieties, climatic information and technical assistance.
5. **Zone 4.** Acoyapa, Villa Sandino, El Almendro and El Castillo: Most of these areas need to support practices related to drainage and soil management. A predicted increase in the suitability for growing cocoa in Villa Sandino and El Castillo strengthens the decision of several initiatives to support this crop, including NGOs, and the public and private sectors. A silvo-pastoral system is recommended for Acoyapa as the main activity is livestock and an increase in maize is predicted. More analysis is required for livestock system vulnerability to climate change.

Chapter 2: Potential benefits and barriers to the adoption of climate-smart agricultural practices in coffee and cacao production

A case study in Rancho Grande, El Cuá and Waslala

I. Introduction

One of the primary crops of interest is coffee, which is the backbone of the Nicaraguan rural economy and accounts for more than 20 percent of the country's total exports (World Bank and CIAT 2015). According to a study by Läderach et al (2012b) on the potential impacts of climate change on coffee production zones in Nicaragua, these areas will experience a significant reduction in climate suitability. Currently, the optimal altitude for coffee production in Nicaragua is between 700–1500 metres above sea level (MASL) with climate suitability of between 40 and 70 percent. However, there are times when coffee is cultivated below the optimal altitude of 700 MASL. By 2050, it is expected that the optimal altitude will climb to 1000–1600 MASL with climate suitability reduced to between 30 and 60 percent. The current area of coffee being cultivated under 700 MASL is expected to become devoid of climate suitability (see Figure 7).

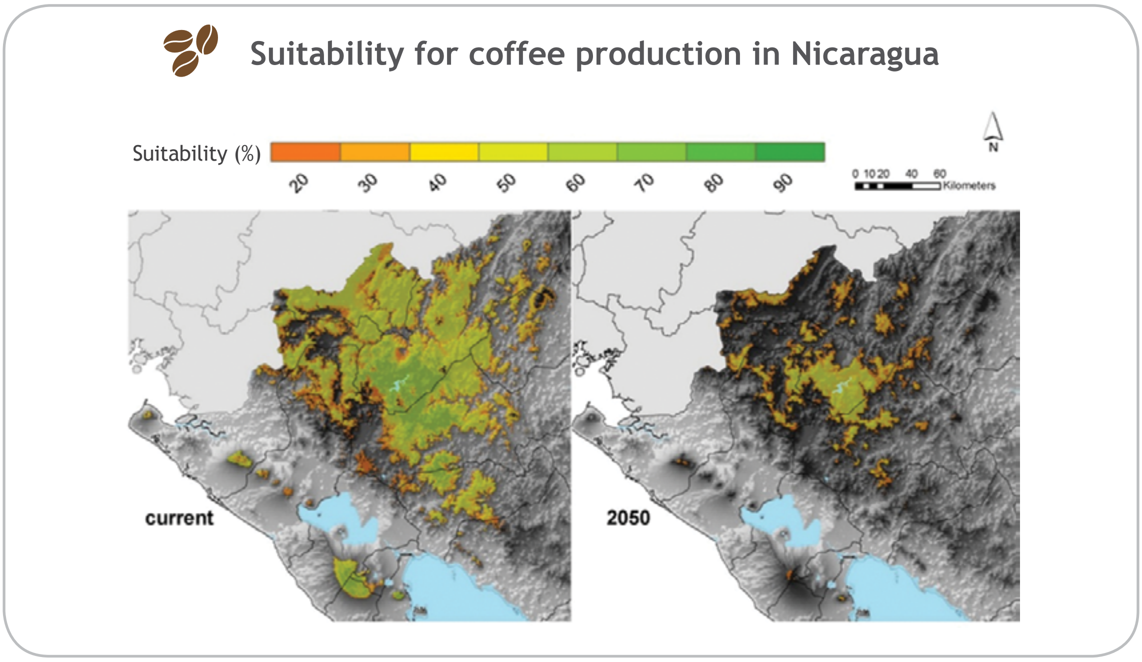

Suitability for coffee production in Nicaragua

Figure 7. Suitability for coffee production in Nicaragua (now vs. 2050)

Source: Zelaya 2015.

Given the relatively high importance of coffee production at low altitudes and the limited land availability at higher altitudes, we need to work towards developing a climate change adaptation pathway. A comprehensive approach, such as the CSA practices, is recommended to mitigate the effects of climate change impacts in areas where coffee will still have climate suitability (Läderach et al 2012a; Vermeulen et al 2013).

Although not presently a primary crop, cacao can have significant effects on current production systems (MASRENACE 2010). Its climate suitability makes it a viable option for replacing coffee in areas where present-day coffee production will no longer be feasible in the coming years (Läderach et al 2012c). Although climate change should not reduce cocoa's climate suitability, it would still require adaptation measures, such as CSA practices, to mitigate abiotic factors such as temperature increases.

Given the necessity to tackle climate change impacts at a local level, it is important to utilize an evidenced-based decision-making process for developing climate change adaptation strategies. Although there is already convincing evidence of the mitigating effects of CSA practices on coffee and cacao, there is limited data on farmers' adoption patterns, specifically about perceived trade-offs (Läderach et al 2012a; Schroth et al 2016). Therefore, considering the complexity of assessing and selecting CSA practices to address locally uncertain climate change impacts, this study has developed and tested a set of methodologies and tools for CSA prioritization and evaluation. It focuses on three municipalities with elevated levels of agricultural vulnerability to climate change as explained in Figure 8 below. Also, this study is part of a climate change research collaboration between Nicaragua, Uganda and Vietnam.

In a complementary effort to NICADAPTA, this is a cacao- and coffee-based case study that provides a CSA practice prioritization and cost-benefit, trade-off analysis. This study also aims to provide some introductory data on adoption potential and the impacts of scaling-up within a specified target population. To meet these goals, the methodological logic of the project has been developed using two important tools: the CSA practices prioritization process developed by Mwongera et al (2015) and a cost benefit analysis (CBA) program for tropical agriculture.

This study is a collaboration between the International Centre for Tropical Agriculture and the Research and Development Institute (NITLAPAN) of the Nicaragua's Central American University. Its aim is to understand the CSA practices, preferences and priorities and the challenges faced for their adoption, for cacao and coffee farmers.

The specific objectives are:

- Characterizing coffee and cacao farmers' climate change local context and household and farming factors of CSA practice adoption
- Identifying and describing prioritized coffee and cacao farmers' CSA practices
- Assessing the coffee and cacao farmers' potential benefits and barriers to adoption of CSA practices.

The first section of this working paper will present the methodological component of this study, including a site description and the data and analysis methodological activities. The second section will present results, starting with the target population, contextual and household descriptive and inferential analysis. It will then be supported with the CBA results for CSA practices and the prioritization of CSA practices. Finally, a discussion section will contrast the CSA and CBA results with the prioritization of local famers.

II. Methodology

1. Study sites

The study sites are located in three Nicaraguan municipalities: Waslala for cacao, and Rancho Grande and El Cuá for coffee. These municipalities were selected because of their elevated level of climate change vulnerability predicted in an ongoing parallel study (Bouroncle et al 2017) on climate change agricultural vulnerability in Nicaragua (see Figure 8). For coffee, the chosen municipalities also provided topographic variance, which will allow for the utilization of several CSA practices by altitude levels.

These sites provide valuable examples of municipalities where more than 80 percent of the population was dedicated to agriculture and for which coffee and cacao were two of the three most widely cultivated crops (Bouroncle et al 2014).

2. Overall approach

The overall methodological approach of this study was based on a mix methods strategy aimed at the collection of qualitative and quantitative data. This allowed for a comprehensive assessment of potential benefits and barriers to adopting CSA practices in coffee and cacao.

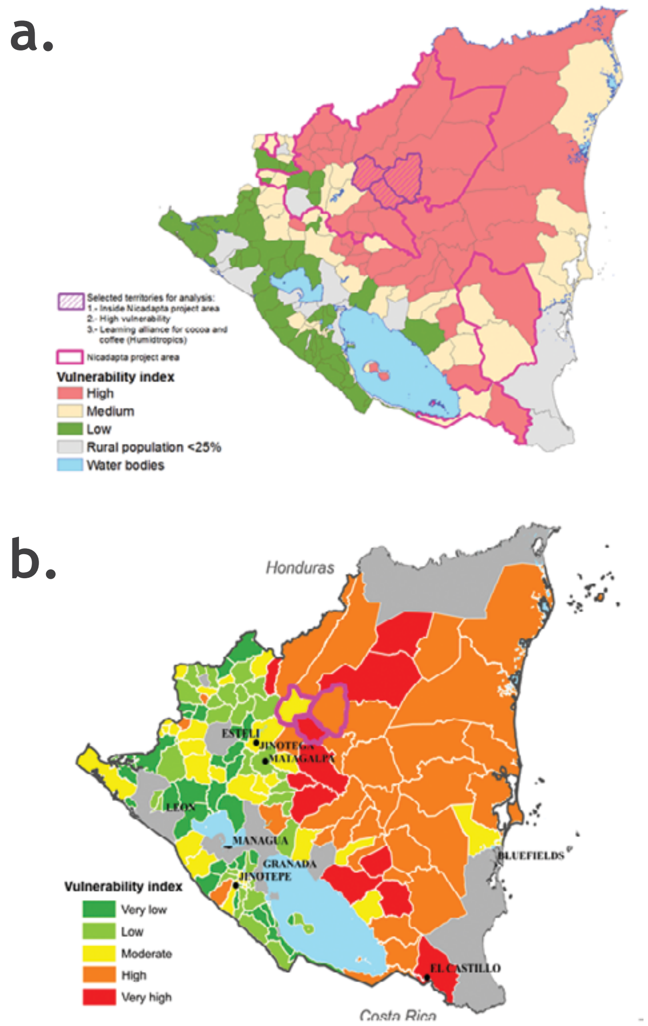


Figure 8: Agricultural vulnerability to climate change map of Nicaragua with selected territories for analysis

a) Results from Bouroncle et al (2017) and b) from this analysis including impact of climate change on cocoa and natural hazards.

The methodological process commenced with workshops focusing on coffee and cocoa producers in the previously identified Nicaraguan municipalities. Based on the results of these workshops, surveys were developed and conducted in different sites to gather case-specific information on the adoption of CSA practices in different climate change contexts. The process was concluded with an experts' workshop where the experts provided additional analysis of the data collected in the initial workshop, and gave expert opinions on CSA practices and their applicability in Nicaragua. In a parallel process, a CBA was performed through data collection and analysis of primary and secondary information on the costs and benefits of some of the CSA practices.

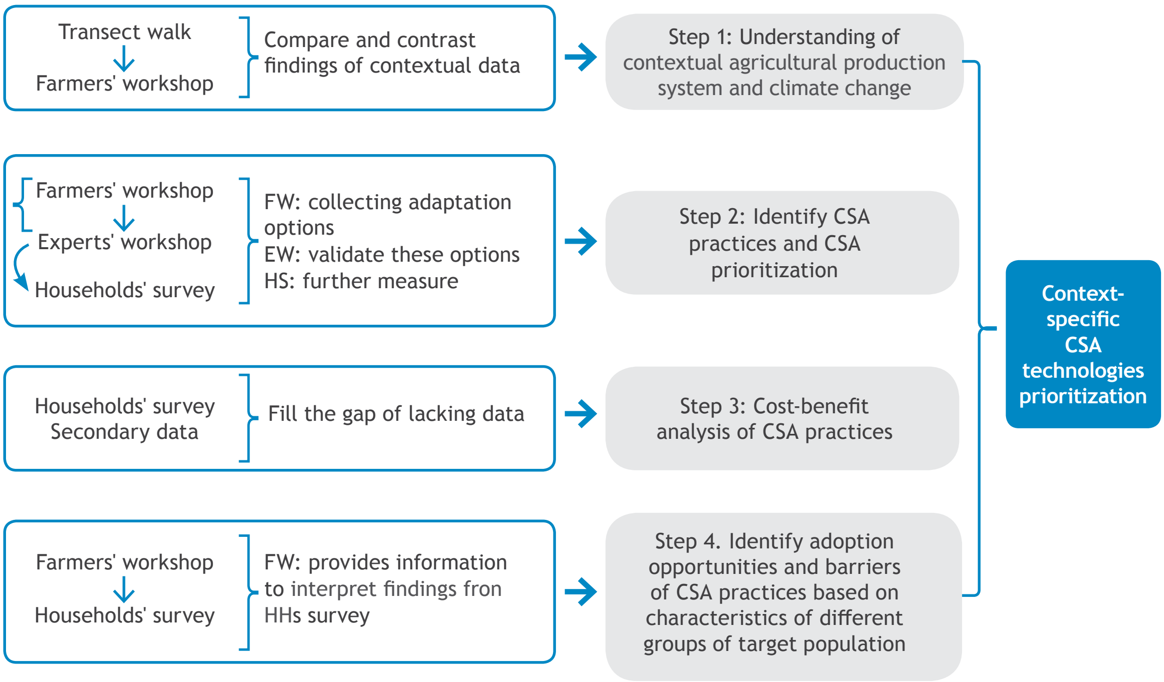


Figure 9. Methodological approach

Source: Own elaboration (2016).

This methodological process is based on the rapid assessment of CSA work developed by Mwongera et al (2015). It was adapted to conform to the joint parallel effort of a similar study in Vietnam.

Principally, a bottom-up approach was taken based on the assumption that coffee and cacao farmers are currently facing climate change and they are already undertaking climate change adaptation measures using a certain level of CSA knowledge. Under that assumption, the methodology was focused on gathering knowledge and perceptions of climate change from coffee and cacao farmers in their specific local climate change context.

There is an obvious bias towards farmers with a lack of knowledge about CSA practices that are not currently or have not previously been used. However, this bias is compensated to some extent through triangulation (i.e. expert consultations and secondary information). This bottom-up approach contributes to existing knowledge gaps for CSA practices that have been tested locally and for which there is a certain level of awareness. This could bring relative advantages to the promotion of these practices on a larger scale by IFAD.

3. Data collection

3.1. Workshops

In total, three workshops – one each per municipality – were held with farmers. The general objective was to collect information about the CSA practices that coffee and cocoa farmers prioritized. To complement this the workshops also aimed at collecting information that contextualizes these practices in terms of perceptions and experiences specific to the differing agricultural system in each zone. Additionally, the workshops generated information on the criteria for prioritization of CSA practices and the specific ranking of CSA practices. Therefore, data was gathered on the perceived benefits, limitations, awareness, adoption and abandoning of CSA practices.

Upon completing the preliminary processing of the results of the workshops with farmers, a discussion session with experts was organized on the adoption of CSA practices in coffee and/or cocoa systems. This session was intended to complement previously conducted workshops with farmers in El Cuá, Waslala and Rancho Grande. In short, the purpose of this session was to gather expert knowledge on coffee and/or cocoa systems.

The ranking was based on the CSA practices the farmers identified in each municipality. Some of the practices identified might not actually refer to practices, but to activities or strategies that farmers believed to be practices. A list of CSA practices relevant to their farming systems from the NICADAPT project design was presented to farmers to complement their initial list. They selected the ones they though were relevant and included them in their initial list of CSA practices. They were then ranked using a voting system and supported with a discussion based on reflections on the results obtained for ranking.

3.2. Surveys

Subsequently, the relevant inputs were extracted from the workshop discussions to serve as a basis for defining several sections of a survey for coffee and cocoa producers in the area. The household survey sought to better understand the socio-demographics, productivity, climate change vulnerability and perceptions of CSA practices. The survey started with a familiar socio-demographic and economic characterization, followed by a socio-economic characterization of incomes used to further identify vulnerable families. Finally, the instrument incorporated a production system characterization for coffee and cocoa systems and CSA awareness.

The process by which communities were selected to be surveyed first identified regions where clusters of coffee and cacao farmers existed to ensure the technical feasibility of the survey in the selected municipalities. A second key criterion in the selection of sites corresponded to the interest of having representative cases at different altitudes, as explained previously.

The sample size was established – a minimum of 30 surveys was needed by farmers' clusters (communities) to be a statistically representative sample (Shively 2011). That is why selected communities had a minimum population equivalent to 30 families producing coffee and/or cocoa. NITLAPAN estimations made by local technicians were utilized as there was no official statistics on the number of coffee and/or cacao farmers in each community. Finally, the sample size by site was established to get a statistical representativeness with a margin of error of 5 percent and a confidence level of 95 percent. For this, a statistical formula and a standard sample population was used. Thus, from these criteria, a total sample of 182 surveys distributed as follows was calculated.

Table 5: Survey sample design

Municipality	Community	Main crop	Average altitude (masl)	Sample size	Population of producers
El Cuá	Las Pavonas (Arriba, Central, Abajo)	Coffee	750-1100	60	65-70
Waslala	El Caño de los Martínez	Cacao	450	40	40-45
	La Posolera	Cacao	600	31	33
Rancho Grande	El Comején	Coffee	550 a 750	51	58
Total sample				**182**	

Source: Own elaboration based on interviews of NITLAPAN's technicians.

After collection, the survey data was then cleaned, analysed to obtain a statistical description and inferential analysis conducted with SPSS.

4. Data analysis

4.1. Cost benefit analysis

As a complementary part of the joint effort between CIAT researchers in Nicaragua, Uganda and Vietnam, a CBA tool was developed for CSA practices in tropical agricultural systems by an external consultant. Some of the key features of this tool included user friendliness and flexibility, as it could be applied to a multitude of farming systems and contexts. In terms of data requirement, the CBA tool was flexible enough to produce an analysis based on either secondary literary information or primary field data. However, given that in this case the approach was to undertake such an analysis from an ex-ante perspective, the type of data used was mainly from secondary information adjusted to a Nicaraguan context.

The CSA practices assessed with this tool were selected from the prioritized list of CSA practices from each municipality. The first criterion was feasibility, as many of the practices required data that was not currently available, such as the case of improved varieties that did not exist or were not been tested under similar conditions to those in one of the study sites. The second criterion was to provide an assessment of diverse types of prioritized practices. A last consideration in order to select the CSA practices to be analysed with the CBA tool was their rank in accordance to farmers' prioritization. The CSA practices selected that ranked highly were selected to provide additional information on their cost and benefits to support their future promotion. The selected CSA practices that did not rank highly were chosen based on their value according to expert or secondary information for climate change.

4.2. Cluster analysis

As the descriptive analysis of coffee and cacao farmers per site has demonstrated some social heterogeneity, we needed to understand how it could play a role in the adoption of CSA practices. Moreover, the complexity and diversity of factors limiting adoption, discussed in farmers' and experts' workshops, also suggests the need for a differentiated analysis of coffee and cacao farmers. This distinction contributes to providing inputs to support coffee and cacao farmers, considering their capacities, access to resources and specific contexts.

Six variables were selected and tested to undertake the clustering of coffee and cacao farmers. The variables selected were chosen to measure the factors that were locally identified as key for adoption of climate change adaptation measures (Zuluaga et al 2015). The variables were: income per capita, household land area worked, hectares per active population, yield of coffee and cacao, proportion of income from coffee and cacao and credit access. Income per capita and credit access were selected to estimate the access to capital, which was key for the initial investment in a CSA practice. The land area worked was selected to estimate both the size of the farming system and the investment size of the CSA practice. The hectare per active population was a proxy created to produce a relative labour availability estimate per household. The yield of coffee and cacao was selected to estimate the gap of production performance in coffee and cacao. The income from coffee and cacao was selected to estimate the economic relative importance of coffee and cacao for that household.

A hierarchical clustering was undertaken due to the data versatility of this method and the multiple partitions allowing selection of the level of desired similarity. The ward's method was applied to ensure a minimum variance within each cluster. The number of clusters was selected with a dendrogram to maximize the similarity of each cluster and obtain a reduced number of clusters with enough farmers in each cluster.

Once the clusters were obtained, they were tested to verify the average statistical difference between different variables through ANOVAs. Satisfactory results were obtained, with four out of six variables for the coffee cluster and three out of six variables for the cacao cluster.

III. Results

1. Target population descriptive analysis

In Table 6, some general socio-demographic and labour characteristics of the communities are presented. This information can be used to identify factors that are correlated with the adoption of climate change adaptation practices in the case of coffee (Zuluaga et al 2015).

On average, the head of households are between 46 and 52 years of age, which is a relatively senior age bracket that is positively correlated with adoption. However, the heads of households within the study sites report a relatively small number of years of education, with only 22–40 percent completing primary school. This could contribute negatively towards the adoption of climate change adaptation measures as low education levels show a negative correlation with adoption. In the case of heads of households being members of an organization, the proportion is relatively diverse, ranging from 30 to 60 percent. This is interesting as the site where 60 percent of adopters are participants in organizations shows a positive correlation and the site where only 30 percent of adopters are participants shows a negative correlation. Finally, the relative labour availability consists of about one active individual (between the ages of 18 and 65) per 2 ha of land under coffee cultivation, and around one active individual per 3 ha of land under cacao cultivation. However, cacao is generally less labour intensive than coffee.

Another important aspect which is integral to understanding the value of CSA practices adoption at the household level is the concept of climate change exposure or changing climatic conditions currently faced by producers. The current perceptions of climate change exposure are a crucial factor in the adoption of the decision-making process used by farmers (Zuluaga et al 2015). This will only continue to become more relevant as the prevalence and intensity of extreme events increases in the coming years.

Table 6: General socio-demographic and labour characteristics of households

		Head of household				Household	
		Average age	Std. dev.	Completed primary school	Organization membership	Ha per active pop	
Municipality	Community	years	years	percent	percent	Average	Std. dev.
Rancho Grande	El Comején	49.76	17.39	35.29	43	2.23	2.30
El Cuá	Pavona	46.10	12.85	28.33	61	1.89	4.69
Waslala	La Posolera	52.10	14.66	22.58	45	2.80	2.89
	Caño de los Martínez	49.37	13.56	40.00	32	3.22	4.15

Source: Households' survey (2015).

Table 7: General levels of households' total gross income and the relative importance of coffee and cacao

		Total income (gross)				Land worked	
		USD / year		Coffee	Cacao	Ha	
Municipality	Community	Average	Std. dev.	percent	percent	Average	Std. dev.
Rancho Grande	El Comején	5440.29	9177.94	45.04	21.04	5.59	4.84
El Cuá	Pavona	9110.70	11684.43	74.7	0.24	4.85	6.59
Waslala	La Posolera	4785.25	4492.19	22.03	35.89	9.19	11.43
	Caño de los Martínez	6988.73	14455.78	27.38	35	10.18	10.55

Source: Households' survey (2015).

The gross average income of coffee and cacao producing households within the four communities selected varies from USD 4 700 to 9 200. However, the high standard deviation provides some evidence of heterogeneity in terms of total income levels. The average size of cultivation in each household was about 5 ha in Rancho Grande and El Cuá and about 10 ha in Waslala. Like the case of total gross income, the high standard deviation within the cultivation area provides some evidence of heterogeneity.

The distribution of total gross income as illustrated in Figure 10 shows a positively skewed income distribution. It confirms that households can in fact increase their average total income. Looking at Figure 11, it is possible to see a similar outcome for the land area under cultivation, except for La Posolera and Caño de los Martínez, were the distribution of cultivated land area is negatively skewed.

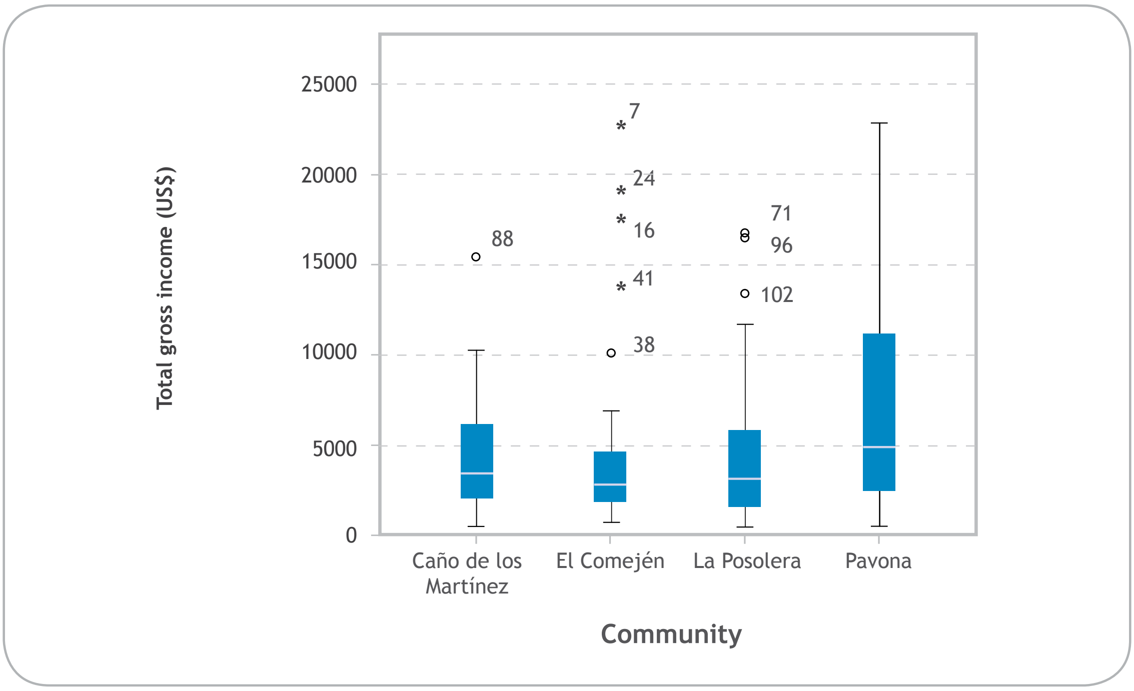


Figure 10. Household total gross income (USD) box plot per community

Source: Households' survey 2015.

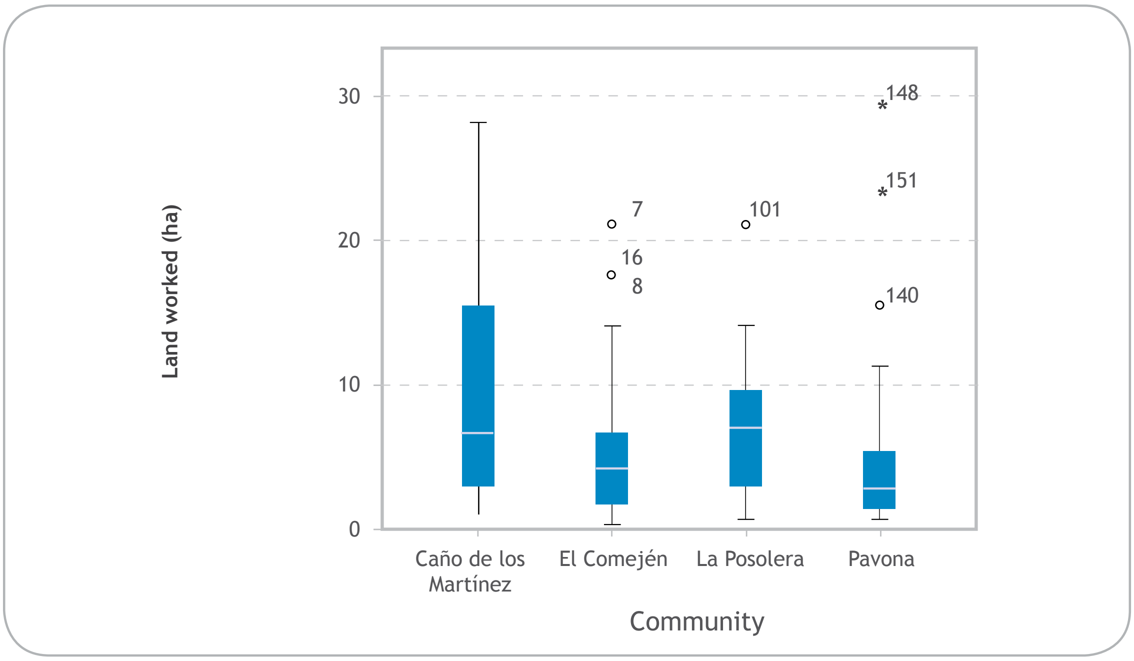


Figure 11. Household land worked (ha) box plot per community

Source: Households' survey 2015.

2. Agricultural systems and climate change threats

2.1 Cropping system

The study sites selected consist of populations with diverse production systems. In general, the farming systems are composed of staple grain production (e.g. maize and beans), cash crop production, (e.g. coffee or cacao), and fruit/horticulture production. These systems are often also combined with minor livestock production (e.g. poultry), and in the cases of Waslala and El Cuá, beef and milk production, which is generally not associated with coffee and cacao production.

In general, the farmers participating in the study commercialized their cash crops, staple crop surpluses and livestock. Their minor crops were generally intended for consumption, and in some cases for partial commercialization. The categories created in Table 8 corresponded to a ranking undertaken during a workshop with farmers on the relative contributions crops had as a source of income and for self-consumption. This categorization does not completely reflect the specific livelihood strategies of households participating in the workshop, but their general perception that are then related to the municipalities. Labour dynamics are generally composed of family labourers with some hiring for the cultivation and harvesting of primary crops. Minor crops and livestock are generally solely under family labour with stronger participation by women for horticultural crops.

Table 8: Farming system components in study sites

Product	Municipality		
	El Cuá	Rancho Grande	Waslala
Primary crops	coffee, maize, beans, Musaceae,[1] rice	coffee, beans, maize, cacao, Musaceae	cacao, coffee, maize, beans, rice
Minor crops	fruit (e.g. watermelon, orange) vegetables (e.g. chili pepper, ayote [hard squash]) tubers (e.g. potato, yuca [cassava])	fruit (e.g. orange, mango) vegetables (e.g. avocado, chili pepper) tubers (e.g. yuca [cassava])	Vegetables (tomato, chili pepper, ayote [hard squash]) tubers (e.g. yuca [cassava])
Livestock	poultry	poultry and bovine	poultry and bovine

Source: Farmers' workshops (2015).

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[1] A family of flowering plants which includes bananas and plantains as well as many lesser known edible fruits.

Delving deeper into crop production as a livelihood strategy, coffee and cacao have a key role as they often represent a crucial portion of household income and cash sources. In fact, of the four communities selected for this study, the survey reveals that together coffee and cacao represent on average, 50 percent of the total gross income for coffee and cacao producer's households. In the case of coffee, 74 percent of the producers undertake cultivation on shaded fields, and in 76 percent of the cases the variety is *Catimor*. The remaining 24 percent are divided between the *Borgon*, *Catuai*, *Pacamara* and *Paraimeño* varieties. The average age of coffee trees is 5.4 years and the interquartile range is between three and seven years. In the case of cacao, all the farmers undertake cacao cultivation use shaded plots. Additionally, 56 percent of the producers are using hybrid varieties, generally *Trinitario*, around 32 percent use *Forastero* and 12 percent *Criollo*. The average age of cacao trees is 9.8 years and the interquartile range is between 6 and 12 years.

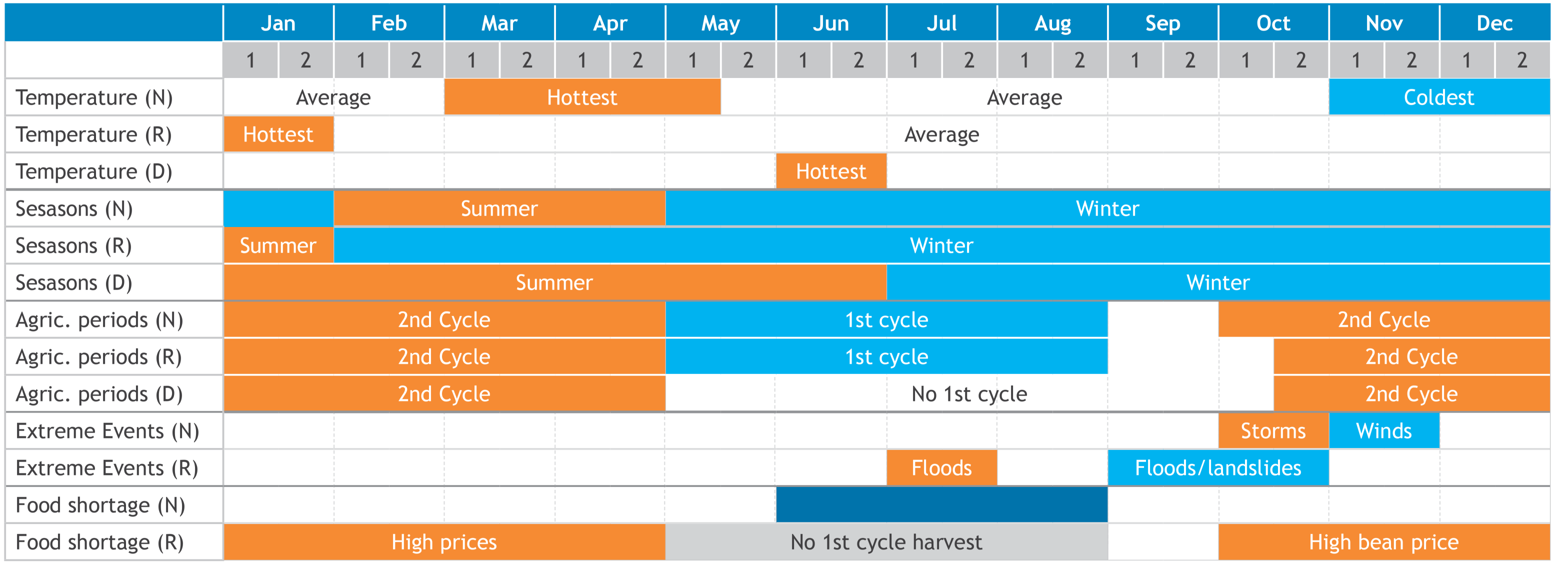
2.2 Climate calendar

Currently perceived climate change exposure - El Cuá

The following tables correspond to information gathered during a workshop with producers in the municipality of El Cuá for a year with average rainfall, a year with heavy rainfall – 2014; and a year with light rainfall – 2007.

In Table 9, normal year weather conditions are summarized for the municipality of El Cuá, as perceived by those attending the producers' workshop. Producers reported two seasons: winter (May–January) and summer (February–April). The table further illustrates that the coldest month of the year is generally December (a winter month), which corresponds with the rainy season. The warmer months include March and April, occurring during the dry season. Additionally, two major planting cycles were reported. The first occurring from May to August and the second from October to April. Also, according to the producers, during the months of June, July and August, food shortages are more likely due to insufficient grain stored from the previous cycle. A year of heavy rainfall, displays the fact that winter, or the rainy season lasted almost an entire year, reducing summer to the month of January. This was especially relevant during the months of September and October when flooding and landslides resulted from the intense rainfall. These extreme weather events were further exacerbated by the loss of the first harvest, which in turn meant increased bean prices and production shortages. In sharp contrast to the wet year of 2015, the dry year of 2007 summer, or the dry season, lasted until June, two months longer than normal. This forced farmers to put off planting until the first rains, thus increasing the number of months producers were susceptible to food shortages.

Table 9: Climate calendar: Normal (N); Rainy (R) 2014; Dry (D) 2007 year in El Cuá



	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Temperature (N)	Average				Hottest					Average											Coldest			
Temperature (R)	Hottest		Average																					
Temperature (D)											Hottest													
Sesasons (N)			Summer						Winter															
Sesasons (R)	Summer		Winter																					
Sesasons (D)	Summer												Winter											
Agric. periods (N)	2nd Cycle								1st cycle										2nd Cycle					
Agric. periods (R)	2nd Cycle								1st cycle											2nd Cycle				
Agric. periods (D)	2nd Cycle								No 1st cycle											2nd Cycle				
Extreme Events (N)																			Storms		Winds			
Extreme Events (R)													Floods				Floods/landslides							
Food shortage (N)																								
Food shortage (R)	High prices								No 1st cycle harvest										High bean price					

Source: Farmers’ workshop in El Cuá (2015).

Currently perceived climate change exposure - Rancho Grande

During the farmers' workshop in Rancho Grande, producers were asked to recall the last year that was characterized by heavy rainfall, 2014. However, although asked for a "dry year", all the participants agreed that they could not remember a drought in recent years.

Rancho Grande's average weather conditions have a winter, or wet period of nine months (mid-May to mid-February) and a summer, or dry period of three months (mid-February to mid-May). The most extreme temperatures occur between November and December (colder) and in April (warmer). There are two agricultural cycles in the area and like the previous case, families often experience food shortages during the first few months of winter. However, in this case, the food shortage is perceived to be caused by a lack of liquidity as the financial capital of the family is usually spent on agricultural tasks at the start of the planting season.

For the rainy year (Table 10), the most significant deviation from the average was in terms of rainfall. Although the rain occurred during October (the wet period), the rainfall was so intense it caused landslides. Luckily, this had no influence on the timing of the agricultural seasons and plantings and harvests occurred on schedule. In the case of a dry year, farmers could not recall any dry season in the past decade to establish an adequate comparison.

Table 10: Climate calendar: Normal (N) and rainy (R) 2014 rainfall in Rancho Grande

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Temperature (N&R)	Average						Hottest			Average											Coldest			
Season (N&R)	Winter			Summer						Winter														
Agricultural periods (N&R)	2nd cycle						1st Cycle															2nd cycle		
Exteme Events (R)																			Landslid					
Food Shortage (N)										Lack of cash														

Source: Farmers' workshop in Rancho Grande (2015).

Currently Perceived Climate Change Exposure – Waslala

For this municipality, Table 11 shows the climatic characterization for both an average year and the conditions of the period 2014–2015, which was identified as both as rainy and a dry year.

Overall, Waslala shares many similarities with El Cuá in terms of weather conditions in an average year. Winter occurs from May to January (with the months of November and December being the coldest), and summer lasting from January to April (with the months of April and May being the warmest months). There are also two agricultural cycles and food shortages occurring when families did not store sufficient grain from the previous agricultural cycle, usually because of overselling.

Table 11 shows that the second half of 2014 was characterized by an extended winter, occurring from May to February, reducing the summer to only a couple of months (March and April). It was also mentioned in the workshop that temperature changes were more pronounced during this year, with a warmer than normal summer and a colder than normal winter. The period of rain remained between the months of July and August, but the perception of the participants was that the volume of rainfall was higher than in a normal year.

It can then be concluded that there are shared perceptions of drastic changes in the climate. These include both impacts on the structure of climate and an increased presence of extreme events. Overall the comparison of climate calendars by farmers suggest that there are multiple climate stresses that have been detected and are associated with strong negative consequences for agricultural production. The complementary group discussion on climate calendar changes demonstrated not only the concern about climate change impacts, but also the existence of several types of climate change adaptation responses.

Table 11: Climate calendar: Normal (N) and Rainy (R) and Dry (D) 2014 year in Waslala

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Temperature (N)	Average						Hottest				Average										Coldest			
Temperature (R&D)	Average						Hottest		Average												Coldest			
Seasons (N)	🟦	Summer							Winter															
Seasons (R&D)	🟦	🟦	🟦	🟦	Summer				Winter															
Agricultural periods (N)	2nd cycle										1st cycle									2nd cycle				
Extreme events (N)													Landslides											
Food shortage (N)											Labour, Migration, Presales													

Source: Workshop with farmers in Waslala (2015).

3. CSA prioritization

Another element of the workshops undertaken with farmers was the identification of what they perceived to be CSA practices. The individual farmers, based on value and usefulness to their farming system then ranked these CSA practices. These rankings are presented in Table 12 with the practices receiving the most votes at the top and those receiving the lowest number of votes at the bottom. As explained in the methodology section of the Annex, the aim of this exercise was to identify the CSA practices that were most important to farmers given their current perception of climate change and climate variability.

Table 12: List of prioritized CSA practices

El Cuá	Waslala	Rancho Grande
Coffee	Cacao	Coffee
Improved varieties	Disease control (Monilia)	Urea and foliar feed
Establishment of timber	Weeding	Improved varieties
Diversifying with cacao	Sucker removal	Shade control
Musaceas shade	Pruning	Diversifying with Musaceaes
Establishment of citrus	Shade regulation	Establishment of timber
Fruit trees	Residue mulch	Windbreak
Living fence	Organic fertilizer	Fallow
Drainage trenching	Liming	Living fence
Trash lines	Timber tree shade	Trash lines
Organic fertilizer	Temporal shade	Contour line
	Drainage trenching	Trenching

Source: Farmers' workshop 2015.

Table 12 shows that most of the practices that lead the ranking, regardless of location, refer to techniques that are associated with crop management. The producers tend to prioritize the practices they considered essential for the development and management of coffee and cocoa crops, such as disease control, weeding, shade regulation and fertilizer use.

> *The plant is first. I cannot engage in erosion control or crop diversification if I do not first engage in pest control.*[2]
>
> Cacao farmer of Waslala (Farmers' workshop, 22 October 2015)

Through engaging in interviews and workshops, experts agreed that disease control (particularly Monilia) and weeding should be a priority for commercial cacao plantations in Waslala. Also, the use of improved varieties, i.e. those with resistance to drought and/or pests and high yields, were also highly valued by producers. For experts, this positive assessment is not surprising.

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[2] Slight changes in wording due to translation efforts

> *For several years producers have been adopting different cacao varieties.*
>
> (Expert from the Cooperative of Professionals for Comprehensive Development, Workshop with experts, 30 November 2015)

For experts, higher productivity and resistance to diseases, such as coffee rust are basic criteria that must be considered by the producers when adopting CSA practices. Also, these same experts highlight the influence of export companies in the decision-making process:

> *In the financial system, exporters will tell you: I will not risk my money with Caturra or other varieties that are susceptible to rust. I will give money for renewal (of coffee plants), but using resistant varieties.*
>
> (Expert from the Cooperative of Professionals for Comprehensive Development, Workshop with experts, 30 November 2015)

Experts estimate that the strong importance given by the producers of Rancho Grande to the use of urea and foliar fertilizer may be due to the low levels of adoption of this practice “Perhaps the importance comes from the fact that no one adopts it” (Workshop with experts, 30 November 2015). Basically, it is a practice that has not yet been adopted, but many producers hope to do so in the future. One of the experts also highlighted the key role of fertilization in adapting to climate change: “A better nourished coffee plantation is better able to cope with the ravages of nature” (Expert from NITLAPAN, personal communication, 2 December 2015).

Practices that received the lowest number of votes in the ranking were those that were considered less essential to the survival and development of the plant. Most of the workshop attendees claimed that their farms were in areas with adequate slope for the flow of rainwater. This means many of them were not engaging in drainage works, contour lines and/or trenching, which were undervalued practices. Similarly, the practice of using organic fertilizer was not valued in El Cuá or Waslala despite the recognized benefits by both farmers and experts. In general, the farmers claimed that implementing this practice requires a lot of work and several inputs, such as organic waste - which was not always readily available. Therefore, they decided to give priority to other tasks within the coffee and cocoa management scheme. The experts confirmed this assertion:

> *The production of organic fertilizer for coffee and cocoa is a practice that demands a lot of labour. To fertilize a* manzana *of land with 1 000–2 000 odd plants, you need at least two pounds (of fertilizer) per plant. Imagine the amount you would need to apply only once.*
>
> (Rappaccioli McGregor, Expert workshop, 30 November 2015)

As for the planting of timber trees and the corresponding benefits, tree planting was ranked in the top three practices only in El Cuá. In Waslala and Rancho Grande, it was placed in ninth and fifth respectively (Table 8). For experts, this relatively low valuation of timber trees was due to heavy government restrictions that limited the use of trees. These restrictions should be reformulated to encourage the planting of trees and reforestation, as well as sustainable management of forest resources to generate additional income for farming families. One of the experts explained:

> *This is a matter for the (legislative) assembly. We have the forestry laws, but no agroforestry law, and we are in an agroforestry system. So they treat any tree as it was a forest and it's not true.*
>
> (CATIE–MAPN Expert workshop, 30 November 2015)

Table 13 below sums up the different trade-offs that have been identified and the relative importance for the adoption of the climate-smart agricultural practices identified in the workshops and established by IFAD as part of their NICADAPT project design.

Table 13 summarizes the trade-offs subjective assessment of each CSA practice prioritized. A variety of criteria were used to provide a more comprehensive assessment of CSA practices and contrast the results obtained through CBA. As explained in the methodological section, the criterions reflect a variety of elements that were highlighted as key factors in the decision making for the adoption of these practices. Each criterion was given a value on the performance of the CSA practice assessed for that criteria with a scale of low, medium and high.

The relative relevance of that value for the overall assessment of that practice for its adoption was then highlighted. Finally, the relatively relevant values were coloured in green as positive factor and red as negative factor for adoption. In that sense, the colours should be understood as a way to signal both the most relevant positive and negative factors affecting the adoption decision-making.

The CSA practices listed and prioritized by farmers were regrouped in distinct categories of types of CSA practices. These categories were created based on similar aims and types of activities. Therefore, they also have similar cost and benefit structures. It can also be observed in Table 9 that categories of CSA also have similar trade-offs.

Table 13: Summary table of adoption trade-offs of climate-smart agricultural practices

Type of CSA practice	CSA practice / selection criteria	IFAD	Effective problem solution	Importance of problem	Complexity of adoption	Negative outcome	Expected rentability	Co-benefits importance	Initial cost stake	Maintenance cost stake
Infrasctructure heavy	Windbreak for coffee	X	High	Low	Medium	Low	Medium	High	High	Medium
	Drainage Trenching for cacao	X	High	Medium	High	Medium	Low	N/A	High	Medium
	Contour line for coffee	X	High	Medium	High	Low	Low	N/A	High	Medium
Infrastructure light	Living fence for coffee	(X)	Medium	Low	Medium	N/A	Low	Low	Medium	Medium
	Trash lines for coffee		Medium	Low	Low	N/A	Low	Low	Low	Low
Shade & diversification establishment	Establishment of timber trees for coffee & cacao	X	High	High	High	Medium	High	High	High	Medium
	Establishment of Musaceae for coffee & cacao	X	Medium	Medium	Medium	Low	High	High	Medium	Low
	Diversification of coffee with cacao		Medium	Medium	High	Medium	Medium	Medium	High	High
	Establishment of citrus for coffee	X	Medium	Medium	High	Medium	Medium	Medium	High	Medium
	Establishment of truit trees for coffee	X	Medium	Meidum	High	Medium	Medium	Medium	High	Medium
Management practices P & D	Monilia control for cacao		Medium	High	Low	N/A	High	N/A	Low	Low
	Weeding for cacao		Medium	Medium	Low	Low	Medium	N/A	Low	Low
Management practices crop	Sucker removal for cacao		High	Low	Low	N/A	Medium	N/A	Low	Low
	Pruning for cacao	(X)	High	Medium	Medium	Low	High	Medium	Medium	Low
	Shade control for cacao & coffee	(X)	High	Medium	Medium	Low	High	Medium	Medium	Low
Management practices nutrient cycle	Organic fertilizer for cacao & coffee	(X)	Medium	Medium	Medium	N/A	Medium	Low	Medium	Medium
	Residue mulch for cacao		High	Low	Low	N/A	Medium	Medium	Medium	Low
	Liming for cacao		High	Medium	Medium	Low	High	N/A	Medium	Low
	Urea and foliar feeding for coffee		High	Medium	Low	Low	Medium	N/A	Medium	Medium
Others	Coffee improved varietes		High	High	High	Medium	High	N/A	High	Low
	Fallow for coffee		Low	Low	High	High	Low	High	High	High

Source: Farmers' workshop, expert and farmers interviews (2015)[3]

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[3] X: matches exactly with a CSA practice of the IFAD's NICADPAT project.
(X): matches partially with a CSA practice of the IFAD's NICADPAT project.

4. Cost benefit analysis of CSA practices

As explained in the methodological annex section, some CSA practices were selected providing several types of CSA practices and CBA tool examples for supporting CSA adoption. Overall, the CBA tool results provided valuable quantitative assessment of the monetary benefits and costs of the different CSA practices selected. The CSA practices presented were tested, with consideration of initial conservative scenarios to provide useful information for non-optimistic scenarios.

Monilia control (cacao)

Description	Discussion
Manually eliminate the affected pods, complemented by proper shade levels and weeding to reduce monilia prevalence. The manual elimination of affected pods requires the skills to identify infected pods at an early stage. The practice reduces monilia prevalence and its propagation. In the long-term farmers will breed less infected cacao plants.	The CSA monilia control in cacao is an essential practice in the context of high prevalence of monilia and strong negative impacts. As a cultural preventive measure, it is not 100 percent effective and its results can generally be underestimated, as there is little comparative information on monilia impact in its absence. Therefore, the CBA results provide an interesting input, with high profitability. It is a continuous activity that can, in theory start at any point in the production cycle of cacao, although it should be undertaken since its establishment. It also provides good comparable information in regards of the cost of opportunity of labour for this activity versus the other alternatives as using non-organic inputs.

Table 14: CBA tool summary results for monilia control in cacao

CBA tool Summary Farm (1 ha) results	Net present value (NPV)	Internal Rate of Return (IRR)	Payback Period	Scenario in the analysis	
Unit	USD/cycle	%	Years	Before	After
Value	126	88	2	High risk of monilia	Low risk of monilia
Aggregate analysis CBA tool summary	Households	Total area of cacao affected	Projected adoption rate	Aggregated NPV	Period
	100	62 ha	62%	USD 22 085	6 years

Source: Own elaboration based on Navarro Prada and Mendoza Alonso (2006) and farmers and expert interviews and surveys.

Overall in a period of six years, with a reasonable adoption rate of 62 percent, it could provide an avoided loss of USD 22 085 in a population of 100 households.

Windbreak (Coffee)

Description	Discussion
Introduce three rows of Neem trees opposite to the wind direction and maintain them. Ensure manual activities for the co-benefits. The introduction of tree rows is not complicated per se but requires some planning and design skills. The practice requires a high initial investment and starts providing benefits years later.	The windbreak in coffee is not a commonly adopted CSA practice in Nicaragua, as explained by experts in interviews. However, this CSA practice provides direct benefits in coffee by avoiding coffee loss due to high winds and provides indirect benefits ranging from firewood to carbon storage. It also requires an area that would otherwise be generally utilized for coffee production, which is as an important trade off. The CBA results provide convincing evidence to support its adoption as it is highly profitable with an internal rate of revenue of 48 percent. Furthermore, its initial costs are compensated by a net present value of USD 662. This practice was tested assuming its adoption on already established coffee fields to assume bigger cost of opportunity of the area used for the windbreak. In that sense, these numbers are conservative and provide convincing evidence of even bigger benefits of windbreaks that are established concurrently with coffee fields. For this case, it was essential to assume windbreak technology is implemented with species that are commercially viable and well accepted in Nicaragua, e.g. Neem.

Table 15: CBA tool summary results for windbreaks in coffee

CBA tool Summary Farm (1 ha) results	Net present value (NPV)	Internal Rate of Return (IRR)	Payback Period	Scenario in the analysis	
Unit	USD/cycle	%	Years	Before	After
Value	662	48	4	Minor constant losses	No losses
Aggregate analysis CBA tool summary	Households	Total area of coffee affected	Projected adoption rate	Aggregated NPV	Period
	100	12 ha	12%	USD 23 058	11 years

Source: Current (1995) and INTA (unknown) and surveys.

Overall in a period of 11 years with a minor level of adoption, it can provide over USD 23 000 of net present value.

Organic fertilizer (cacao)

Description	*Discussion*
Manually introducing twice a year, organic fertilizer bought locally for cacao production aimed at 500 kg/ha. It is a simple practice but requires the necessary awareness for a consistent willingness to use organic fertilizer, notably during the first years of absence of harvest of cacao pods.	The organic fertilizer is a CSA practice that rapidly increases income, but given the conservative scenario under which it has been assessed has a reduced internal rate of return and net present value. Given the current limitations in terms of labour and input availability by farmers for creating and using organic fertilizer, this CSA practice refers to the purchasing and use of organic fertilizer for cacao. In that sense, these results are conservative and still provide positive assessment for its adoption. It is also conservative in terms of adopting it at the establishment of a cacao field and targeting a stable average production level of 500 kg. In a real-life scenario, an increase in income would probably generate an additional incentive to increase the quantity of fertilizer introduced and generate additional income.

Table 16: CBA tool summary results for organic fertilizer in cacao

CBA tool Summary Farm (1 ha) results	Net present value (NPV)	Internal Rate of Return (IRR)	Payback Period	Scenario in the analysis	
Unit	USD /cycle	%	Years	Before	After
Value	60	17	8	Low use of inorganic fertilizer	High use of organic fertilizer
Aggregate analysis CBA tool summary	Households	Total area of cacao affected	Projected adoption rate	Aggregated NPV	Period
	100	74 ha	74%	USD 11 801	8 years

Source: Based on expert interviews and surveys.

Overall in a period of eight years, with a reasonable adoption rate of 74 percent it could provide a gain of USD 11 801 in a population of 100 households.

Establishment of Musaceaes as temporal shadow (cacao)

Description	Discussion
Introduce Musaceae at the establishment of a cacao field to provide temporal shadow for the first years while shadow trees are growing and do not yet provide adequate shade. It is a very easy and responsive practice and has the potential to provide an additional cash crop if there is an adequate market access.	The establishment of Musaceaes as temporal shadow is a very short life cycle CSA practice. Musaceaes are well established in Nicaragua and are intercropped with cacao. In this case the aim is to provide shade for the first 2-3 years of initial establishment and obtain the benefits of a year of Musaceaes production before the elimination of the plants. The Musaceae plants could potentially remain, but to a lesser density as required for temporal shadow. The benefits obtained are high, with USD 181 of net present value and 590 percent of internal rate of revenue, as costs are limited. Currently 12 percent of households intercrop Musaceaes with cacao in Waslala at the density levels of Musaceaes that would be appropriate with this practice (Estrada 2010). The logic would be to promote this practice within the other households for future cacao field establishment.

Table 17: CBA tool summary results for Musaceae as temporal shadow in cacao

CBA tool summary Farm (1 ha) results	Net present value (NPV)	Internal Rate of Return (IRR)	Payback Period	Scenario in the analysis	
Unit	USD /cycle	%	Years	Before	After
Value	181	590	1	Temporal shadow not Musaceae	Temporal shadow of Musaceae
Aggregate Analysis CBA tool Summary	Households	Total area of cacao affected	Projected adoption rate	Aggregated NPV	Period
	100	88 ha	88%	USD 46 971	3 years

Source: Own elaboration based on Navarro Prada and Mendoza Alonso (2006) and farmers and expert interviews and surveys.

Overall in a period of 3 years, with a reasonable adoption rate of 88 percent of 100 households, it can generate USD 46 971.

5. Cluster analysis

5.1 Cluster description

As shown by Zuluaga et al (2015), households' socio-economic characteristics are key factors in the adoption of coffee and cacao CSA practices. Therefore, given the high socio-economic heterogeneity and diversity of coffee and cacao households, it is important to distinguish between households accordingly. To do so, as explained in the methodology section, a cluster has been undertaken.

Tables 18 and 19 present the coffee and cacao farmers clusters main characteristics. Particularly, the variables presented in the tables are the ones that have been used to define the clusters for coffee and cacao farmers. Those main characteristics and others are described in Tables 20 and 23 in terms of their influence in the adoption of CSA practices.

Table 18: Coffee farmers cluster main characteristics

Coffee	Income per capita	Land area worked (ha)	Hectares / active population	Yield of coffee	Income from coffee	Credit access
Cluster	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	percent
	USD	ha	ha/active pop.	QQ/ha	percent	
1	841.87 ± 821.07	6.7 ± 10.29	2.26 ± 3.16	7.88 ± 6.87	29.1 ± 18.49	100
2	2196.62 ± 3164.17	8.27 ± 7.41	2.81 ± 3.16	14.33 ± 9.65	76.37 ± 14.08	100
3	2626.74 ± 3597.7	7.63 ± 9.66	2.83 ± 3.16	16.95 ± 8.84	81.5 ± 16.83	0
4	632.87 ± 452.66	4.46 ± 5.13	1.29 ± 3.16	7.12 ± 6.39	21.91 ± 13.77	0

Source: Own elaboration based on survey data (2015).

Table 19: Cacao farmers cluster main characteristics

Cacao	Income per capita	Land area worked (ha)	Hectares / active population	Yield of cacao	Income from cacao	Credit access
Cluster	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	Av. ± Std. Dev.	percent
	USD	ha	ha/active pop.	QQ/ha	percent	
1	1115.05 ± 1487.72	7.84 ± 9.95	2.82 ± 3.4	5.85 ± 5.61	20.71 ± 13.08	0
2	1789.18 ± 3485.79	8.48 ± 8.98	3.42 ± 6.11	8.31 ± 11.17	32.9 ± 28.81	100
3	959.04 ± 1335.72	7.17 ± 4.61	2.1 ± 1.37	7.9 ± 5.3	77.5 ± 15.49	0

Source: Own elaboration based on survey data (2015).

Looking at the characteristics identified within the coffee farmers clusters, Group one and Group four are comprised of households with low income levels and reduced levels of dependants on coffee. This means that these farmers have a relatively low level of coffee production, but enormous potential to expand and improve their current systems.

Groups two and three are composed of farmers with higher levels of income and greater economic dependency on coffee. This also means that they are not only potentially less likely to improve their current coffee production systems, but are also more vulnerable to decreases in yields.

To better understand the specific direct and indirect climate impacts on crop production for each cluster group, please refer to Tables 21 and 22 below.

Table 20: Typical characteristics of coffee cluster populations and CSA practices most likely to be adopted

	Coffee cluster population	
	Group 1	Group 2
Characteristics	This group represents 31% of the households and has the following characteristics: • It has low income level (59% of H under USD 1.9/day/capita) • Very low level of coffee yield (-34% less than national average yield 2015) • Low income dependency on coffee (only 31% of income) • 24.5% of the households are headed by women • It has not had a credit in the past 12 months	This groups represents 22% of the households and has the following characteristics: • It has medium-low income level (39% of H under USD 1.9/day/capita) • Very high coffee yield (+20% more than national average yield 2015) • High income dependency on coffee (76% of income) • 22% of the households are headed by women • It has not had a credit in the past 12 months
CSA Practices	This group is more likely to adopt CSA practices that increase their yield and income: • (1) Management of pests & diseases as well as (2) Management of practices of nutrient cycle: Labour trade-off for a low initial and maintenance cost. Complexity of adoption might be minor additional barriers Once undertaken Group 4 moved towards a Group 2-3 condition	This group is more likely to adopt CSA practices that prevent losing crop yield and increasing added value (to reduce their vulnerability) & complement with some additional yield increasing CSA practice: • (1) infrastructure heavy & light as well as (2) Shade & diversification establishment: High/Medium trade-off to lose any productive field space for a high initial and maintenance cost. Complexity of adoption and long/medium-term return need are additional barriers • (3) Management of pests & diseases: Labour trade-off a low initial and maintenance cost. Complexity of adoption might be minor additional barriers

(continues)

(continued)

	Group 3	Group 4
Characteristics	This group represents 32% of the households and has the following characteristics: • It has medium income level (26% of H under USD 1.9/day/capita) • Very high coffee yield (+43% more than national average yield 2015) • 10% of the households are headed by women • It has had a credit in the past 12 months	This group represents 13% of the households and has the following characteristics: • It has low income level (76% of H under USD 1.9/day/capita) • Very low level of coffee yield (-40% less than national average yield 2015) • 9.5% of the households are headed by women • It has had a credit in the past 12 months
CSA Practices	This group is more likely to adopt CSA practices that prevent losing crop yield and increasing added value (to reduce their vulnerability): • (1) Infrastructure heavy & light as well as (2) Shade % diversification establishment: High/Medium trade off to lose any productive field space for a high initial and maintenance cost. Complexity of adoption and Long/Medium term return need are additional barriers	This group is more likely to adopt CSA practices that increase their yield and income: • (1) Management of pests & diseases as well as (2) management of practices of nutrient cycle: Labour trade-off for a low initial and maintenance cost. Complexity of adoption might be minor additional barriers

Source: Households' survey (2015).

Table 21: Proportion of coffee farmers affected by events causing crop losses by cluster groups (part 1)

Cluster/ causes of crop loss	Erratic rain	Flood	Landslide	Soil run-off	Strong winds	Storm	Households
	percent						N
1	12.24	4.08	10.20	0.00	10.20	12.24	49.00
2	8.82	8.82	14.71	2.94	8.82	2.94	34.00
3	14.00	2.00	8.00	4.00	14.00	4.00	50.00
4	0.00	0.00	4.76	0.00	19.05	9.52	21.00

Source: Households' survey (2015).

Table 22: Proportion of coffee farmers affected by events causing crop losses by cluster groups (part 2)

Cluster/ causes of crop loss	Fire	Heat wave	Drought	Disease	Insects	Households
	percent					N
1	0.00	6.12	16.33	73.47	22.45	49.00
2	0.00	14.71	29.41	76.47	20.59	34.00
3	0.00	12.00	20.00	82.00	24.00	50.00
4	0.00	0.00	4.76	76.19	0.00	21.00

Source: Households survey (2015).

The most common factors causing crop losses are disease and insect related. In all the cluster groups, more than 70 percent of the farmers stated that plant disease resulted in primary crop loss. In the case of insects, about 20 percent, except for cluster four who reported crop loss due to insect infestation. To a lesser extent – and primarily in clusters of two and three – droughts paired with extreme, prolonged heat were identified as factors resulting in primary crop loss. Strong winds were also identified as a contributing factor to crop losses of about 10 percent. Finally, there are other factors that affect coffee production, but on minor scale, such as landslides, erratic rain and storms. Therefore, it can then be theorised that these events or factors have the greatest effect on coffee farmers engaging in elevated levels of production.

Table 23: Cacao farmers cluster group typical characteristics and CSA practices likely to be adopted

<table>
<tr><th colspan="3">Cacao cluster population</th></tr>
<tr><th></th><th>Group 1</th><th>Group 2</th></tr>
<tr><td>Characteristics</td><td>This group represents 53.1% of the households and has the following characteristics:
• It has low income level (53.3% of H under USD 1.9/day/capita)
• Medium-Low level of cacao yield (-5% Less than national average yield 2013 - which is low)
• Low income dependency on cacao (only 20.7% of income)
• 21.6% of the households are headed by women
• It has not had a credit in the past 12 months</td><td>This group represents 36.3% of the households and has the following characteristics:
• It has low income level (48.8% of H under USD 1.9/day/capita)
• Medium level of cacao yield (+36% more than national average yield 2013 - which is low)
• Low income dependency on cacao (only 32.9% of income)
• 7.3% of the households are headed by women
• It has had a credit in the past 12 months</td></tr>
<tr><td>CSA Practices</td><td>This group is more likely to adopt CSA practices that increase their yield and income:
• (1) Management of pests & diseases as well as (2) Management of practices of nutrient cycle:
Labour trade-off for a low initial and maintenance cost. Complexity of adoption might be minor additional barriers</td><td>This group is more likely to adopt CSA practices that prevent losing crop yield and increasing added value (to reduce their vulnerability) & complement with some additional yield increasing CSA practice:
• (1) infrastructure heavy & light
High/Medium trade-off to lose any productive field space for a high initial and maintenance cost. Complexity of adoption and long/medium-term return need are additional barriers
• 3) Management of pests & diseases:
Labour trade-off for a low initial and maintenance cost. Complexity of adoption might be minor additional barriers</td></tr>
<tr><th colspan="3">Group 3</th></tr>
<tr><td>Characteristics</td><td colspan="2">This group represents 10.61% of the households and has the following characteristics:
• It has very low income level (83% of H under USD 1.9/day/capita)
• Medium level of cacao yield (+29% more than national average yield 2013 - which is low)
• 8.3% of the households are headed by women
• It has had a credit in the past 12 months
• 75% of the household reported crop losses due to P&D</td></tr>
<tr><td>CSA Practices</td><td colspan="2">This group is more likely to adopt CSA practice that prevent losing crop yield and increasing added value (to reduce their vulnerability) & complement with CSA practice that contribute to diversifying income:
• (1) Management of pests & diseases
Labour trade-off for a low initial and maintenance cost. Complexity of adoption might be minor additional barriers
• (2) Shade & diversification establishment:
High/Medium trade-off to lose any productive field space for a high initial and maintenance cost. Complexity of adoption and Long/medium-term return need are additional barriers
Once undertaken Group 4 moved towards a Group 2 conditions</td></tr>
</table>

Looking at the characteristics identified in the cacao farmer clusters, group three is composed of low income and cacao dependent households and they generally have a relatively high cacao production performance when compared to the national average yield. Groups one and two are composed of farmers with average and low levels of income and low economic dependency on cacao. In the case of group one, they have a lower cacao yield and in group two have a relatively higher cacao yield in comparison to the national average.

Furthermore, Tables 24 and 25 present data on the number of producers affected by the varying crop loss events.

Table 24: Proportion of cacao farmers affected by crop loss events by cluster groups (part 1)

Cluster/ causes of crop loss	Erratic rain	Flood	Landslide	Soil run-off	Strong winds	Storm	Household
	percent						N
1	8.33	3.33	0.00	11.67	3.33	5.00	60.00
2	4.88	2.44	0.00	7.32	9.76	7.32	41.00
3	33.33	0.00	0.00	8.33	8.33	8.33	12.00

Source: Households survey (2015).

Table 25: Proportion of cacao farmers affected by events causing crop losses in their main crops by cluster groups (part 2)

Cluster/ causes of crop loss	Fire	Heat wave	Drought	Disease	Insects	Household
	percent					N
1	0.00	1.67	10.00	60.00	26.67	60.00
2	0.00	0.00	9.76	63.41	9.76	41.00
3	0.00	0.00	8.33	75.00	0.00	12.00

Source: Households survey (2015).

The most common factor causing primary crop loss is disease, affecting over 60 percent of households. In the case of low-income cluster three, that percentage even reaches 75 percent. Furthermore, insects are listed as a factor affecting crop loss for more than 25 percent of households in cluster one and 9.7 percent in cluster two. In addition, erratic rain is recorded as a crucial factor of crop loss by cluster three with 33 percent of households having listed it. Finally, drought and soil run-off are recorded as factors of crop loss in all clusters, affecting about 7–12 percent of households.

5.2. CBA results on cluster population

The net present value of the control of monilia represents a relatively important increase of income that should be understood as an avoided loss. This single CSA practice implemented in 1 ha could provide an increase of the total income of 1.9 to 3 percent of coffee farmers. If implemented on the full area of a typical cacao field, it could represent a 2.6 to 4 percent total income increase for cacao farmers.

Table 26: CBA tool adoption benefits and costs for monilia control in cacao farmers' cluster

CSA practice adoption impact indicators/ Population Cluster	NPV	NPV (average cacao field)	Initial cost (average cacao field)	Main crop loss due to plague
	% eq of total income			% eq of households
Group 1	2.8	3.8	0.40	60
Group 2	1.9	2.6	0.27	63
Group 3	3.0	4.0	0.42	75

Source: Households survey (2015).

Table 27: CBA tool adoption benefits and costs for organic fertilizer in cacao farmers' cluster

CSA practice adoption impact indicators/ Population Cluster	NPV	NPV (average cacao field)	Initial cost (average cacao field)
	% eq of total income		
Group 1	1.4	1.8	0.00
Group 2	0.9	1.2	0.00
Group 3	1.4	1.9	0.00

Source: Households survey (2015).

Table 28: CBA tool adoption benefits and costs for Musaceaes as temporal shadow in cacao farmers' cluster

CSA practice adoption impact indicators/ Population Cluster	NPV	NPV (Average cacao field)	Initial cost (Average cacao field)
	% eq of total income		
Group 1	4.1	5.5	0.79
Group 2	2.8	3.7	0.54
Group 3	4.3	5.7	0.83

Source: Households survey (2015).

The adoption of organic fertilizer does not require any type of initial cost, as it is already a well-established practice, but in levels that don’t provide the incentive to undertake it under the best management practice conditions. Still, if implemented on a full cacao field it can represent an average total income increase of between 1.2 and 1.9 percent.

The adoption of Musaceaes as temporal shadow for cacao can generate the equivalent of between 3.7 and 5.7 percent additional income, if implemented in the full cacao field when establishing it. It requires very little initial cost, the equivalent of less than one percent of the total income of a cacao farmer.

For coffee, the adoption of windbreaks can provide a high net present value. If implemented for the whole coffee field, its net present value would be the equivalent of between 24 and 34 percent of total income from coffee farmers’ clusters population

Table 29: CBA tool adoption benefits and costs for windbreaks in coffee farmers’ cluster

CSA practice adoption impact indicators/ Population Cluster	NPV	NPV (average coffee field)	Initial cost (average coffee field)	Main crop loss due to strong winds
	% eq of total income			% of households
Group 1	18.4	30.4	3.7	10
Group 2	6.8	30.2	3.7	9
Group 3	5.9	24.9	3.0	14
Group 4	19.8	33.7	4.1	19

Source: Households survey (2015).

For the coffee farmers with the smallest coffee field area from cluster 1 and 4, who are also the farmers with lower incomes, its implementation in one ha could alone represent an increase of income from 18.4 to 19.8 percent. Windbreak in coffee is also a CSA practices that avoids losses and provides additional income. However, the avoided losses it generates in coffee production can be underestimated as it represents a slight increase and requires several years before being able to obtain its benefits in the field. In that sense, it is not a CSA practice for which coffee farmers can easily compare and measure the avoided losses. Furthermore, its adoption requires farmers to bear an initial cost that is relatively high as it is the equivalent of 3 to 4 percent of the average total income of coffee clusters population.

IV. Discussion

The results of the climate change and climate variability context of coffee and cacao farmers suggest some similarity in the type of climate impacts perceived. It also highlights the weight of those impacts in terms of their farming system activities and outputs. For instance, in the case of El Cuá, in 2007 and 2014 respectively perceived as dry and rainy years, the first cycle of staple grain production could not be undertaken. Still coffee farmers in the study site in El Cuá have an income that is highly dependent on coffee, making them less vulnerable to staple grain issues. Nevertheless, staple grain is also important for household consumption and even in the extreme case of not producing it, coffee farmers are affected by its increase in price. Moreover, this information must be put into the context of last decade's recurrent and severe coffee crisis episodes, such as the coffee rust crisis of 2012–2013 (Avelino et al 2015). As such, 2007 and 2014 should correspond to recovering years for coffee farmers. This complex dynamic could explain some of the additional factors limiting the access to capital necessary for the adoption of CSA practices. Therefore, coffee farmers' responses to climate change including CSA practices must be understood considering additional farming system priorities and dynamics.

The cluster analysis of coffee and cacao farmers allows for a more in-depth and specific analysis considering the characteristics of households. For instance, the initial cost for the adoption of some of the CSA practices might be an important limiting factor for coffee and cacao farmers with less access to capital. All the clusters with high proportions of female headed households were consistently the ones that did not have access to credit in the past 12 months. As Mason (2014) points out, women had lesser access to credit in Nicaragua and when they did the conditions were generally less beneficial, for instance they only had access to smaller loans.

The identification and further prioritization of CSA practices by farmers must be also been understood as part of the group discussion and reflection process undertook in the workshops. The complexity of the CSA practices identified by farmers varied, giving the broad understanding of the term practice. Furthermore, the limited understanding of CSA practices and its difficult differentiation with best management practices seems to have influenced the prioritization undertaken by farmers. Considering this, the expert workshop and interviews provided highly relevant contrasting information. In consequence, CSA practices specific relevance to tackling climate change issues must be taken carefully.

For instance, the case of weeding of cacao which ranked so highly, can be explained by its high prevalence of insect and disease as a factor of crop loss in cacao cluster population. It is however not a practice generally associated to CSA as experts pointed out in the experts' workshop. Furthermore, during cacao farmers' workshop, the indirect benefits they listed for this practice can easily be associated to CSA, with an increase in productivity, reduction of disease and even a marginal increase in soil organic matter.

In addition, the results of the CBA provide supporting data to promote the adoption of CSA practices for coffee and cacao. Furthermore, the trade-off analysis brings a complementary and comprehensive assessment of the non-monetary dimension of the costs and benefits of such adoptions. In that sense, it allows for the contrasting of results obtained in the CBA of the CSA practices assessed. It also provides information on other similar CSA practices that could be perceived as better alternatives than the promoted CSA practices. Or it can provide information on slight improvements in current CSA practices already adopted.

For instance, in the case of organic fertilizer in the municipality of Waslala, which has a high proportion of cacao farmers currently using organic fertilizers but in limited amounts and not following the best practices (Estrada 2010). Other sources of fertilization are also very limited and overall provide negative nutrient balances in cacao fields (Estrada 2010). In that sense, the organic fertilizer in cacao assessed with the CBA tool consists of using organic fertilizers in optimal amounts and under the best practices. It has synergy with current practices and demonstrates sensible increase in economic returns. During the farmers' workshop, the biggest limitations were the labour intensity, the production of organic fertilizer required and the input availability. However, there are now organic fertilizers for cacao that are becoming available for purchase that will provide a solution to this situation. The CBA evidenced the high profitability of organic fertilizer even under increased costs due mostly to the purchase of the inputs and a slow payback return period. In that sense, the fact of having a return payback only after 8 years is still an important limitation.

V. Conclusions

This concluding chapter elaborates on the conclusions of this study, which centres on the main analysis of three rural municipalities of Nicaragua in terms of CSA practices adoption, its barriers and benefits.

First, the characterization of the local context demonstrates that significant changes have occurred in the climatic conditions of rural communities of Waslala, El Cuá and Rancho Grande. For instance, (drastic) variations in temperature, the amount of rainfall and the presence of more extreme events (i. e. floods and landslides) were some of the changes identified in the agriculture-climate calendar compiled during farmers' workshops. Moreover, in most cases these changes have led to shifts in agricultural periods and eventual food shortages. Consequently, local producers are adopting several practices that aim to help them to adapt to their environment.

Particularly, coffee and cocoa – two key crops for local livelihoods strategies – are not excluded from this dynamic. Given that context, farmers are implementing CSA practices to increase/maintain productivity, reduce vulnerability to (extreme) climatic events and/or adapt to these climatic events. The prioritization exercise conducted with farmers and experts concludes that practices considered essential for the development and management of coffee and cocoa crops are generally locally contextually grounded and very familiar for both farmers and experts. The contrast between the CSA practices prioritized by farmers and the experts has been explained by multiple factors such as legal and labour availability constraints. Remarkably, some CSA practices positioned in the low and middle range of CSA practices, as prioritized by farmers, were highly recommended by experts, showing a big gap of knowledge.

A comprehensive assessment of CSA practice adoption trade-offs differentiates some main constraints and potentials of adoption at the farmer level. Results show a uniformity of main trade-offs per type of CSA practices and a main overall constraint generating an important cost of opportunity through the initial cost of adoption. It is generally associated with a costly adoption input and/or limited labour availability, and to some extent on a low expected economic benefit. As such, the economic benefit of many CSA practices could be undervalued and require additional assessment of their objective economic return. Considering this, the CBA tool was tested with some specific CSA practices providing a different structure of cost and levels of prioritization.

The CBA assessment of four CSA practices, such as monilia control, organic fertilizer and Musaceae establishment as temporal shadow for cacao and windbreaks for coffee provided positive results for their promotion. Given the conservative context through which they were assessed, the net present values of USD 60 to 662 per cycle are encouraging for their future promotion. The internal rate of return from 17 to 590 percent showed more mitigated results as elevated levels of cost of opportunity exists in Nicaragua given the 12 percent discount social rate established. In aggregated terms with conservative levels of adoption for a population of 100 households, aggregated net present values can yield benefits from USD 11 000 to 47 000 during the life cycle of respective CSA practices.

The positive results of the CBA does not imply that all CSA practices should be systematically undertaken, but if they are relevant in the climate change context and farmers' context there is enough information to undertake an evidenced-based decision-making process.

A further analysis of farmer climate adversity context and household and farm characterization provided differentiated understanding of the type of farmer constraints and potentials, as well as and *ex-ante* impact assessment of some CSA practices. An overall high prevalence of adverse climatic events was found, with some resulting effects which can be mitigated through selective CSA practices. Furthermore, two relevant categories of farmer's types were identified for targeting of CSA practices. First, a group of very low-level income farmers with very low productivity levels and a diversified income could potentially benefit from small, responsive and high-return CSA practices. They have similar levels of land and labour availability but are probably trapped in a low-input and low-productivity cycle. Second, a group of relatively mid-level income farmers with high productivity levels and high dependence on coffee and/or cacao as a cash crop could potentially benefit from CSA practices to reduce their productivity vulnerability. They should prevent any future losses that might take them into a low input and productivity cycle trap.

The *ex-ante* impact adoption assessment of the selected CSA practices showed net present value increases of annual income equivalent of between 5 and 19 percent in a life cycle of the practice in coffee and from 0.8 to 5 percent in cacao. Specific attention must be given to target populations accordingly to differentiate the support provided for CSA practices adoption.

Annex 1. List of GCMs

Centre(s)	model	xRes	yRes	nCols	nRows	xMin	xMax	yMin	yMax
Beijing Climate Center, China	bcc_csm1_1	2.8125	2.789327	128	64	-181.406	178.5938	-89.2585	89.25846
Beijing Climate Center, China	bcc_csm1_1_m	1.125	1.121277	320	160	-180.563	179.4375	-89.7022	89.70216
Beijing Normal University, China	bnu_esm	2. 8125	2. 789327	128	64	-181. 406	178. 5938	-89. 2585	89.25846
Canadian Centre for Climate Modelling and Analysis, Canada	cccma_canesm2	2.8125	2.789327	128	64	181.406	178.5938	89.2585	89.25846
National Center for Atmospheric Research, USA	cesm1_bgc	1.25	0.942408	288	192	-180.625	179.375	-90.4712	90.4712
National Center for Atmospheric Research, USA	cesm1_cam5	1.25	0.942408	288	192	-180.625	179.375	-90.4712	90.4712
Commonwealth Scientific and Industrial Research Organization/Bureau of Meteorology Australia	csiro_access1_0	1.875	1.25	192	145	-180. 938	179. 0625	90.625	90.625
Commonwealth Scientific and Industrial Research Organization/Bureau of Meteorology, Australia	csiro_access1_3	1.875	1.25	192	145	-180. 938	179. 0625	90.625	90.625
Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence, Australia	csiro_mk3_6_0	1.875	1.864677	192	96	-180. 938	179.0625	89.5045	89.50451
The First Institute of Oceanography, SOA, China	fio_esm	2.8125	2.789327	128	64	181.406	178.5938	89.2585	89.25846

(continues)

(continued)

Centre(s)	model	xRes	yRes	nCols	nRows	xMin	xMax	yMin	yMax
Geophysical Fluid Dynamics Laboratory, USA	gfdl_cm3	2. 5	2	144	90	-180	180	-90	90
Geophysical Fluid Dynamics Laboratory, USA	gfdl_esm2g	2.5	2.01111	144	90	-180	180	90.4999	90.49994
Geophysical Fluid Dynamics Laboratory, USA	gfdl_esm2m	2.5	2.01111	144	90	-180	180	-90. 4999	90.49994
NASA/GISS (Goddard Institute for Space Studies) USA	giss_e2_h_cc	2.5	2	144	90	-180	180	-90	90
NASA/GISS (Goddard Institute for Space Studies) USA	giss_e2_r	2.5	2	144	90	-180	180	-90	90
NASA/GISS (Goddard Institute for Space Studies) USA	giss_e2_r_cc	2.5	2	144	90	-180	180	-90	90
Russian Academy of Sciences, Institute of Numerical Mathematics, Russia	inm_cm4	2	1.5	180	120	-181	179	-90	90
Institut Pierre Simon Laplace, France	ipsl_cm5a_lr	3.75	1.894737	96	96	-181.875	178.125	-90.9474	90.94737
Institut Pierre Simon Laplace, France	ipsl_cm5a_mr	2.5	1.267606	144	143	-181.5	178.75	-90.6338	90.6338
Institute of Atmospheric Physics, Chinese Academy of Sciences, China	lasg_fgoals_g2	2.815	3.050847	128	60	-181.406	178.5938	-91.5254	91.52542
Atmosphere and Ocean Research Institute (The University of Tokyo),National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	miroc_esm	2.8125	2. 789327	128	64	-181. 406	178. 5938	-89. 2585	89. 25846

(continues)

(continued)

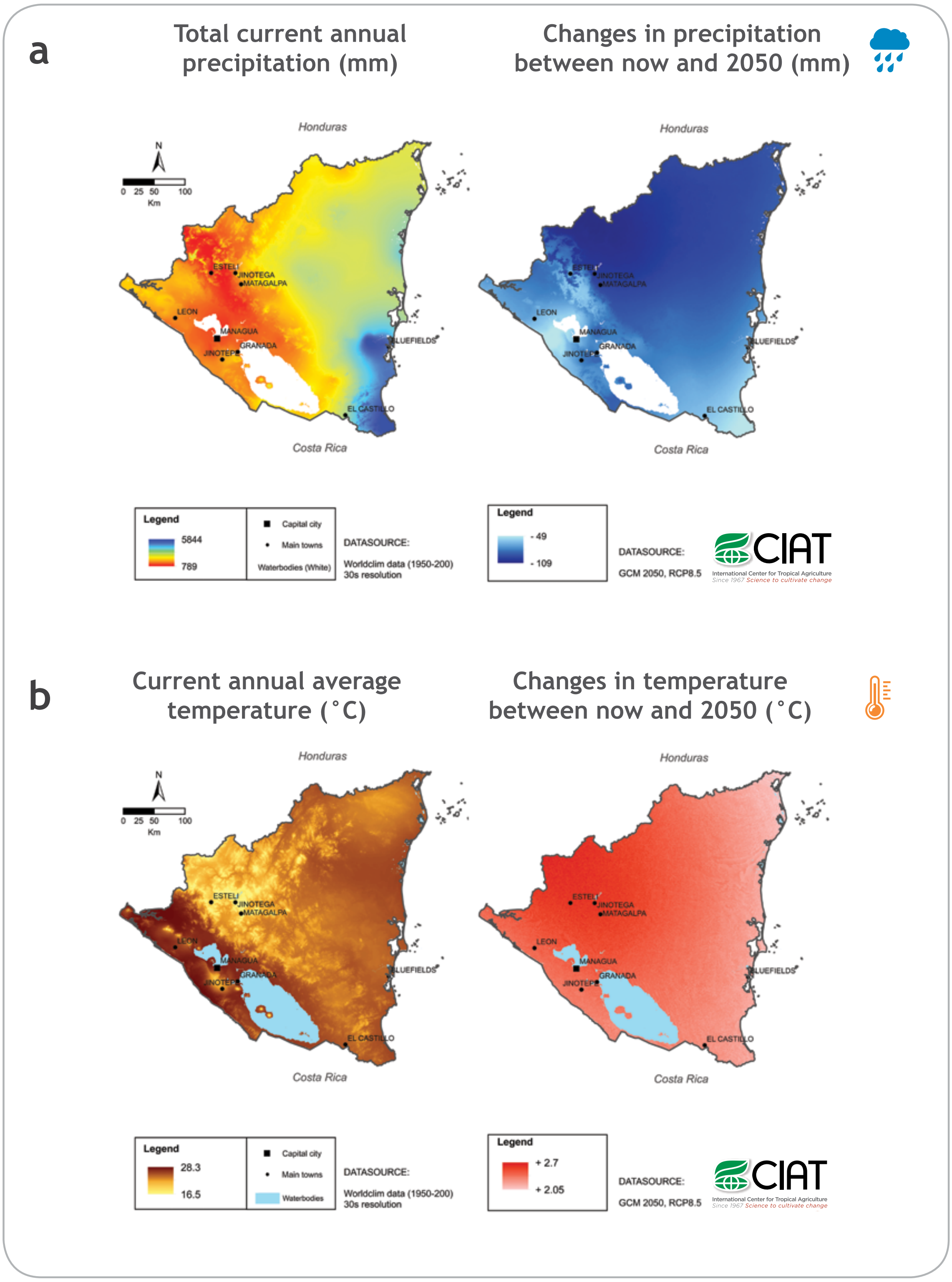
Centre(s)	model	xRes	yRes	nCols	nRows	xMin	xMax	yMin	yMax
Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	miroc_esm_chem	2.8125	2. 789327	128	64	-181. 406	178. 5938	-89. 2585	89. 25846
Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	miroc_miroc5	1.40625	1. 400437	256	128	-180. 703	179. 2969	-89. 628	89. 62795
Met Office Hadley Centre, UK	mohc_hadgem2_cc	1.875	1.25	192	145	-180. 938	179. 0625	-90. 625	90.625
Met Office Hadley Centre, UK	mohc_hadgem2_es	1.875	1.25	192	145	-180. 938	179. 0625	-90. 625	90.625
Max Planck Institute for Meteorology, Germany	mpi_esm_lr	1.875	1. 864677	192	96	-180. 938	179. 0625	-89. 5045	89. 50451
Meteorological Research Institute, Japan	mri_cgcm3	1.125	1. 121277	320	160	-180. 563	179. 4375	-89. 7022	89. 70216
National Center for Atmospheric Research, USA	ncar_ccsm4	1.25	0. 942408	288	192	-180. 625	179. 375	-90. 4712	90. 4712
Bjerknes Centre for Climate Research, Norwegian Meteorological Institute, Norway	ncc_noresm1_m	2.5	1. 894737	144	96	-181. 25	178. 75	-90. 9474	90. 94737
National Institute of Meteorological Research, Korea Meteorological Administration, South Korea	nimr_hadgem2_ao	1.875	1.25	192	145	-180. 938	179. 0625	-90. 625	90.625

Annex 2. Sea-level rise studies

Possible sea-level rise by 2100 based on the academic literature:

- “Model projections of future global mean sea-level change, based on temperature change projections, show a rise of between 13 and 94 cm by 2100, with a central estimate of 49 cm (IPCC 2001)”. This information was discussed in a paper assessing the impacts of CC vulnerability of Rice Prod in SE Asia (Wassmann et al 2009).
- “A pragmatic choice is to consider 48 cm (or in round terms, 50 cm) as a lower range for the twenty-first century sea-level rise in a beyond 4◦C world” (Nicholls et al 2011).
- A rise of 0.8 m is possible (Nicholls et al 2011).
- Rohling et al (2008) concluded that plausible global sea-level rise scenarios were 0.55–1.10 m in 2100, and 1.5–3.5 m in 2200.
- Maximum global rise of 2.5 m is according to Lowe and Gregory (2010) very unlikely to occur during next 100 years.
- “The global distribution of effective sea-level rise (ESLR) under the contemporary baseline condition (Figure 5) shows estimates ranging from 0. 5 to 12. 5 mm yr^{-1} with a mean value of 3.9 mm yr^{-1} and a median of 4.0 mm yr^{-1}.” (Ericson et al 2006).
- Church and White (2006) discovered a significant acceleration of sea-level rise in the twentieth century and estimated a sea-level rise from 2.0 to 3.4 m between 1990 and 2100.

Annex 3. Changes in temperature and precipitation for the 2050s



a

Total current annual precipitation (mm)

Changes in precipitation between now and 2050 (mm)

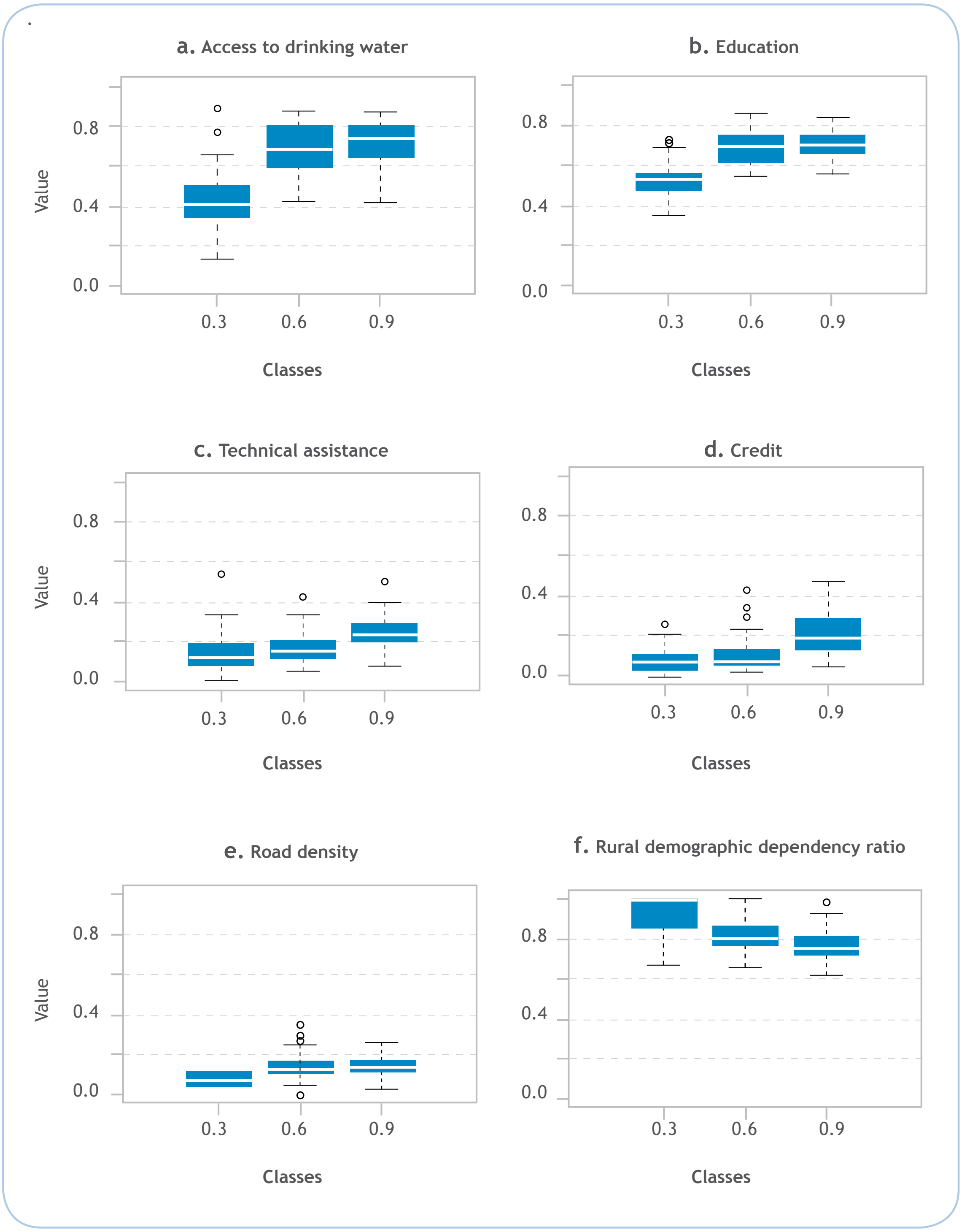
b

Current annual average temperature (˚C)

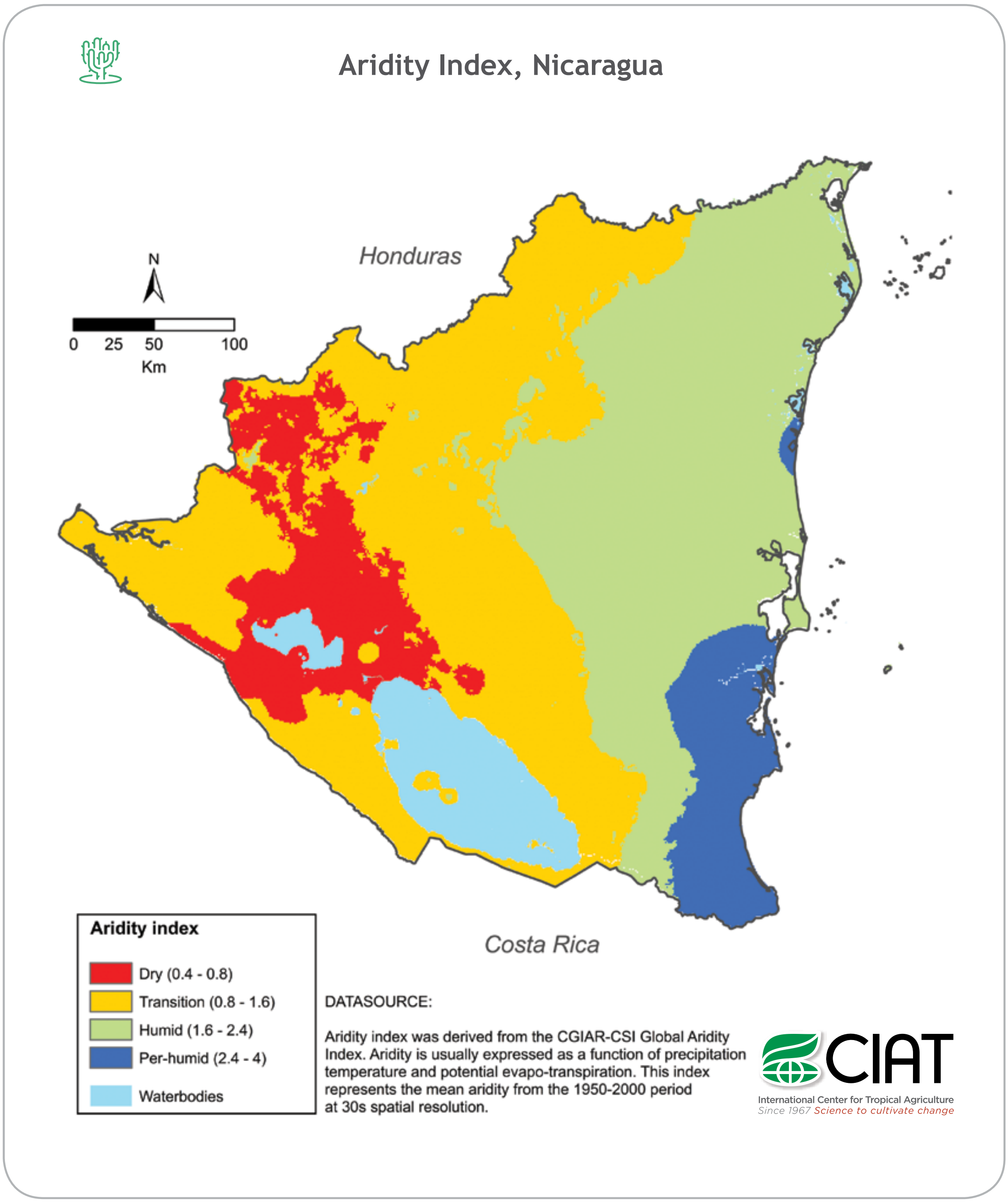
Changes in temperature between now and 2050 (˚C)

Figure 12: Current and changes in precipitation are represented in top map (a) using mm as units. Current and changes in temperature are represented in the bottom map (b) in degrees Celsius

Annex 4. Adaptive capacity and indicators



Annex 5. Exposure II (Biophysical indicators)



Aridity Index, Nicaragua

DATASOURCE:

Aridity index was derived from the CGIAR-CSI Global Aridity Index. Aridity is usually expressed as a function of precipitation temperature and potential evapo-transpiration. This index represents the mean aridity from the 1950-2000 period at 30s spatial resolution.

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Figure 13: Aridity Index map

Based on the index, the class “dry” represented in red colour matches with the dry corridor in Nicaragua.

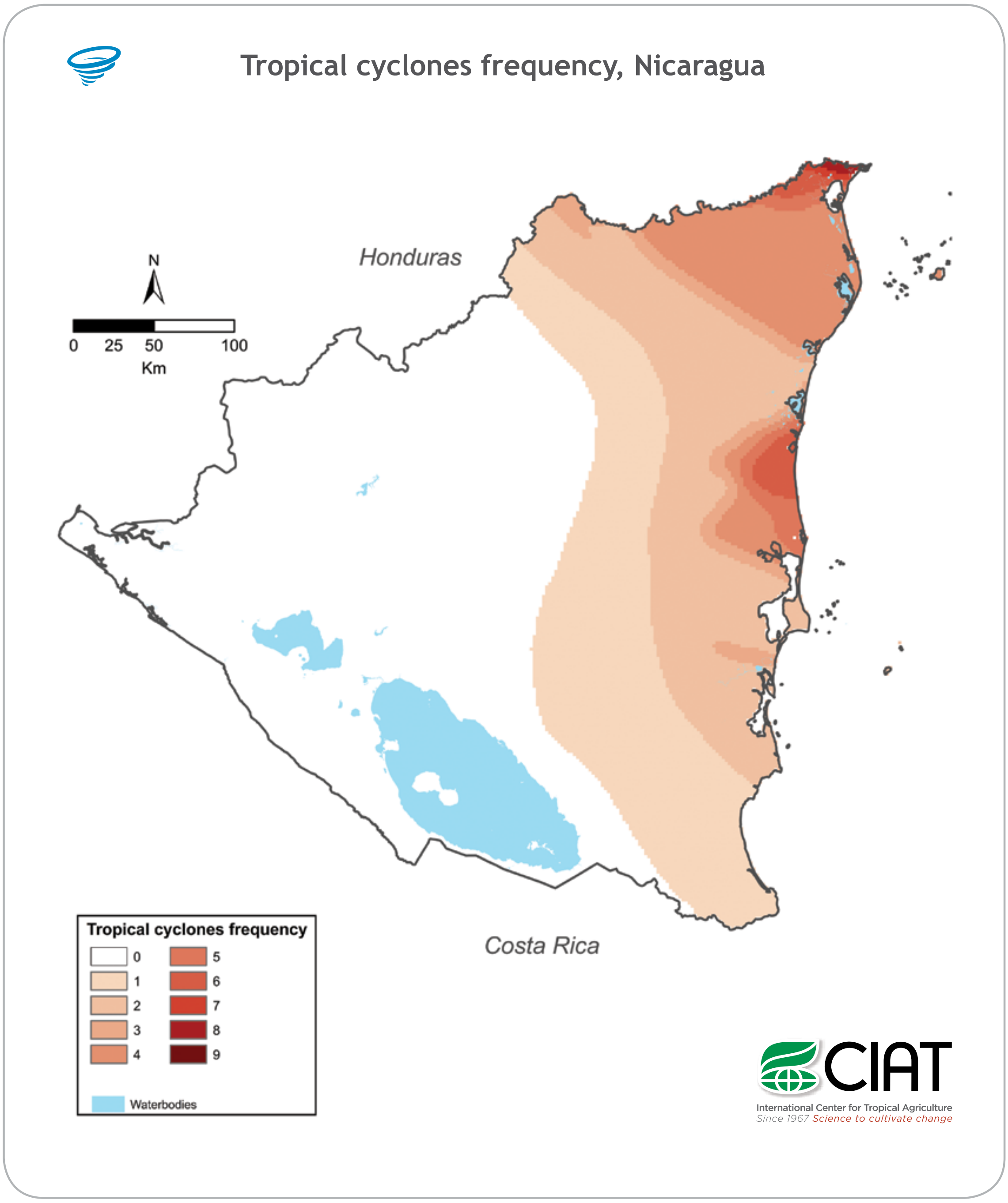


Figure 14: Tropical cyclones frequency map. Unit is expected average number of event per 100 years

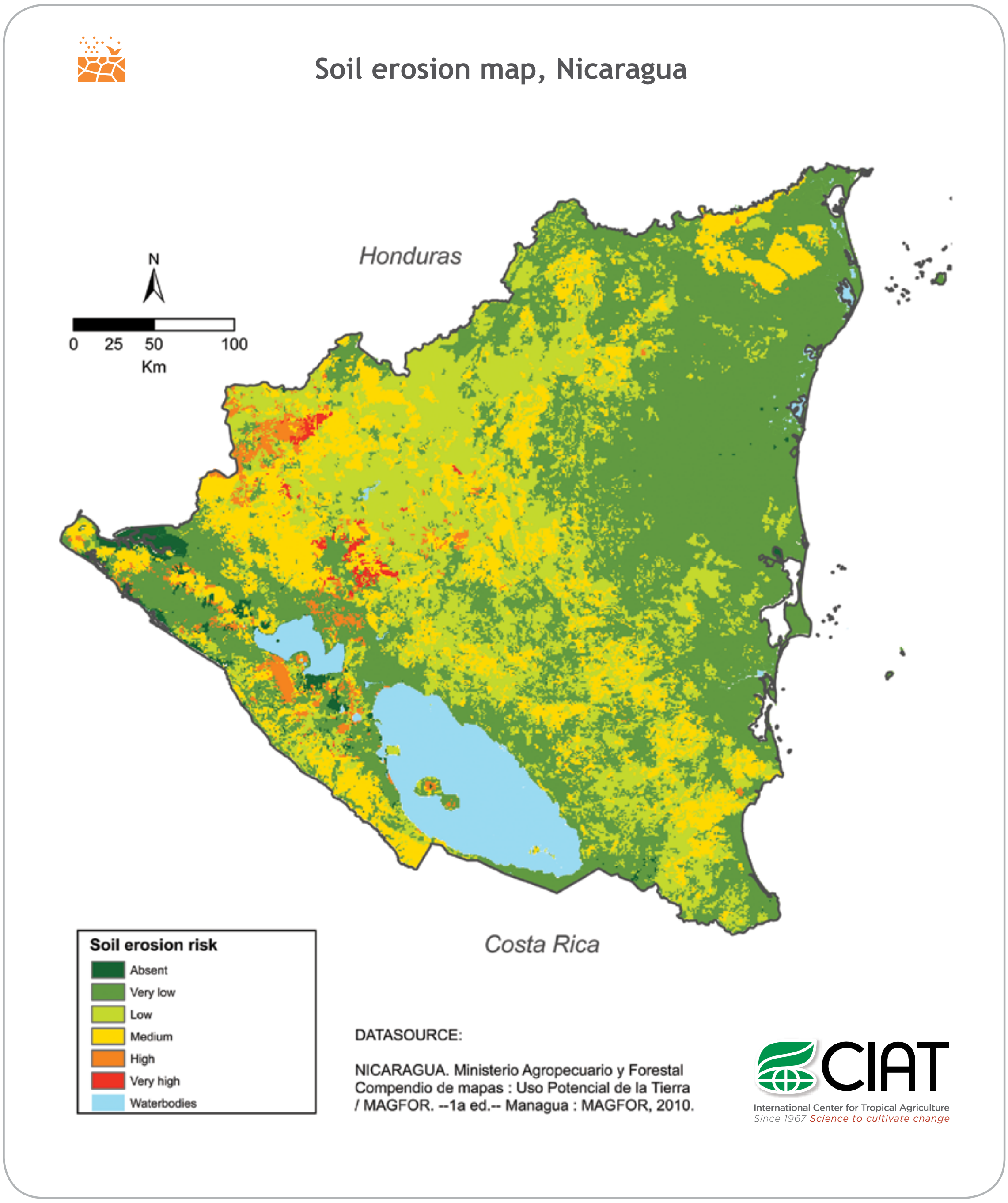
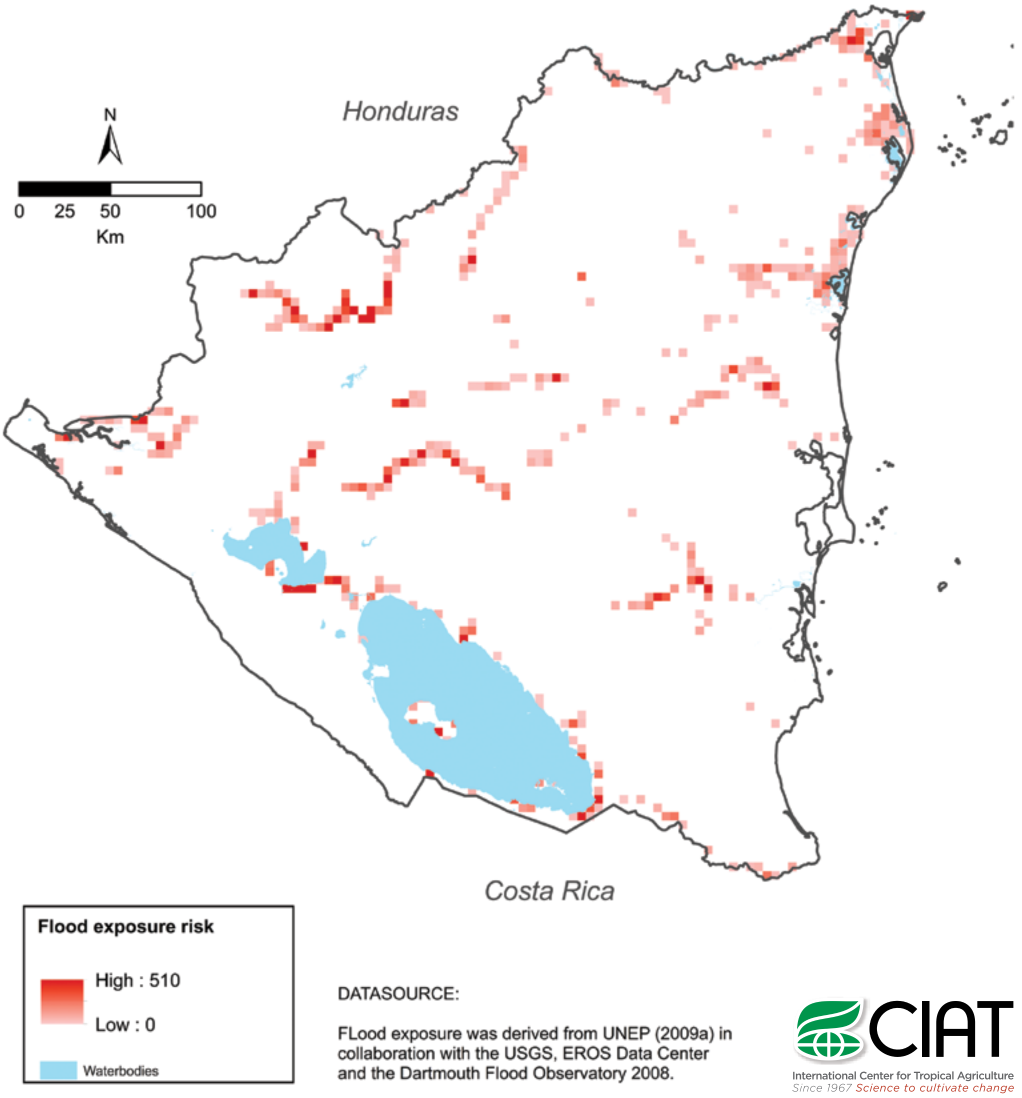


Figure 15: Soil erosion map for Nicaragua

Source: MAG (2010).



Flood exposure map, Nicaragua

DATASOURCE:

FLood exposure was derived from UNEP (2009a) in collaboration with the USGS, EROS Data Center and the Dartmouth Flood Observatory 2008.

Figure 16: Flood exposure map. The map expresses the number of weeks a year that an area is affected by flood

Source: Flood exposure was derived from UNEP (2009) in collaboration with the USGS, EROS Data Center and the Dartmouth Flood Observatory (2008).

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