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Mapping coffee producers' transition to cocoa as a response to global change: smallholders' perceptions in Nicaragua

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Abstract: Coffee producers in Mesoamerica are already facing some of the expected challenges arising from pressures derived by climate change, principally lowered water supply. Some farmers have implemented strategies of adaptation based on crop diversification, being the introduction of cocoa one of the main alternatives. The focus of this research is to analyse coffee producers' perceptions on changing from coffee to cocoa as an adaptation strategy. Here we simulate the farmers' response to climate factors and water needs, also considering its relationship with humankind, specially through variables related to economic and social development. Farmers' perceptions were extracted via a specifically designed questionnaire applied to 219 small coffee producers in the departments of Estelí and Jinotega in Nicaragua. A Multivariate probit econometric model was estimated to analyse diversification through three simultaneous equations—for climatic, economic and social development drivers. Marginal effects of these drivers were calculated and used to simulate farmers' response to global change scenarios. Regional distribution of crop diversification probability was mapped considering different global change scenarios. The importance of climatic factors over the decision process is, as data shows, higher than social and economic issues. The environmental implications of this change, such as deforestation, have also been discussed.

Keywords: Water needs, crop diversification as adaptation, Nicaragua, climate change impacts, coffee and cocoa production, Multivariate Probit

JEL Codes: Q15, Q54, I32, O54, C34, C35

1. Introduction

Climate change impacts are expected to hit harder developing countries, among other reasons, due to their lower capacity to adapt [1]. Food security, water supply and agricultural production will be some of the most important troubles to be faced by countries that already face important challenges. Poor households with coffee farms represent one of the vulnerable segments of these counties' populations, as they strongly depend on crops due to their limited access to other income sources. Many small producers are already observing some early effects of climate change overwhelming their response capacity [2]. Farmers in developing countries already face problems arising from diminished productivity rates caused by lack of access to extension services, credit and quality agrarian inputs. This exacerbated vulnerability is expected in poor countries whichever their climatological characteristics [3].

Recognising that climate change generates negative impacts on agricultural output has spawned a desire to increment resilience in agrarian systems. A rational and efficient method of improving resilience may relay in a higher diversification of agricultural crops [4]. This might serve as an incentive for farmers to incline for strategies that increase resistance while generating economic profits.

Coffee crop productivity and its adequacy in a context of climate change have been extensively analysed for the short term [5-9]. Forecasts for coffee producing countries show scenarios of high uncertainty originating from the expected effects of climate change. This will increase the impacts of pests and diseases, which will imply a shrinking productivity and a decreasing quality, as well as increases in production costs, and therefore, will negatively affect small producers. In the case of Central America and, more concretely, Nicaragua, climate change has the potential of reducing crops by a 40%. In the long term, it must be noted that impacts are expected to rise. Reductions on quality and yields are expected, accompanied by a raise in production costs. As a direct implication of this new state, drastic reductions in smallholders' incomes will occur. Poor households with small plantations with high dependence on their yield will be the most vulnerable; some of them have already seen their bearing capacity overwhelmed [2].

Cocoa cultivation has been proposed as an alternative for coffee production. Cocoa tree is a sylvatic plant which is known to be sensitive to drought, though quantitative information about the hydric relationship of cultivated plants is scarce [11]. Cocoa has played a fundamental role in wood conservation and biodiversity both in a positive and in a negative way. Cocoa has also been an important factor in the agricultural transformation of woods. Moreover, cocoa's shade offers a valuable habitat for flora and fauna in woods belonging to agricultural landscapes [12, 13].

Cocoa is the main exportation product in various countries of the Western African region (which are responsible of 68% of world's production). Ivory Coast, Cameroon, Nigeria and Ghana are the countries that most profit from this crops, while Ecuador, Venezuela, Brazil, Panama, Costa Rica, Malaysia and Indonesia also appear among the biggest cocoa exporters. Vietnam and India have also recently made cocoa a priority yield in some of their regions. Climate change and the improving international market prices of cocoa have forced the expansion of agrarian land and the reduction of natural forest land. On the demand side, a 100% increase is expected for 2050. Worldwide, 5 to 6 million people work at small-scale agriculture, cultivating more than 7 million ha and providing an important share of their family income. According to the World Trade Organization (WTO), the exportation of cocoa products accounts for 5 to 6 million euro per year, and the use of cocoa and cocoa mass for chocolate and cosmetics production allows for a bigger and fairer market [14, 15]. The decision on how to respond to these challenges will have important effects on tropical woods and wild species in cocoa producing countries [16]. The present trend favours unsustainable practices, less conscious about environment that concentrates mainly on satisfying consumer demand [17].

On the other side of the balance, sustainable agriculture and rural development's success will depend greatly on the involvement of different sectors, such as rural populations, governments, private sector and international cooperation. The response to climate change impacts will require multi-scale action. This means that even when dealing with local impacts, all rural, national and global agents must take action, especially where vulnerable populations are involved. When considering rural response, we must also note that this must be oriented by research in order to generate adequate measures for adaptation and mitigation that consider newly developed scenarios [18].

Participatory agricultural research has been defined as the collaboration of farmers and scholars in agricultural research and development [19]. There is a need to explore the climatic, market and institutional aspects that coffee producers could take into account when dealing with the possibility of introducing cocoa production into their economies. This work has the aim of analysing the factors taken into account by smallholders when deciding if they switch from coffee to cocoa agriculture. In order to analyse this issue, we performed an econometric analysis of both subjective and objective determinants influencing the decision of changing or not the crop type. A Multivariate Probit was estimated, which calculated three simultaneous equations for three different incentives. Different indicators for climate change were included, alongside with information about producers' vulnerability, percentage of damaged plants in the last decade in incidents that could be related to climate change, water scarcity, price ad production cost awareness, and vulnerability indicators.

2. Materials and Methods

2.1 Conceptual framework

In order to analyse the drivers behind the decision of changing crops from coffee to cocoa, set of possible variables was chosen. These possible variables were classified into three groups: Climatic variables, economic variables and those related to social development. Each group was related to one of the possible answers stated by farmers as reasons for the crop change: climatic change, economic reasons or government support (respectively). A fourth set of variables was later defined, and included transversal variables that affected their decision over the three levels. Figure 1 outlines the general framework of our drivers and variables.

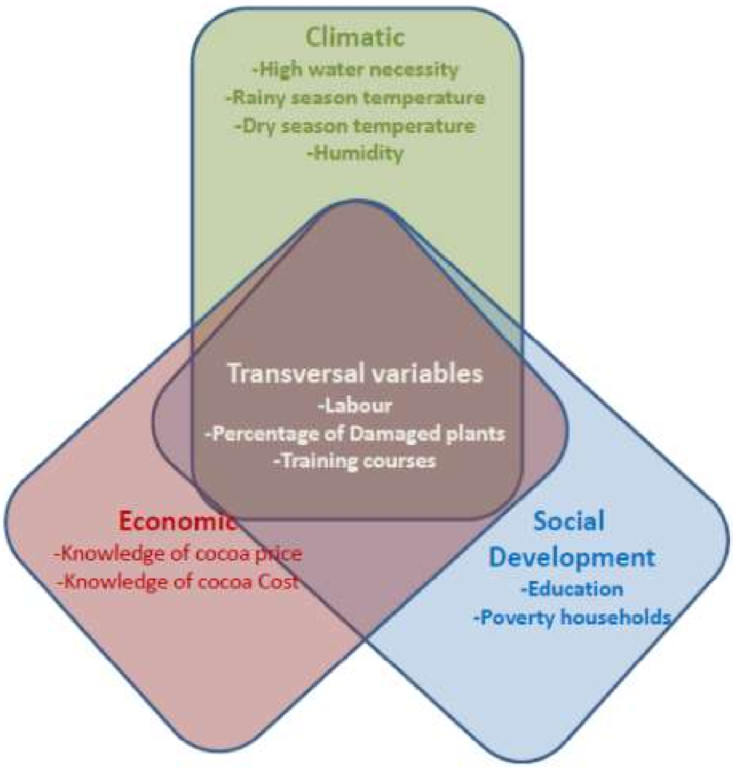


Figure 1. Conceptual model showing variables affecting farmers' choices.

2.2 Data collection

The first source of data was a survey conducted within the area of the Nicaraguan departments of Jinotega and Estelí. This process counted with the collaboration of the Ministry of Agriculture and Forestry of Nicaragua (MAGFOR). The departments analysed were located in the volcanic region of northern Nicaragua, a high area where an important part of coffee is produced. 215 farmers were selected from a population of 1,624. This process was performed between February and March 2016.

The data used for this research was taken from two different sources : i) data on temperature, rainfall and humidity registered from the Nicaraguan Institute of Territorial Research (INETER), which were used to offer estimations of the values at the points where farms were located (Fries et al., 2012); ii) data provided by coffee producers through a survey; and iii) data on social vulnerabilities provided by the National Institute of Development Information (INIDE).

2.3 Description of variables

Table 1 summarizes all relevant variables used for the study, as well as descriptive statistics linked with them. It includes both subjective and objective measurements, such as production factors, water requirement, percentage of plants presenting climate-induced damages, precipitation and temperatures –which includes measures for both dry and wet semesters. This information was complemented with the subjective views given by participants over issues such as cocoa's prices and costs. This analysis includes also indicators for vulnerability, such as education and households in a situation of extreme poverty [20, 21]. These descriptive statistics include averages and standard deviations for quantitative data and frequencies for qualitative variables.

This section should be divided by subheadings. Materials and Methods should be described with sufficient details to allow others to replicate and build on published results. Please note that publication of your manuscript implicates that you must make all materials, data, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Table 1. Descriptive statistics of the variables (mean and standard deviation for the quantitative variables and frequency of qualitative variables).

	Name	Unit	Mean	Std Dev	Source
Dependent variables	Climatic change	0=No	17.3		
		1=Yes	82.7		
	Economic reasons	0=No	62.7		
		1= Yes	37.4		
	Government support	0=No	94.9		
		1= Yes	5.0		
Transversal variables	Labour	Number	12.2	11.0	
	%Damaged plants	Number	4.1	3.2	
	Training courses	0=No	47.4		
		1= Yes	52.6		
Climatic Variables	High water nec.	0=No	47.9		
		1= Yes	52.1		
	Temp. rainy season	Number	23.5	1.8	
	Temp. dry season	Number	22.5	1.8	
	Humidity	Number	78.1	3.6	
Economic Variables	Know. price cacao	0=No	69.4		
		1= Yes	30.6		
	Know. cost cacao	0=No	80.4		
		1= Yes	19.6		
al Vari able	Education	Number	32.5	8.9	
	Poverty households	Number	445.8	1.1	

This data shows that 82.7% of coffee producers would consider switching to cocoa trees because of climate change related impacts, that 37.4% would have in mind purely economic reasons, and that for 5% of them government aid. An average plantation has 12 workers, and has seen a 4.1 % of its plants damaged by climate related issues in the last 10 years. 30.6% of coffee farmers know about cocoa's market prices and 19.6 % of them are aware of the production costs.

2.4 Econometric model for farmers' perception

The econometric model that summarizes the theoretical analysis presented so far includes as interdependent variables the main reasons for changing coffee for cocoa (climatic, economic and governmental support). The econometric procedure used to jointly estimate the interrelated equations is the multivariate probit model [22, 23]; this model was selected from the intuition that farmers are more likely to change for a mix of reasons than for a single one. We consider two main sets of explanatory variables to evaluate the reasons for adaptation: transversals which are common to all the alternatives (X) and specifics which are particulars for the reasons (W). The model is specified as follows:

$$Y_{ij} = \mathbf{1}[\beta_j' X_i + \gamma_j' W_{ij} + \varepsilon_{ij} > 0] \qquad [1]$$

where i = 1, . . . , N are farmers, j = 1, ..., J are reasons for changing coffee for coca, 1[·] is the indicator function that shows the reason j why the farmer i would change the coffee for cocoa. Xi and Wij are vectors of variables that collect farmers characteristics which may be common (X) or not (W) in the specifications of equations; β and γ are parameters to be estimated; and εij are the error terms distributed as a $N(0.\Sigma)$ with the variances equal to one and also the model allows for correlation between unobservable information from equations. To obtain the multivariate probit marginal effects, we follow Mullahy's work [24].

3. Results and Discussion

3.1. Drivers for crop diversification: from coffee to cocoa

The regression run explains the relationship among different variables and the probability of farmers answering yes to the question on whether each of the three proposed factors would affect their decision of switching crops from coffee to cocoa; being the factors climatic, economic or the existence of government support. As stated previously, regressions combined a set of transversal variables (labour, %Damaged plants and Training courses) and three sets of specific variables grouped intro climatic variables ("High water nec., Temp. rainy season, Temp. dry season and humidity), economic variables (Know. price cacao and Know. cost cacao), and variables related to social development (Education and poverty households).

Table 2. Results obtained from the regression.

	Climatic change			**Economic reasons**			**Government support**		
	Coef	**Std. Err.**		**Coef**	**Std. Err.**		**Coef**	**Std. Err.**	
Labour	0.034	(0.015)	**	-0.013	(0.008)		-0.011	(0.014)	
%Damaged plants	0.295	(0.066)	***	-0.143	(0.034)	***	0.199	(0.073)	***
Training courses	-0.107	(0.277)		-0.267	(0.195)		0.893	(0.403)	**

High water nec.	0.609	(0.265)	**						
Temp. rainy season	1.010	(0.506)	**						
Temp. dry season	-1.156	(0.523)	**						
Humidity	-0.262	(0.117)	**						
Know. price cacao				0.355	(0.213)	*			
Know. cost cacao				1.053	(0.251)	***			
Education							-0.069	(0.032)	**
Poverty households							0.002	(0.001)	***
Cte	22.359	(11.333)	**	0.206	(0.233)		-2.095	(0.925)	**
ϱ21	-0.492	(0.125)	***						
ϱ31	-0.379	(0.195)	**						
ϱ32	0.855	(0.109)	***						
LR test (ϱ21 = ϱ31=ϱ32=0): χ2(3)		34.640	***						
Log likelihood		-201.579							
LR test: χ2(17)		78.970	***						
Obs.		209							

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

It is shown in table 2 whether each of the variables found impacts the response probability in a positive or negative way. As for transversal variables, their impact varies in both sign and significance level for all equations, while specific variables obtain higher levels of significance.

Among the variables affecting the idea that climate wold be a reason for switching crops, "labour", which refers to the number of workers at each farm, is positively and significantly correlated to dependent variable. Percentage of damaged plants also significantly increases the probability of farmers answering positively, which is a result consistent with the intuition that costs caused by climatic variability would favour farmers' interest in adapting into more resistant crops. Whether or not the farmer has received specific training courses was not found to be significantly related to the result.

The specific variables affecting climate as a trigger for crop change allude to four climate-related issues such as water need, average temperatures for rainy and dry season and humidity. Pressures over water supply positively affect this variable. This result is significant at the 95% confidence level and also corresponds with the intuition that worse climatic conditions are linked to a positive response. Dry season average temperature and wet season average temperature offer results similar in magnitude and significance but of opposite sign. While higher temperatures in the rainy season increase the probability for a "yes" as an answer, higher dry season temperatures decrease it. Finally, higher humidity has a negative impact over the dependent variable, a result also significant at the 95% confidence level.

Less variables offered significant results for the question on whether the economic pressures would be important when facing the decision of switching crops. Among the transversal variables, the percentage of damaged plants was found significantly correlated to the answer for this question. This relation was negative, i.e. the higher the amounts of plants lost the lower the probability of a positive answer for this question. The number of labourers and training were not found to be significantly related to the dependent variable.

Both specific variables related to market and economic issues were found to be significant in the relation. Knowledge of the prices and costs associated to cocoa were positively related to the variable, implying that the more the knowledge of the market conditions, the higher the chance for taking economic and market conditions into account when considering a change into cocoa production.

Again, the percentage of damaged plants was found relevant when questioning farmers on whether government support would be a relevant issue when deciding on using a new crop as a way for adaptation. As with the first equation, this variable was positively related to the outcome. The reception of training courses was also found to be positively related to the result, while the quantity of people working at the plantation was not.

Specific variables affecting this response were also found significant. Education was positively related to the outcome. The number of households under the poverty line in the municipality was also found to be positively related to the probability for answering yes to this question.

3.2. Pressures in coffee production as drivers for introducing cocoa

Probabilities associated to different answers presented different behaviours. The studied sample of farmers was more prone to allege climatic reasons as a determinant factor when changing from coffee to cocoa plantations. It was the only of the factors found to have an average probability over 0.5, which would imply a higher probability associated to a positive answer. On the contrary, probability distributions associated to the consideration of economic reasons and government support were significantly lower. While economic reasons presented a high variance skewed towards low probabilities, government support was generally associated to low probabilities often close to 0.

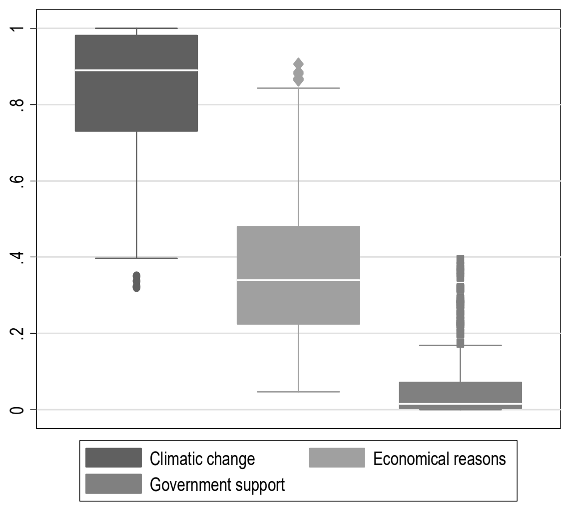


Figure 2. Probabilities predicted by the model for the three main drivers: Climatic change, economic factors, and government support.

Figure 3 shows how the amount of plants lost in the previous 10 years impacts the probability of each answer given by farmers. We observe that, while farmers will generally have climatic and ecologic reasons into account, they are more likely to take them as a relevant factor when their losses in the past decade are higher. Probability of considering economic reasons as a reason for the change in crop type behaves in a different way, as it diminishes from a probability slightly below 0.5 to values near 0.1 when the percentage of lost plants in the previous decade gets near the 10% line. Finally, farmers focusing on government support are more present among those that have lost more plants, though numbers are low at most points.

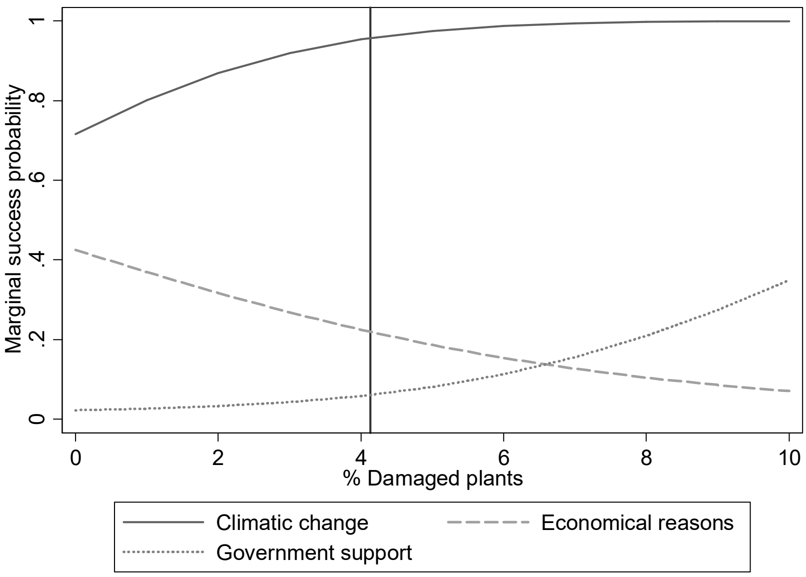
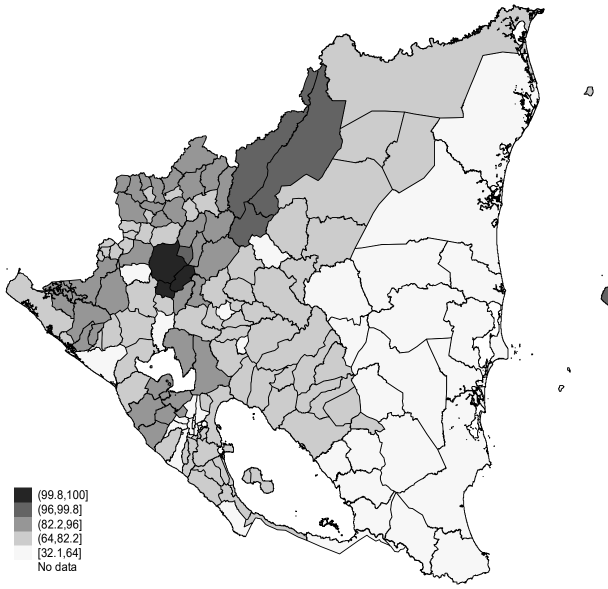


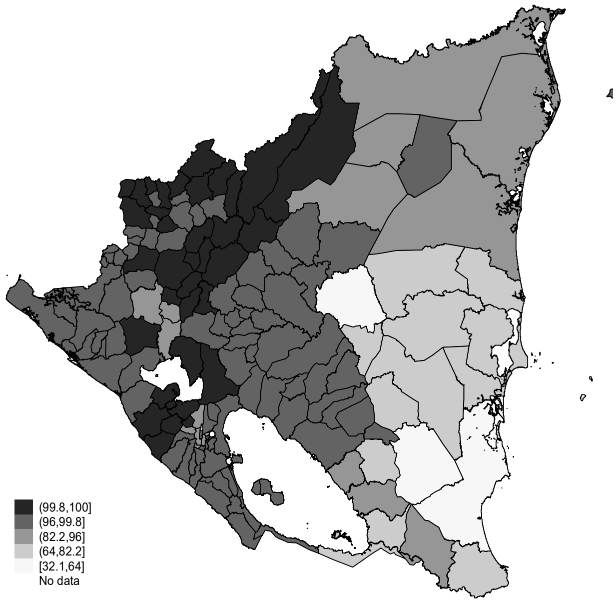
Figure 3 Main drivers for crop substitution and modelized behaviour against amount of damaged plants in the previous decade.

3.3 Cacao as an adaptation option

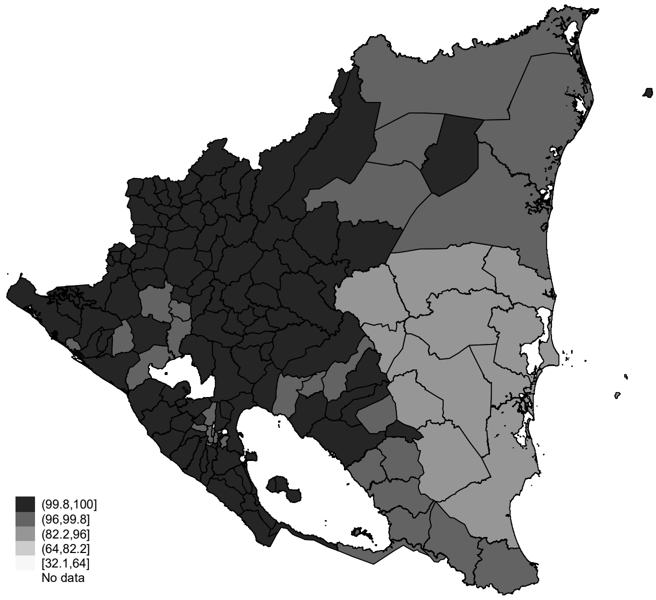
Climate change will impact some of the variables affecting farmers' decision to change crops and substitute coffee plantations for cocoa. Under the baseline scenario it can be seen that high probabilities for crop change are restricted to the driest areas in the north-west highlands, while central and eastern Nicaragua, as well as most of the west coast present lower probabilities. Under conditions related to the RCP 4.5 scenario, which presents a reduction of carbon emissions, higher probabilities of change expand to most of the country. More humid mountain and coastal areas in eastern Nicaragua retain lower probabilities, but the impact of climate change is notorious even in the most optimistic scenario. Under RCP 8.5 or business as usual scenario, probability for change is further expanded. Lower probabilities remain just in the restricted areas of the southern zone of Nicaragua's east coast. Moreover, probabilities increase all over the rest of the country, and reach levels over 0.9 in most of Nicaraguan geography.



(a)



(b)



(**c**)

Figure 4. This figure shows how climate change will affect the probability of farmers across Nicaragua to change from coffee to cocoa: (**a**) Shows humidity in under the baseline scenario, which represents present climatic conditions; (**b**) Shows humidity under the RCP 4.5 scenario; (c) Shows humidity under the assumptions associated to the RCP 8.5 scenario.

Water scarcity is one of the main drivers behind the decisions according to the studied data. Both humidity and capacity to obtain enough water for plantations were found significantly correlated to farmers' probability of changing crops due to climatic reasons. The graph below shows us how the probability of changing crops due to climatic reasons is only low under certain specific conditions, i.e. high humidity rates and absence of high water necessities.

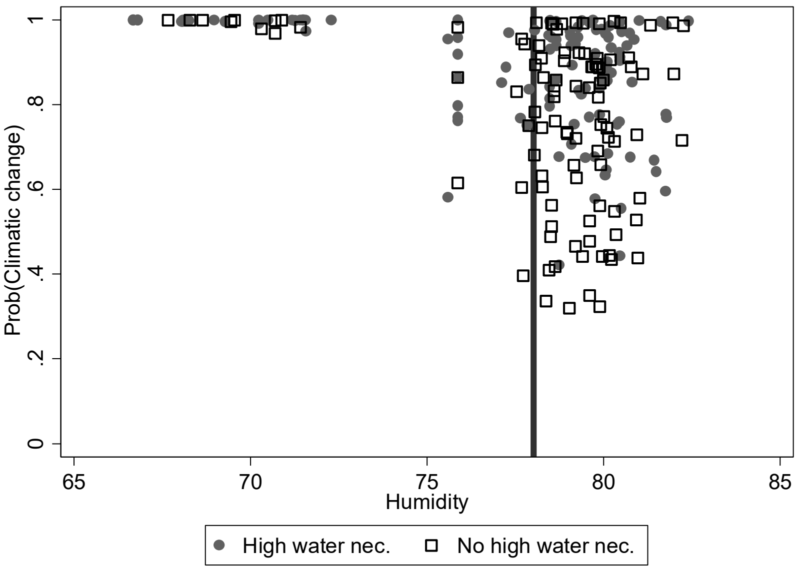


Figure 5. Relation between the humidity, high water necessity and the probability of signalling climate as a driver for crop change.

4. Conclusions

This study presents the results regarding perceptions of Nicaraguan farmers, trying to determine the main variables behind the decision of introducing cocoa crops as a measure to adapt to climate change. According to these perceptions and a series of variables specific to each farm it can be stated that there is evidence signalling crop diversification and change as a method to deal with consequences of climate change. Water is a central aspect in this decision. Both availability of enough water to irrigate plantations are significantly related to farmers' decision making process. As models predict, water systems will be seriously affected by climate change conditions, due to probable changes in rainfall cycles and atmospheric humidity levels. Events such as El Niño Southern Oscillation will also be affected, and with it most of the population that lives under its area of influence.

While the introduction of cocoa is itself an adaptation mechanism for changing environmental conditions, this change may suppose an ecosystemic change by itself. Changes in the composition of crops such as coffee and cocoa in a biodiverse ecosystem may have several impacts. Agricultural systems and techniques play an important role at this point, as impacts may have both positive and negative effects over such environments.

Moreover, livelihoods of smallholders may be severely affected by climate change in developing countries such as Nicaragua. High dependence on agriculture posts an increased vulnerability to changes in climate and the ecosystem. Cocoa may also help in this sense, providing more reliable rents in such areas.

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