Framing vulnerability and coffee farmers' behaviour in the context of climate change adaptation in Nicaragua

Sonia Quiroga[1*], Cristina Suárez[2], Juan Diego Solís[3], Pablo Martinez-Juarez[4]

[1] Department of Economics, University of Alcalá, Alcalá de Henares, Madrid, Spain, e-mail: sonia.quiroga@uah.es
[2] Department of Economics, University of Alcalá, Alcalá de Henares, Madrid, Spain, e-mail: cristina.suarez@uah.es
[3] Department of Economics, Universidad Nacional Autónoma de Nicaragua, León, Nicaragua, e-mail: jdsa@ac.unanleon.edu.ni

[4] College of Medicine and Health, University of Exeter, e-mail: P.Martinez-Juarez@exeter.ac.uk

[(*)] Corresponding author:
Plaza de la Victoria, 2., 28802 Alcalá de Henares (Madrid), Spain
Phone: +34918856370. Fax number: +34918854202

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Abstract

This paper analyses coffee producer's vulnerability and adaptive capacity to climate change in Nicaragua. By its geographical position, Nicaragua is one of the countries most affected by climate change, and coffee production is expected to vastly shrink in some critical areas, suitability being reduced by up to 40% in the country. This paper analyses farmer's perceptions and vulnerability indicators to find which indicators are linked to farmers' perceived capacity to adapt to climate change, paying special attention to the issue of whether farmers perceive they have any capacity at all to adapt.

The analysis was conducted through a survey to 212 representative farmers jointly with an analysis of vulnerability indicators. A Heckman selection model was estimated to jointly analyse the probability of being able to cope with climate change and the level of adaptive capacity that farmers perceive. We have simulated different policy scenarios considering the sustainable development goals of United Nations in terms of poverty reduction and education concerns. We also analysed the effects of specific programs on education about climate change awareness. Finally, we extend our analysis to a geographical evaluation of the farmer's perceived vulnerability.

The analysis shows that aspects such as farm size or education levels are relevant for modulating farmers' perceptions on their own adaptive capacity. Large farm managers find themselves more often able to cope with climate change impacts though they find their capacity to be limited. Farmers that could not rely on rainfall water for their plantations also reported being less able to cope with climate change impacts. Poverty was also found to be correlated to perceptions, as regions lower proportions of inhabitants under poverty levels showed higher levels of confidence in adaptive capacity

Keywords

Climate change adaptive capacity, vulnerability indicators, Mesoamerica, coffee production, Heckman selection model, behavioral economics

1. Introduction

Present climate change projections point towards Mesoamerica as an area where important changes are expected in the future. This includes an abrupt increase in temperatures; less frequent but more intense rainfall events associated to both more frequent drought and flood episodes; and weather-related disasters being tripled by 2030 among other changes (Global Humanitarian Forum, 2010; IPCC, 2014a). These impacts are also linked to an increase in agricultural systems' vulnerability in response to changes (CEPAL, 2010). This circumstance results in aggravated dangers to health and safety of people; increase in poverty levels; and important losses in agriculture, food insecurity, etc.

Nicaragua is one of the four most impacted countries by climate change following the Global climate risk index (Kreft et al., 2015) and it ranks 27^{th} most vulnerable in the world following the indicators for vulnerability-resiliency developed by Yohe et al. (2006). Therefore, it can be considered that a range of international indicators classify Nicaragua as one of the most vulnerable countries to climate change. There is, nevertheless, room for improvement, since agriculture is also an activity that shows a high capacity for adaptation (IPCC, 2014a; Baca et al., 2014). However, shaping how to address these adaptation efforts is a challenge itself, since it is necessary to tackle climate change impacts while also to coping with the barriers for the implementation in the local communities and trying to take advantage of potential opportunities (IFAD, 2012). This paper analyses the determinants that affect the perception of adaptive capacity of Nicaraguan smallholder farmers. About 97 percent of Nicaraguan coffee producers are smallholders and the rest of the production is considered medium or large plantations (USDA, 2016). Smallholder producers that face low and unstable prices and incomes are compounded by lack of access to social infrastructure and services (MacDonald, 2014). These groups are also among the most vulnerable to global change (Schroth et al., 2009).

A range of studies predict high climate change impacts for both economy and society in Nicaragua, especially for the agricultural sector (Iglesias et al., 2012; Anwar et al., 2013; Novo and Garrido, 2014; IPCC, 2014a). Nicaragua has been highly affected by the ENSO phenomenon due to its geographical situation, with important losses for the society (Basso et al, 2001). For example, hurricane Mitch, a tropical storm occurred in 2005, hugely affected the whole economy in Nicaragua with losses reaching 988 million US$ and with damages over more than 80 million of arable land hectares (CEPAL, 2010; MAGFOR, 2013). Increasingly intense and recurrent ENSO phenomena would significantly impact agricultural production, fluctuation of natural resources and groundwater (Ewbank et al, 2019; Hannah et al, 2017).
Nicaragua by its geographical position is one of the countries most affected by climate change (Eckstein et al, 2018). Its coffee production is expected to vastly shrink in some critical areas (Davis et al., 2012) as suitability is to be reduced by up to 40% in the country (Glen et al., 2013; Rahn et al., 2014). Coffee is the largest national export in Nicaragua (18.2% of total exports). Coffee production has been widely reported to be Particularly sensitive to climate change (DaMatta, 2004; Läderach et al., 2011; Läderach et al., 2013; Glenn et al., 2013; Quiroga et al., 2015). Unpredictable rainfall, extended drought periods and extreme weather events are likely to threat a number of coffee producing areas throughout the world (Ericksen et al., 2011), which would imply relevant threats to the Mesoamerican region and particularly to Nicaragua.
About 44,519 Nicaraguan smallholders rely on incomes derived from coffee production, with a land tenure of about 127,000 ha. About 300,000 people are employed in related activities, representing 53% of employment in the agricultural sector and 14% of national employment, also contributing up to 20% of GDP (Blundo et al., 2015). Many ecosystems in the world are the result of a close interaction between local people and their environment, which are currently recognized as social-ecological systems. Climate change can degrade those systems to a point

where those systems stop being autonomous (Fernández-Manjarrés et al. 2018). The degradation of the environmental side of the system has an impact over the social half. Human societies stop being able to rely on their environment to obtain basic ecosystem services such as clean air and water, recreation and leisure, water regulation, etc. Societies are then reliant on external inputs of those services and front the need to migrate in order to avoid a degradation of their living conditions.

Exposure is just one among the many variables determining the risk posed by climate change. As shown in the framework for risk assessment and management designed by IPCC's Working Group II (IPCC, 2014b), adaptation, while not affecting climatic hazards (which are affected by mitigation practices), has an implication over the social side of the equation. Our research interest lies on the interlinkages between adaptation and vulnerability. Less developed countries will have more difficulties for coping with some of the impacts due to their handicaps in terms of adaptive capacity (Alfaro and Rivera, 2008; Warner and Geest, 2013). Therefore, increased efforts on adaptation will be needed to reduce threats to aspects such as food security, livelihoods and biodiversity, associated with the rapid spread of coffee leaf rust and falling commodity prices (Bacon et al., 2014).

We distinguish between two different perceptions that are actually linked: (i) whether the farmer thinks that climate change induced losses are irreversible, and therefore will make no additional effort oriented to adaptation. It is important to characterise which factors from the farmer's perspective affect the perception on reversibility not to adapt to climate change. (ii) if the farmer perceives that the losses are not unavoidable, the perception of adaptive capacity level is important in order to determine the potential barriers for adaptation.

Figure 1 outlines the general framework of our analysis. RQ1-3 mark the interactions that are studied in each on the three research questions described in Figure 2. This figure marks the initial dichotomy farmers face: whether they have capacity to reverse the impacts of climate change they will be facing in the coming years or their capacity to adapt to the new situation. The analysis of the perception on reversibility marking the frontier between farmers assuming any kind of capacity to reverse climate change impacts is the starting point for this study.

Those that find themselves able to reverse those impacts were classified according to their perceived level of adaptive capacity (high, medium and low). Finding the determinants (Conditioning factors) for the degree of adaptive capacity perceived (RQ1) or the perception of capacity to reverse impacts at all (RQ2) were the first two objectives of the study.

Furthermore, this work adds to the conditioning factors two perspectives based in the two scenarios constructed for this work (see section 2.6). These scenarios are based on differentiated levels of investment on education over climate change impacts. The third aim of this work was to find how different levels of investment on this type of education could modulate farmers' perceptions (RQ3).

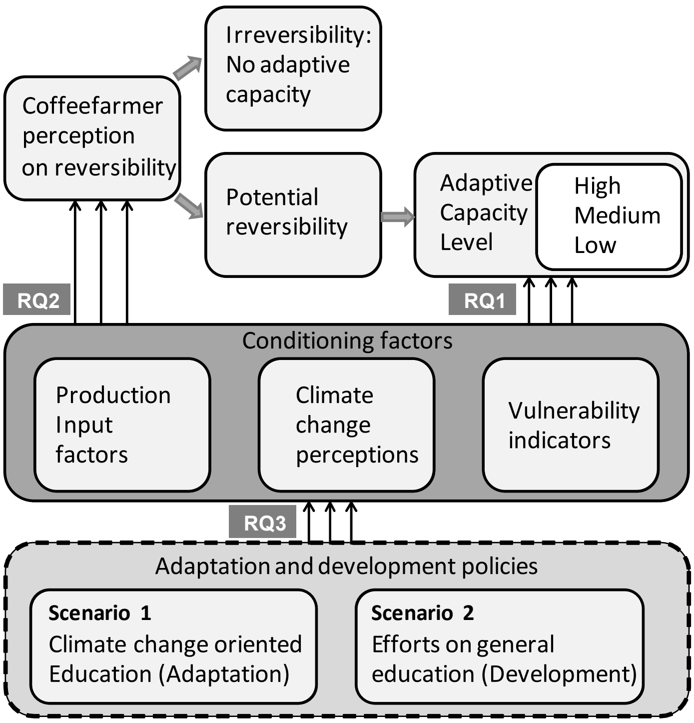

Figure 1. General framework of our analysis.

Section 2 describes the methods used for estimating the probabilistic model. Descriptions on the methodological framework, the data collection and description of variables, as well as details on the econometric model are provided in this section. Section 3 presents the results on the estimations, marginal effects and some policy driven simulations based on development factors. Finally, some conclusions are outlined.

2. Materials and Methods

2.1. Methodological framework

In this paper, we estimate a Heckman model with sample selection to simultaneously regard the different components affecting individuals' perception of irreversibility as well as their perceived level of adaptive capacity.

Figure 2 shows a summary of the methodological steps taken in this paper and a general perspective of methods and research findings. The methodology is based on the estimation of Ordered Probit with sample selection to analyse the main determinants influencing smallholders' perceived adaptive capacity. Sample selection models have been widely used to analyse participation processes results when there are some censored observations. This phenomenon needs to be taken into account in the context of environmental economics (Ekeland et al., 2004; Bosselmann, 2012; Drake et al., 2013; García de Jalón et al., 2013; Noblet et al., 2015). We study the determinants for farmers' perception on adaptation options.

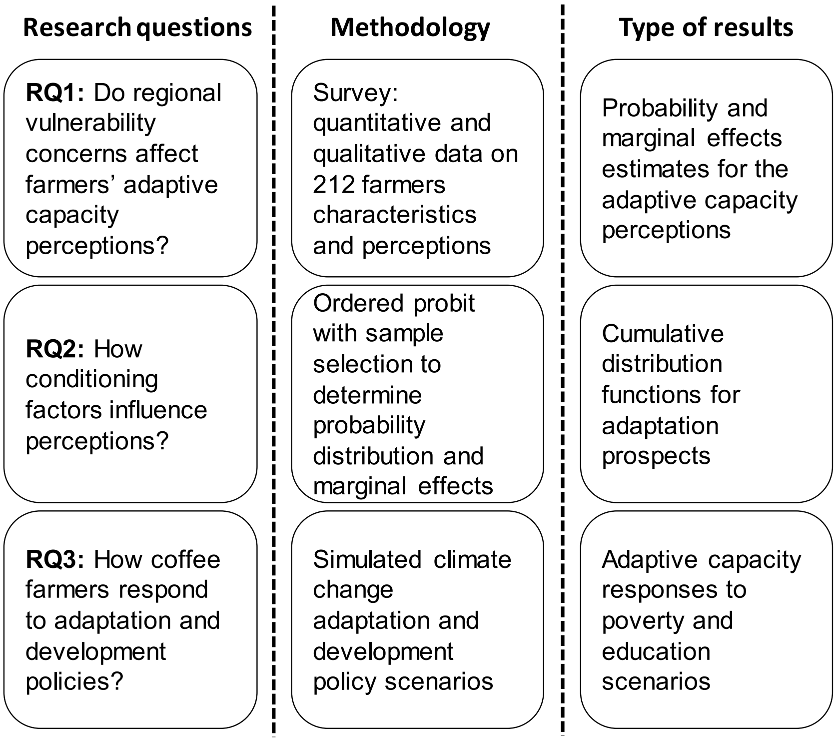

Figure 2. Description of the study.

We explore the determinants of this perception over adaptive capacity considering different types of conditioning factors, including: (i) the investment on or needs for traditional production factors– such as labour, current crop water needs, (ii) perceptions on climate change—such as expectations about climate change impacts, erosion risk or water availability– and (iii) vulnerability indicators – such as poverty, education and economic dependence.

Within the production factors, the size of a farm can be measured in terms of area, stock numbers, money turnover, labour units, etc. (DEFRA, 2010). In this paper, farm size is measured in terms of labour units, since IXMATI and CIRAD (2014) consider labour as a central criterion for classifying agricultural holdings from a socio-productive perspective in Nicaragua. With respect to crop water needs, the measure is taken from the farmers' perspective, depending on the need for additional water sources such as rivers and wells, taking a binary perspectives. A quantitative measure of the current water use would be interesting to characterize the marginal effect for each additional dotation but it is difficult to obtain accurate information at the farm level for this aspect.

For our approach, we follow Kelly and Adger's (2000) approach defining vulnerability in terms of the human dimension alone, and understanding that provides a policy-relevant framework, within which, the value of specific interventions aimed at improving the capacity of people to respond to stress can be judged

Regarding these vulnerability aspects, our approach aims to focus on the most relevant aspects for local communities' vulnerability. We used three indicators related to socioeconomic aspects such as rent, education other socioeconomic aspects. The selection of these variables took into account the national strategy designed to put the country in the path of achieving the Sustainable Development Goals (SDG), the National Environmental Strategy and Climate Change in Nicaragua (2010-2015). This guiding program is oriented to reduce poverty at the rural areas and increasing education as the fundamental axis of development and sustainability (MARENA, 2010).

Instead of rent, our analysis focused on poverty, in order to provide a clear link to the objectives defined in the (SDG) framework, i.e. the eradication of poverty stated in goal number 1, goal number 2 being the eradication of hunger. Education levels were measured according to access to education in each of the municipalities. Education plays also a basic role in the SDG framework. In order to control for other aspects, an index on economic dependence, which included aspects such as access to labour by each family head in the different municipalities. Considering this approach and building on previous discussion of the relationship between vulnerability and adaptive capacity (Brooks et al., 2005; Füssel and Klein, 2006; Rahn et al., 2014).

We present the estimations of marginal effects of the analysed drivers on the estimated probability of smallholders' responses. Finally, we have simulated adaptation responses to development and policy scenarios based on the international development agenda.

2.2. Data collection

Database on this paper comes from two combined sources: (i) a survey to 212 coffee smallholders in two representative regions of Nicaragua, the departments of Jinotega and Estelí, and (ii) secondary information on vulnerability indicators.

The survey was conducted with the auspices of the Ministry of Agriculture and Forestry of Nicaragua (MAGFOR) in the aforementioned Nicaraguan regions. These departments are located in the northern and high-altitude volcanic region of the country were most of the coffee production comes from. Here we use a stratified random sampling as a proportion of a department population. The sample size was determined using the following expression (Scheaffer et al., 2012):

$$n = \frac{\sum_{i=1}^{n} N_i p_i \, q_i}{ND + \frac{1}{N}\sum_{i=1}^{n} N_i p_i \, q_i}$$

where p_i is the proportion of farmers that hold the characteristics of interest. We can substitute $p_i = 0.5$ to obtain a conservative sample size. $q_i = 1 - p_i$; $D = \frac{B^2}{4}$, with B being a bound on the error sampling. N is the population. There are a population of 1624 smallholder coffee producers, and we determine the sample size needed as 215 farmers to be interviewed, with a bound on the error equal 6.34% and a confidence level of 95%. Figure 3 shows the spatial distribution of the farms surveyed, all in the representative locations of Jinotega and Estelí, in central northern Nicaragua.

Figure 3. Sampled farm sites in Jinotega and Estelí coffee intensive regions in Nicaragua.

The information on the survey has been combined with local vulnerability indicators. Vulnerability indicators are based on three indexes representing: (i) poverty in the region, (ii) access to education and (iii) economic dependence (based on labour dependence, so the higher the index the more vulnerable the family is). The coffee farmers from the counties of Jinotega and Estelí are subdivided into municipalities (26 for Jinotega and 112 for Estelí). The National Institute for Development Information provides those regional vulnerability indicators at municipal level (INIDE, 2008a, 2008b) and we matched this detailed information with the data obtained from the survey to geo-referenced farms. Figure 4 shows the histograms of these three variables for the geo-referenced farms.

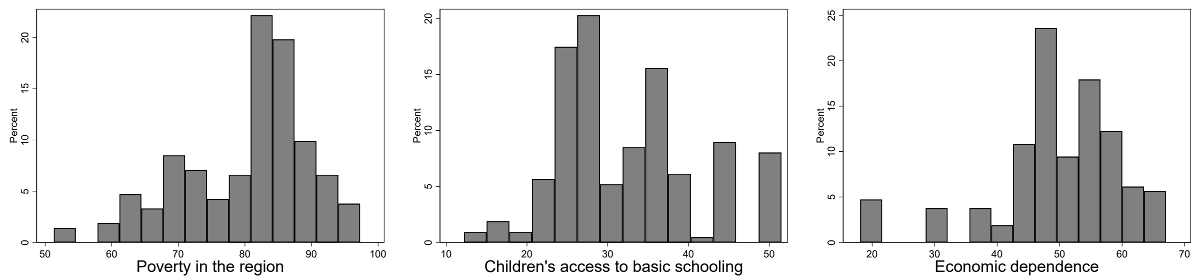

Figure 4. Distribution of response frequency (as percentage) of local vulnerability indicators

2.3. Description of variables

Table 1 describes the variables included in the study, as well as the descriptive statistics of the data. Among the self-reported data, we have included objective indicators of production factors—such as labour force or water needs-- and subjective opinions about climate risk concerns and adaptive capacity perceptions for the 212 individual farmers. In addition, the analysis includes vulnerability indicators at the local level—such as education or economic independence (INIDE. 2008a, 2008b). Descriptive statistics include the mean and standard deviation for the quantitative data and the frequency for qualitative information.

Table 1. Descriptive statistics of the variables

Variable Type	Name	Rationale	Description	Unit	Mean /Freq*	Std Dev.
Dependent variables:						
Climate change adaptation	R_i	Perception on reversibility to climate change	Perception of feasibility and potential reversibility of climate change impacts. (Appendix, Q15)	0= No adaptive capacity (irreversibility)	0.3116	
				1= Potential reversibility	0.6884	
	AC_i	Perceived adaptive capacity	Adaptive capacity level perceived by farmers to cope with the potential impacts. (Appendix, Q16)	1= low AC	0.2449	
				2= medium AC	0.3061	
				3=high AC	0.4490	
Independent variables						
Produc. factors	L_i	Farm size measured as amount of labour force	Total of workers in the farm. (Appendix, Q5)	Number	12.22	11.00
	Wn_i	Water needs	Water needs from rivers and wells for the coffee yield. (Appendix, Q6)	1=Yes	0.1907	
				0=No	0.8093	
Perceptions on climate change	$CCrisk_i$	Climate change risk	Perception about climate change risk. (Appendix, Q7)	1= Worried	0.0512	
				0= Not worried	0.9488	
	Lt_i	Long-term impacts	Perception about long term (more than 10 years from now) climate change impacts in farm. (Appendix, Q8)	1=Yes	0.2977	
				0=No	0.7023	
	$CCim_i$	Perception of climate change on production	Perception of climate change impacts affect coffee production. (Appendix, Q9)	1=Yes	0.1907	
				0=No	0.8093	
	Cco_i	Climate change as opportunity	Perception of climate change as something positive for farm business. (Appendix, Q10)	1=Yes	0.0186	
				0=No	0.9814	
	$Ccwr_i$	Climate change as willingness to renew	Willingness to renew the coffee plantation as a consequence of climate change. (Appendix, Q11)	1=Yes	0.2512	
				0=No	0.7488	
	$Erosion_i$	Erosion risk	Perception about climate change impacts on soil erosion for coffee production. (Appendix, Q12)	1=Yes	0.1953	
				0=No	0.8047	
	Wa_i	Water availability	Perception about climate change impacts on water availability for coffee production. (Appendix, Q13)	1=Yes	0.7302	
				0=No	0.2698	
	$Coop_i$	Perception of farm adaptation cooperative funds	Perception of support (funding) from the farm cooperatives to cope with the potential impact.	1=Yes	0.2605	
				0=No	0.7395	
Vulnerability indicators	$Poverty_i$	Poverty in the region	Percentage of poverty in the region where the farm is located. Source: INIDE (2008a, b) and (Appendix, Q1, Q2, Q3)	Number	80.23	9.37
	Edu_i	Children's access to basic schooling	Index based on children's access to basic schooling in the region where the farm is located. A low education index Source: INIDE (2008a, b) and (Appendix, Q1, Q2, Q3)	Number	32.48	8.90
	Dep_i	Economic dependence	Index of Economic dependence (labour dependence index based on the education of the family head, access to labour of family members, etc.) in the region where the farm is located. Source: INIDE (2008a, b) and (Appendix, Q1, Q2, Q3)	Number	49.58	10.43

Note: *Frequency for discrete variables and mean for continuous variables

The survey data shown in Table 1 indicates that about 31.2% of the farmers perceive themselves as unable to adapt to climate change impacts (i.e. they show a perception of irreversibility). Among those farmers who consider that the situation is not completely beyond their control, most of them reported a high adaptive capacity perception (44.9%). Most of farmers are not worried about climate change risk and they do not have the perception that these changes will affect their production, therefore they do not perceive the need for changes. Due to several problems associated to climate and non-climate-related disasters (e.g. Hurricane Mitch, earthquakes, volcanic eruptions, etc.), farmers might not consider climate change related impacts as their main source of risk. However, they are vulnerable to climate and they do not find they have the capacity to cope with those risks. Nevertheless, most of them are aware of potential water limitations in the future as consequence of climate change.

2.4. Econometric model for farmers' perception

There are two important considerations to take into account for the empirical analysis. First one is that not all farmers perceive they have any kind of adaptive capacity to cope with the climate change impacts (see Figure 1). Farmers who think that have some degree of capacity to adapt to climate change are a subset of the total number of sampled farmers leading to a non-randomly selected sample from the entire set of farmers. Sample selection arises when observations selected are not independent of the outcome variable. Ruling out farmers who think that the impacts will be irreversible, the data becomes censored and the results would be inefficient, inconsistent and will include biased parameter estimates. The second consideration is that for our subset of sampled farmers who think that have reversibility to climate change (Table 1; Appendix, Q15), their perception on reversibility is indicated by the selection from a list of different intervals, then the perceived adaptive capacity is represented by a series of ordered outcomes.

The Heckman model for an ordered decision variable is used to achieve conclusions on the entire sample of farmers as well as the sub-sample of farmers from which the degree of adaptation to climate changes were solicited, (see Greene and Hensher, 2010, and De Luca and Perotti, 2011). The model assumes that both decisions are made concurrently and, therefore, under the assumption that the error terms of the two equations could be correlated. Applications of this model have been prominent in several fields such as finance, law and security, or sports (Rostamkalaei and Freel, 2016; Chowdhury et al, 2018; Keogh et al, 2019).

The objective is to analyse the quantification of farmer-perceived adaptive capacity to cope with the potential climate change impacts (AC_i). This variable is a qualitative ordered one, which we can only observe if a farmer presumes to have adaptation capacity to climate change (R_i). Even though we are interested in modelling a single ordinal outcome, there are two dependent variables in the ordered probit sample-selection model because we must also model the sample selection process (Heckman model). The ordered probit with Heckman sample selection method is reduced to two equations:

$$R_i = \mathbf{1}[\gamma' Z_i + \varepsilon_{1i} > 0] \quad (1)$$

$$AC_i = \sum_{h=0}^{H} h \, \mathbf{1}[\mu_h < \beta' X_i + \varepsilon_{2i} < \mu_{h+1}] \, R_i , \;\; \forall R_i = 1 \quad (2)$$

where $i = 1, \ldots, n$ are observations, $\mathbf{1}[\cdot]$ is the indicator function of the event; and AC_i is not observable , $\forall R_i = 0$.

Threshold $\mu = (\mu_1, \ldots, \mu_H)$ is a vector with $\mu_h < \mu_{h+1}$, $\mu_0 = -\infty$, and $\mu_{H+1} = +\infty$ that partition AC_i into $H+1$ exhaustive and mutually exclusive intervals. X_i and Z_i are vectors of variables that collect individual characteristics that may be common or not in the specifications of both equations (1) and (2) and β and γ are vectors of unknown parameters to be estimated. ε_{1i} and ε_{2i} are, respectively, the error terms for equations (1) and (2) which are distributed according to a bivariate normal distribution with mean zero and variance matrix $\begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}$. Then, the model allows for correlation between unobservable information of equations (1) and (2). As is well known, when $\rho \neq 0$, ordered probit model applied to the equation (2) provides biased results, and, meanwhile, the ordered probit model with sample selection provides consistent and asymptotically efficient estimators for all model parameters. If ρ = 0, ordered probit model applied to the equation (2) will provide consistent and asymptotically efficient estimators for all model parameters.

The conditional probabilities of ordered probit model with sample selection estimated are shown below:

$$\Pr(R_i = 1) = \Phi(\gamma' Z_i)$$

$$\Pr(R_i = 1, AC_i = h) = \Phi_2(\gamma' Z_i, \mu_{h+1} - \beta' X_i, - \rho) - \Phi_2(\gamma' Z_i, \mu_h - \beta' X_i, - \rho)$$

with Φ denoting the standardized normal distribution and Φ_2 denoting the bivariate normal distribution with zero means, unit variances, and correlation coefficient ρ.

The conditional mean function for the ordered model with sample selection is:

$$E\left[AC_i = h \middle| X_i, Z_i, R_i = 1\right] = \frac{\Phi_2(\gamma' Z_i, \mu_{h+1} - \beta' X_i, - \rho) - \Phi_2(\gamma' Z_i, \mu_h - \beta' X_i, -\rho)}{\Phi(\gamma' Z_i)} \quad (4)$$

2.5. Simulation of adaptive capacity perceptions

In order to simulate the effects of different variables we calculated the marginal effects of each of the variables to be analysed. The marginal effects of changes in response variables are obtained once coefficients of the ordered probit model with sample selection are estimated for a continuous variable (W_i) as:

$$\frac{\partial E\left[AC_i = h \middle| X_i, Z_i, R_i = 1\right]}{\partial W_i} = \frac{\partial}{\partial W_i}\left[\frac{\Phi_2(\gamma' Z_i, \mu_{h+1} - \beta' X_i, -\rho) - \Phi_2(\gamma' Z_i, \mu_h - \beta' X_i, -\rho)}{\Phi(\gamma' Z_i)}\right] \quad (5)$$

and for a dummy variable:

$$\frac{\partial E\left[AC_i = h \middle| X_i, Z_i, R_i = 1\right]}{\partial W_i} = \left[\frac{\Phi_2(\gamma' Z_i, \mu_{h+1} - \beta' X_i, -\rho, W_i = 1) - \Phi_2(\gamma' Z_i, \mu_h - \beta' X_i, -\rho, W_i = 1)}{\Phi(\gamma' Z_i, W_i = 1)}\right] - \left[\frac{\Phi_2(\gamma' Z_i, \mu_{h+1} - \beta' X_i, -\rho, W_i = 0) - \Phi_2(\gamma' Z_i, \mu_h - \beta' X_i, -\rho, W_i = 0)}{\Phi(\gamma' Z_i, W_i = 0)}\right] \quad (6)$$

As standard, we used mean values of the continuous variables and median values of the dummy and ordered variables, altering those variables to be analysed for each specific result. Among the variables taken into account, simulations were performed for the two types of farms observed in the sample: (a) farms using water in natural regime (Wn=0) and (b) farms using also water from rivers and walls (Wn=1).

2.6. Policy scenarios for adaptive capacity projections

Nicaragua is one of the poorest countries in Latin America (World Bank, 2015). Rural areas in Nicaragua concentrate a significant part of this problem, also concentrating near half of the Nicaraguan population. Rural households have lower educational levels and larger families than urban households, household heads in this area receive, on average, less than three years of schooling (Wiggins, 2007). This leaves a significant part of Nicaraguan population in a situation of vulnerability, even with declining poverty rates (World Bank, 2017). Natural disasters and distortion of commodity prices in the international market have been phenomena interlinked with poverty. Not only they are a direct cause of it, but also their impacts have been incremented due to this increased vulnerability levels. One of the most affected regions is the coffee-dependent central region.

The United Nations Millennium Declaration, initiated process for international action on human and environmental concerns, including the eradication of extreme poverty and hunger and the achievement of environmental sustainability. Once the 2015-scope of those goals was surpassed, the Sustainable Development Goals were designed as result of the United Nations Sustainable Development 2015 Summit, as a post-2015 development agenda and more ambitious SDG were agreed (UN, 2015), to keep international action in motion.

In the context of these international goals and commitments, Nicaragua developed two important strategic lines to establish the framework of poverty reduction-oriented policies: (i) Enhanced Economic Growth and Poverty Reduction (PRSP) and (ii) National Development Plan (NDP). These actions incorporate indicators to measure the eradication of poverty in the Human Development Plans 2012-2016 and 2018-2021 where the education plays a very important role.

The 2015 United Nations COP-21 meetings in Paris (UNFCCC, 2015), which was a breakthrough in the climate change negotiations, has placed important global attention to inequalities associated with the impacts of climate. An agreement has been developed for mobilizing an important amount of funds for countries affected by ‘El Niño’ and a UN initiative strengthens ability to anticipate, absorb and “reshape” climate impacts. It is therefore a hotspot to understand the contribution of specific educational campaigns focused on strengthening climate change adaptation.

External funding has been destined in Nicaragua as well as in other counties in comparable situations for the financing of a wide range of programs and projects. Several international and regional agencies and institutions such as the International Monetary Fund, World Bank, the

European Union, United Nations, or ALBA coordinate this foreign investment. During the first decades of the present century, public policies originating in external funding have been more oriented to the Millennium Development Goals (MDG) (UN, 2013), and more focused on smallholders and the poorest families. To incorporate the possibility of a change in priorities in the incorporation of the Sustainable Development Goals (SDG), our analysis is based on the comparison between of two different policy scenarios. While both are based on development policies focused on the achievement of the set of goals, they vary in the interpretation made, with a first scenario focusing highly on education on climate change and the second without considering it.

While we do not analyse rural development programme scenarios in detail, we do explore some policy implications in which the perception of adaptive capacity is set to be increased as a consequence of either a reduction in poverty in rural areas or an increase in educational levels. Information about the consequences of vulnerability changes is relevant during the decision-making process. Here we present methods to deal with these alternatives, including: (i) an increase in public education and awareness campaigns about regional climatic change and agricultural consequences s, and (ii) a decrease in rural poverty to achieve the Sustainable Development Goal. Scenario 1 therefore represents a situation in which joint efforts are made in general education and climate change awareness while Scenario 2 represents a situation where the focus is on general education but no specific policies informing about climate change potential impacts and adaptation measures are taken.

Table 2 shows how the variables were adapted for the assumptions in which scenarios were based. As in the previous simulations, mean and median levels were taken as reference for a series of variables and were held constant between scenarios. For those variables that could alter their value through climate change-related education (climate change risk, long-term impacts, perception of climate change on production, climate change as willingness to renew, erosion risk, and water availability) values were altered between scenario 1 and 2, taking a value of 1 in scenario 1 and a value of 0 in scenario 2. For the variable referring to general education, it was assumed a 50% increase in its levels. Both scenarios have We present the results for the different types of perception of adaptive capacity, as well as what we think is the first necessary step to discuss the synergy between potential adaptation and poverty policies.

Table 2. Policy scenarios based on poverty reduction and education efforts

Variable Type	**Name**		**Baseline**	**Scenario 1: Education on climate change**	**Scenario 2: No specific education on climate change**
Production factors	L_i	Labour force	Mean	Mean	Mean
	Wn_i	Water needs	Simulation	Simulation	Simulation
Perceptions on climate change	$CCrisk_i$	Climate change risk	Median	(=1)	Median
	Lt_i	Long-term impacts	Median	(=1)	Median
	$CCim_i$	Perception of climate change on production	Median	(=1)	Median
	Cco_i	Climate change as opportunity	Median	Median	Median
	$Ccwr_i$	Climate change as willingness to renew	Median	(=1)	Median
	$Erosion_i$	Erosion risk	Median	(=1)	Median
	Wa_i	Water availability	Median	(=1)	Median
	$Coop_i$	Perception of farm adaptation cooperative funds	Median	Median	Median
Vulnerability indicators	$Poverty_i$	Poverty in the region	Simulation	Simulation	Simulation
	Edu_i	Children's access to basic schooling	Mean	More general education +50%	More general education +50%
	Dep_i	Economic dependence	Mean	Mean	Mean

3. Results and Discussion

3.1. Estimated model and factors affecting adaptive capacity

Table 3 shows the results of the simultaneous estimation of equations (1) and (2), corresponding to perceived quantification of adaptive capacity to climate change impacts, taking into account that we only observe this variable if farmer belongs to the group of farmers that are conscious of potential reversibility of climate change (sample selection).

Table 3. Ordered Probit regression with sample selection on farmers quantification of perceived adaptive capacity

		Dependent variable: *AC*			Dependent variable: *R*		
		Coef	Std.Err		Coef	Std.Err	
Prod. Factor	*L*	-0.0330	(0.011)	***	0.0378	(0.011)	***
	Wn	-0.9531	(0.294)	***			
Perception climatic change	*CCim*	-0.7158	(0.338)	**			
	Cco	-0.7625	(0.623)				
	Ccwr	1.1560	(0.495)	**			
	CCrisk				-0.2966	(0.532)	
	Lt				0.8233	(0.269)	***
	Erosion				0.9749	(0.326)	***
	Wa				-0.5892	(0.252)	**
	Coop	-0.7565	(0.404)	*	-0.5214	(0.246)	**
Vulnera. index	*Poverty*	-0.0326	(0.019)	*	-0.0416	(0.020)	**
	Edu				0.0639	(0.019)	***
	Dep				-0.0220	(0.015)	
LR test of indep. eqns. (ρ = 0): $\chi^2(1)$			2.7*				
Censored obs			63				
Uncensored obs			146				
Log likelihood			-197.89				
LR test: $\chi^2(7)$			99.09***				

Note: (***) significant coefficient at 1%; (**) significant coefficient at 5%; (*) significant coefficient at 10%.

The joint test of goodness of fit of the estimated model confirms its statistical significance: $\chi^2(7)$ = 99.09 for the model at p<1%. Moreover, the statistical test of the null hypothesis that the correlation coefficient ρ between the residuals of the main (Eq. 2) and the selection equations (Eq. 1) would be equal to zero is rejected. These results confirm the relevance of using the selection equation, so it is important to take into account respondents by perception of the "reversibility" of climate change to explain the adaptive capacity.

Table 4 shows the marginal effects of the estimated drivers affecting the probability of the smallholders' perceptions as proposed in equations (3) and (4). These marginal effects are calculated for each outcome by considering the mean of the continuous variables and the median value of the dummy variables.

Table 4. Estimated marginal effects on farmers quantification of perceived adaptive capacity

	Pr(Low *AC*)=0.074			Pr(Med. *AC*)=0.381			Pr(High *AC*)=0.545		
	Coef.	Std.Err		Coef.	Std.Err		Coef.	Std.Err	
L	0.0046	(0.002)	**	0.0084	(0.003)	***	-0.0131	(0.004)	***
Wn[a]	0.2376	(0.101)	**	0.1069	(0.056)	*	-0.3444	(0.086)	***
CCim[a]	0.1590	(0.099)		0.1126	(0.044)	***	-0.2716	(0.116)	**
Cco_i[a]	0.1736	(0.194)		0.1133	(0.044)	***	-0.2869	(0.202)	
Ccwr[a]	-0.0698	(0.027)	***	-0.2832	(0.102)	***	0.3531	(0.115)	***
Coop[a]	0.1717	(0.127)		0.1133	(0.043)	***	-0.2849	(0.129)	**
Poverty	0.0046	(0.003)		0.0083	(0.005)	*	-0.0129	(0.007)	*

Note: (***) significant coefficient at 1%; (**) significant coefficient at 5%; (*) significant coefficient at 10%. [a] Calculated for discrete change of dummy variable from 0 to 1. The individual of reference takes the mean value for the continuous variables and the median for the qualitative variables.

The signs of the estimated coefficients suggest that the relationship between number of workers in farm and farmers' perception of irreversibility of no adaptation is negative. Larger farms managers seem not to find the effects of climate change as irreversible in so far as those in charge of small farms. They perceive that they can cope to some extent with climate change impacts, so climate change is less perceived as irreversible when the farms get larger—i.e.

concentration processes. This result was also found in previous literature in other countries (Nyangena, 2007; Deressa et al., 2011; Abid et al., 2015).

However, their specific perception of how prepared they are to adapt is less optimistic than in small farms. The larger the size, the lower the perception of being able to adapt to climate change. This can be seen as paradoxical result. In our view, however, this perception can be explained considering that larger farm managers have more resources at their hand and are therefore more aware of their possibilities to adapt. They are not only aware of the fact that adaptation to climate change impacts is possible but are also aware of their limited capacity to do so.

Current water needs from rivers and wells (W_n) is also determinant for farmers adaptive capacity. The farmers have a higher adaptive capacity perception when current water needs are lower. With respect to water availability expectations due to climate change (W_a), the more worried about water availability for coffee due to climate change the farmers are, the lesser their perceptions of reversibility. This could be related to the characteristics of the Nicaraguan climate. Particularly, droughts related to the ENSO could affect farmer perceptions. Those not being able to rely in rainfall-based irrigation are more likely to show lower level of confidence in their adaptive capacity (Quiroga et al, 2015).

Awareness of the problem and potential benefits of taking action is another important determinant for adaptive capacity perceptions (Hassan and Nhemachena, 2008). Maddison, (2007) found that farmers' awareness of changes in climate attributes is important for adaptation decision making. In our model, coffee production risk perception due to climate change decrease the perception of adaptive capacity in farmers. Marginal effects show that probability of observing high adaptive capacity decreases by 0.2716 for farmers having shown a perception of the risk in coffee production due to climate change with respect to those who haven't. At the same time, the willingness to renew the coffee plantation as a consequence of climate change increase the perception of adaptive capacity in farmers. Having the willingness to renew the coffee plantation increases the probability of observing a high adaptive capacity by 0.3531.

As expected, there is a relationship between coffee producer's vulnerability and adaptive capacity to climate change in Nicaragua. Poverty in the region presents a negative and significant result in both equations, which means, the poorer is the county where the farm is located, the lower the perceived quantification of being able to adapt to climate change impacts (level of reversibility) as well as the perceived irreversibility to this phenomenon. Education is an important factor influencing adaptation. There is wide evidence that improving education and disseminating knowledge is an important policy measure for stimulating local participation in adaptation initiatives (Glendinning et al., 2001; Dolisca et al., 2006; Yohe et al., 2006; Anley et al., 2007; Iglesias et al., 2012). Here we also find that education is a key factor for increasing farmer's adaptive capacity perceptions. The higher is children's access to basic schooling the lower is the perception of irreversibility to climate change impacts. These results are consistent with the Intergovernmental Panel on Climate Change IPCC (2014a) that states that adaptive capacity is closely linked to social and economic development.

3.2. Mapping probability of adaptive capacity perception at department level

Figure 5 shows projected probabilities for the farmer's perception of low adaptive capacity as a result of the model estimations being applied to the information on vulnerability indicators for the whole country at the department level. These results have been based on the average levels/median values for each department and comparing between outcomes differing by the variable water needs.

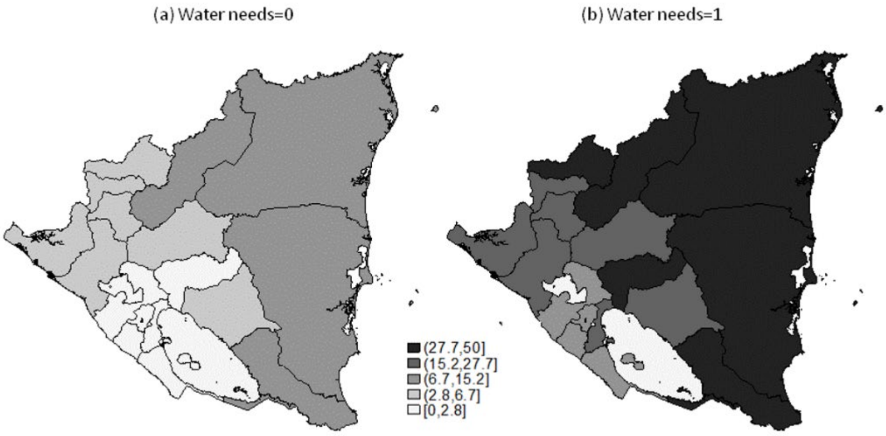

Figure 5. Nicaragua projected probabilities for the farmers perception of low adaptive capacity.

Source: Own elaboration. Simulation from the model for (a) farms without water needs from rivers and wells and (b) farms with water needs from rivers and wells.

We can observe that the perception of low capacity of adaptation to climate change is very sensitive to the vulnerability indicators, and geographical aspects. The areas where farmers feel themselves less able to cope with climate change risks are North-eastern regions, which at the same time are the poorest and more vulnerable areas in the country. Therefore, as has been widely pointed there are a strong link among poverty and climate change vulnerability (Kelly and Adger, 2000; Eriksen and O'Brien, 2007; Myers and Kulish, 2013).

We can observe that the picture is different depending on farmers' current water needs. The probability of perceiving low adaptive capacity clearly increases for farmers that report their water needs are not being met. This may indicate that those farmers that are currently dependent on extra water needs are more aware of climate change.

3.3. Simulation of adaptive capacity response to rural development policies

In this section, we simulate some potential responses to structural adjustments in terms of adaptive capacity level (quantification) perception scenarios from the coefficients estimated in Table 3. Farmers' responses to changes of poverty in the region where the farm is located were simulated for the different levels of adaptation capacity perception. Figure 6 plots the predicted probabilities for each adaptive capacity perception depending on poverty rate. We have run the simulations differentiating between those farms without specific extra water needs (a) – using water in natural regime-- and those with extra water needs from rivers and wells (b). The most important fact we can observe is how the probability for high adaptive capacity will increase if the poverty in the region decrease. Our results show that farmer's perception of high adaptive capacity hugely depends on poverty level. For example, the probability of a farmer without extra water needs perceiving high adaptive capacity based on the 2005 poverty indicators in Estelí and Jinotega is about 54% while being only 20% among those farmers using water from rivers and wells. Both figures show as references for poverty levels, levels of poverty in rural areas extrapolated from the data made available by the World Bank (2008; 2017).

Nicaragua's National Plan for Human Development (PNDH) 2007-12, is updated through 2016. Its overarching goal is to reduce inequality by increasing poverty-reduction spending and boosting investment in social sectors and rural infrastructure. When we project the poverty rate under the Millennium Development Goal (MDGs) objective the farmers perception of having high adaptive capacity goes to 91% for farmers without specific water needs and 66% for those using water from rivers and wells.

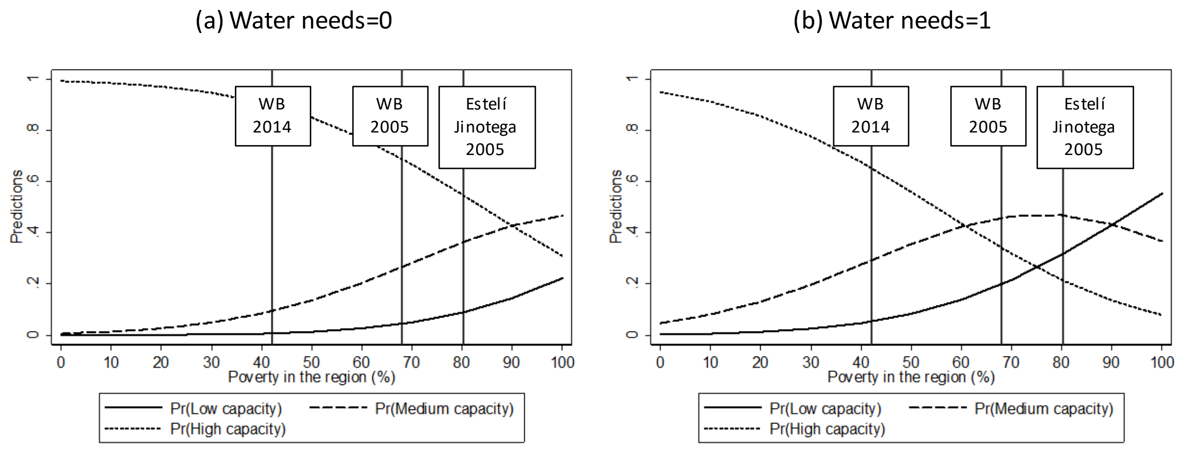

Figure 6. Probability of high, medium and low adaptive capacity perceptions depending on poverty rate (%).

Note: WB denotes World Bank references for poverty levels in rural areas extrapolated from the data made available by the World Bank (2008; 2017).

Source: Own ellaboration. Simulation from the model for (a) farms without water needs from rivers and wells and (b) farms with water needs from rivers and wells.

As a poverty reduction strategy, the PNDH relies heavily on creating the highest possible rate of economic growth. This also means that population need to be educated.

Figure 7 shows the results of simulating some potential responses to structural adjustments in terms of adaptive capacity level perception scenarios related with public education campaigns and those specific campaigns to inform about regional climatic change and agricultural consequences --from the coefficients estimated in Table 3. In general, our results show that those farms without current water needs are more optimistic with respect to their adaptive capacity since they show a higher probability of perceiving high adaptive capacity than those who use water from rivers and wells. Their perception is even better when specific campaigns on climate change impacts and adaptation are developed (Scenario 1). In this case, when the focus is only in general public education (Scenario 2) no significant changes are observed respect to the baseline. However, a very different picture is shown for those farmers who currently use additional water from rivers and wells. In this case, we can observe important differences among the two analysed scenarios and the baseline. Public general education has an effect of increasing the awareness and therefore the perceptions of having high adaptive capacity is reduced with respect to the baseline (more educated the farmers, less optimistic the perceptions). However, when the focus is on specific campaigns on climate change impacts and adaptation measures (scenario 1), the perception of having high adaptive capacity increase with respect to scenario 2 but being still lower than the baseline. In order to obtain these results, marginal values were calculated following the steps described in section 2.5 holding constant all variables but those appearing in the graphs.

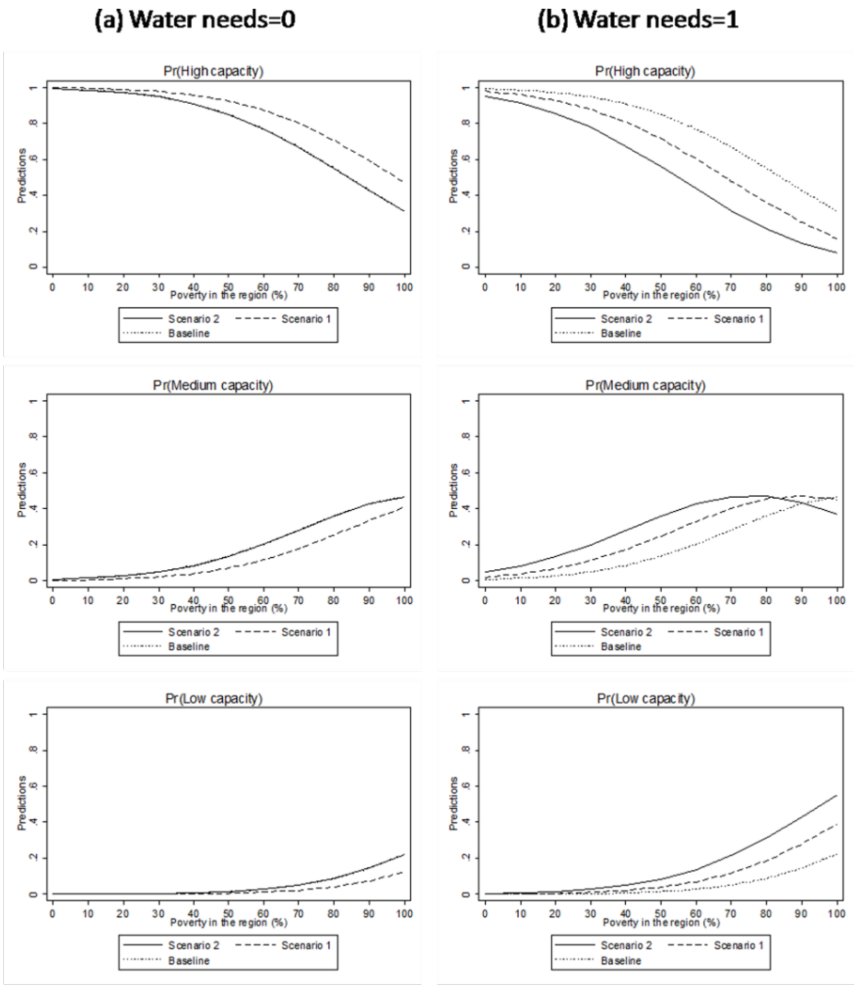

Figure 7. Predictive marginal effects of adaptive capacity levels depending on poverty rate and policy intervention scenarios.

Source: Own elaboration. Simulation from the model for (a) farms without water needs from rivers and wells and (b) farms with water needs from rivers and wells.

Therefore, our results show an important role of the educational policies. An increase in public education efforts would make the people more conscious about climate change and so less optimistic when asked for their own capacity for adaptation. This increase in the awareness could imply less barriers for adaptation. In addition, the specific education focused on climate change increase their adaptive capacity especially for those farmers with higher current water needs.

4. Conclusions and discussion

This paper analyses perceptions on adaptive capacity to cope with the potential climate change impacts. Climate change is perceived as one of the most important pressures over the economic resources in Mesoamerica, and much attention is now being committed to the relationship among poverty, education, and climate change vulnerability and adaptation. Especially since sustainable development and reduction on world inequalities is becoming a main goal for United Nations (UN) and therefore most of National governments starting from the MDG in 2000 (UN, 2013) and being reinforced in the SDG in 2015 (UN, 2015).

Here we have analysed the conditioning factors for adaptive capacity perceptions. We characterize the main drivers affecting farmers' perceptions of their own adaptive capacity and we have simulated different policy scenarios considering the sustainable development goals of United Nations in terms of poverty reduction and education concerns. Poverty and education awareness emerge as key factors for greater concern of farmers with regard to their adaptive capacity. As such, an effort to provide more information on climate change risks can be a determinant of smallholders' acceptance of adaptation measures. Here we analyse also the role of educational programmes to instruct the population about their own adaptation potential. An increase in public education efforts would imply less barriers for adaptation, however, specific education focused on climate change play a major role especially for those farmers with higher water needs in the present. This is important in order to define priorities for adaptation policy at the national and international level.

This approach presents, nevertheless, its own limitations. First, it does not consider several options for adaptation, among them the possibility of changing the crop type. These changes could be relevant from both the human and the environmental perspective. Though introduction of different crops (such as for example cocoa, musaceae, etc.) might help producers deal with some effects derived from climate change, these changes might have grave effects over the ecosystem of the region. Extensive cocoa crops might affect biodiversity and promote soil erosion, therefore constituting a case of maladaptation. This should possibility be considered in a wider analysis and is therefore accounted as a point for further research. Table 5 shows the main adaptation measures that coffee farmers in the region have selected as willing to implement in their farms, either as autonomous responses or with some external support. This is important to provide an idea of which specific measures are behind their adaptive capacity perception.

Table 5. Main adaptation measures selected by coffee farmers in our study

Adaptation measures	Willingness to adopt the measure (%) (Appendix, Q17)	Perceived capacity to introduce the measure without external support (%) (Appendix, Q18)
Reforestation	49.77	31.13
Renew plantations	9.39	20
Soil conservation	6.10	23.08
Crop diversification (cocoa, musaceae, etc)	5.63	33.33
Water protection (contamination)	5.16	54.55
Avoid deforestation	4.69	80
Avoid to burn pastures	4.23	100
Change to organic production	3.29	0
Shade-grown coffee	2.35	0

Good nursery practices	2.35	20
Capital investment	2.35	40
Hedgerows management	1.88	50
Improved varieties	1.41	33.33
Labour training	0.94	0
Migration to optimal altitudes	0.47	0

Extended research may also explore the specific role of pests and diseases in the adaptive capacity perceptions and therefore in the barriers and opportunities for adaptation. The high incidence of pests and diseases in the area could also play an important role in the decision of a transition to other crops. Although after the 2011-2012 harvest, the disease left 20% of the national coffee fields in need of renovation, the coffee rust decimated mainly weaker plantations and less resistant and older varietals (Avelino and Rivas, 2013; Avelino et al, 2015; Ziska et al, 2018). However, future climate change will result in shifts in the incidence of pests and diseases that could be detrimental to coffee yields at a larger dimension (Jaramillo et al., 2009).

The role of water scarcity will also play a significant role in the future. Climatic predictions lie out of this study's reach, but more irregular precipitation patterns often associated to climate change accompanied by a potential increase in ENSO's impacts create a context of uncertainty surely adding to the present perceptions on adaptability.

Nicaragua is a relatively homogeneous country, which implies a straightforward extrapolation of the results. Nevertheless, extending this research beyond its frontiers would improve our understanding of which future policies to better adjust to the aims described in wider programs such as the SDG framework. Particularly, the Mesoamerican region could learn from the lessons drawn from this study. Nevertheless, socioeconomic variations, local governance practices and climatic variations may alter the results in such areas.

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Appendix

Questions related to our study.

	Answers
Q1. Department	_____________
Q2. Municipality	_____________
Q3. County	_____________
Q4. Exploitation area (Ha):	Indicates the total number
Q5. How many people were working in this farm in the last period?	Indicates the total number
Q6. In adition to rainfall water, do you need supplemental water from rivers and wells for your coffee production?	Yes No
Q7. Are you worried about global warming?	Worried Not worried
Q8. Do you think that climate change impacts will affect this farm in the future (more than 10 years from now)?	Yes No
Q9. Do you think that climate change will affect coffee production in your farm?:	Yes No
Q10. Do you think that potential climate change impacts are a business opportunity for your farm?:	Yes No
Q11. Would you consider to renew your coffee plantation as a consequence of climate change?	Yes No
Q12. Do you think climate change is something that is affecting or is going to affect soil erosion for coffee production?	Yes No
Q13. Do you think climate change is something that is affecting or is going to affect water availability for coffee production?	Yes, I think water availability is going to be reduced No, I think water availability is not going to be affected.
Q14. Assuming climate change is happening, do you think you will have the support (funding) from the farmer cooperatives to cope with the potential impacts? Please, indicate if you think you will receive:	No support Support
Q15. Do you think you have the potential to cope in some degree with the impacts of climate change in your farm?	Yes (whatever the degree of adaptive capacity) No (the impacts will be irreversible)
Q16. In the case you answered positively to the previous question (Q15): Please, select the degree of adaptation potential (or level of reversibility) concerning your farm.	Low capacity to adapt Medium capacity to adapt High capacity to adapt
Q17. Please, can you mention the main adaptation measure you could consider implementing in your farm?	_____________

Q18. With respect to the previous adaptation measure you proposed, do you think you can implement it without external support?	Yes No