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Climate variability and vulnerability to poverty in Nicaragua

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ABSTRACT

This study considers the effect of climate variability on vulnerability to poverty in Nicaragua. It discusses how such vulnerability could be measured and which heterogeneous effects can be expected. A multilevel empirical framework is applied, linking per capita consumption to household, regional and climate characteristics. Results confirm a negative effect of climate variability on consumption per capita of Nicaraguan households. This suggests the need for stronger public policies and more resources in order to adapt to the effect of climate change. Furthermore, the poverty reduction attainments reached since the 1990s could be jeopardized if this vulnerability persists.

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Poverty; vulnerability; economic development; climate variability; Nicaragua

1. Introduction

Much of the recent literature on poverty assumes that human well-being is jeopardized by severe consumption crashes, as well as by the absence of a wide variety of other essential resources. The predicaments of the poor may often be owed not only to consumption shortfalls but to disease, illiteracy, or malnutrition. This study focuses on the role of climate variability, which is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events (World Meteorological Organization 2017),[1] as an important source of vulnerability to poverty in Nicaragua.

Nicaragua holds fourth place in the global long-term climate risk index (CRI)[2] for 1993–2012. The country's susceptibility to natural disasters remains a key concern. Distressing climate events such as hurricanes, severe storms, floods, and droughts occur frequently, and the country is also at risk for earthquakes. Following Hurricane Mitch in 1998, an additional 165,000 people fell below the poverty line in the country; the 'poorest' lost 18 per cent of their assets. There was a 19 per cent loss of crops and 20 per cent of hospitals and education centres were affected (World Bank 2008). Over the last few decades, effects of El Niño in Nicaragua have been present every 2.6 years (2002/03, 2004/05, 2009/10 and the latest 2014/15) (World Bank 2015). These events seem to deepen mainly during the August-March period, thus primarily affecting the agricultural production cycles of basic grains. Considering such events, we refer to climate variability within the spectrum of two key variables: precipitation and temperature mean value change during the 2001–2009-time periods.

Climate variability can affect non-poor and poor households, and although risk levels might differ, exogenous shock can reverse the fortunes of both, meaning that the observed factors for estimating income and poverty levels can all too easily change over time due to unexpected external events. Those who have improved their living standards can suddenly face a reversion in their conditions

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due to climate shocks. Therefore, poverty should be observed from a dynamic approach as people can fall in or out of poverty during their life span.

The conventional understanding of poverty[3] based on current income and wealth criterion (Ruben 2011) has driven international development policies over the last 60 years. Nevertheless, new paradigms in the interpretation of poverty recognize that other social, economic and environmental events or shocks (like natural disasters) directly affect people's income potential and can exacerbate structural inherited and chronic poverty factors to the point of driving individuals back below their original level of poverty.

According to Gunther and Harttegen (2006), the probability of becoming poor due to specific idiosyncratic shocks[4] is higher for low-income population groups. On the other hand, covariate shocks[5] apply to all people alike, even those with high incomes and strong capital endowments such as high levels of education, fixed assets, access to basic services, technology and infrastructure. For these reasons, vulnerability assessments try to estimate ex-ante both the expected mean as well as the volatility of consumption.

Furthermore, according to Gunther and Harttegen (2006), Moser (1998) and Philip and Rayhan (2004), vulnerability should be considered a dynamic concept which recognizes and captures change in the economic situation of human beings – not being poor today does not imply that this condition will remain the same in the future. Nevertheless, vulnerability, as with poverty, should be considered multidimensional.

In this study, we define 'vulnerability to poverty' as the ex-ante risk that a household will fall below the poverty line or remain poor if it is already under the line (Chaudhuri, Jalan, and Suryahadi 2002). This definition assumes that climate variability (in extreme magnitudes) could represent a potential threat of suffering poverty in the future by households that are not able to cope with the shock, whether or not they are currently poor. In this context, Udry (1995) manifests that even if a country is achieving economic growth and poverty reduction, it may not have reduced its vulnerability level to the extent that a shock, such as one produced by climate variability, can reverse any progress so far achieved.

Some efforts are made in the literature to empirically unravel this relationship between climate variability and vulnerability to poverty despite a lack of reliable data at country level. Jacobsen (2011) finds that the occurrence of covariate shocks, such as drought intensity, increases the probability of becoming poor for non-poor households in rural Nicaragua. Jacobsen (2012) also tries to assess the impact of Hurricane Mitch on the productive capital stock of households, but results did not confirm a direct negative link and point more to substitution effects (e.g. households protecting their productive assets base by investing less in child education). This means families transferred the shock to the longer term, jeopardizing the future of their children.

This study contributes to literature in two main ways. First, we provide – despite the limitations of relying on cross-sectional data – a detailed examination of the data related to current climate and variability and its potential to change in the future (i.e. climate change) and a suitable empirical multi-level approach for analysing climate-income relationships. Second, we intend to overcome possible specification errors by using direct sub-regional climate variables instead of self-reported questions to assess the extent of climate variability. This enabled us to account for the likely impact of climate variability on vulnerability in Nicaragua.

The remainder of this study is structured as follows. Section 2 reviews the existing literature and discusses predominant views regarding the relationship between vulnerability, poverty and climate variability. Section 3 presents an overview of the evidence on this topic for the country context of Nicaragua. Section 4 describes the analytical model and estimation methodology used for linking climate variability with vulnerability to poverty. Section 5 reports the results of the empirical analysis at different levels. Section 6 concludes with some policy implications.

2. Poverty vulnerability and climate variability: concise literature review

People, societies and ecosystems are vulnerable around the world to climate variability but with varying degrees of vulnerability in different places. Climate variability often interacts with other stresses to increase the risks from a lack of preparedness (vulnerability) and exposure (people or assets in harḿs way) overlapping with hazards (triggering climate events and trends) (United Nations 2014).

Climate events are likely to generate important new inequalities in household wealth and income. Carter and Castillo (2005) note that market mechanisms for protecting and rebuilding assets are often limited in poor rural communities of Honduras, and therefore there is a growing need for informal insurance. The effects of Hurricane Mitch in that country show a drastic long-term impact of the hurricane in the poorest communities evidenced by diminished productive assets.

In a similar vein, Van den Berg and Burger (2010) use two waves of living standard surveys to analyse the impact of Hurricane Mitch on rural livelihoods in Nicaragua. Their findings show that inequity in access to production factors, degradation of natural resources and vulnerability to natural disasters are important problems that reinforce vulnerability to poverty.

One of two main research traditions linking vulnerability to poverty with climate variability regards technological adaptations, such as building flood defences or switching to drought-resistant seeds (O'Brien et al. 2011) and sectorial adjustments as useful mechanisms *to reduce the potential impacts* and contribute to poverty reduction (Katz and Brown 1992; Pittock and Jones 2000; Dessai and Hulme 2004). A second, more suitable research tradition focuses on the study of ex-post responses to climate risks and societal factors and conditions that affect people's *capacity to respond* to climate variability, including health status, education levels and employment opportunities (Chambers 1989; Pritchett, Suryahadi, and Sumarto 2000; Chaudhuri, Jalan, and Suryahadi 2002; Ligon and Schechter 2004; Eriksen et al. 2007; Vakis and Davalos 2011). This approach allows considering a wider range of factors and conditions that households face in dealing with climate variability.

Early contributions on climate-poverty linkages mainly influenced by the work of Udry (1995), hint at the potential impact of exogenous factors (i.e. climate variability) on poverty vulnerability. However, the vast literature has not yet assessed the effect of climate on a household's probability of becoming or remaining poor in the foreseeable future. Karfakis, Lipper, and Smulders (2012) find that developing countries that rely extensively on agriculture, in sectors such as farming, animal pastoralism, fisheries and forestry, are most strongly sensitive to changes in climate variability and poverty dynamics. Thus, negative food security implications are expected to emerge in the areas of high dependence on local food production and with fewer possibilities for internal and external insurance. Furthermore, aggregate impacts on poverty at a village or regional level may reinforce insecurity at the household level, thus urging a multi-level analysis of climate variability effects (Nordhaus 2006). Hence, the principal questions of this research are first, whether climate variability affects consumption patterns in Nicaragua, and, if so, to what extent do the probabilities of becoming poor increase due to these effects.

An approach employed to study the impacts of climate variability includes focusing on the effect of climate variability on key rural assets, mainly through land prices (Mendelsohn, Dinar, and Williams 2006; Masters and McMillan 2001; Skoufias and Vinha 2012). Such an analysis is based on the economic rationality that when farmers maximize profits, land prices are directly correlated to the (future) revenue capabilities of the land. Thus, changes in climatic conditions will impact revenue changes as well, and expected negative climate variability effects will influence land and asset stocks. In this line of thought, Assuncao and Chein (2007) estimate that Brazil may experience a decline in agricultural output of 18 per cent in the next decades, considering the effect of strongly varying climate variability among different communities and land use types.

The second commonly used approach for analyzing the impact of climate variability selects a well-being measure and examines the impact of climate variability directly on household revenues. This measure can consist of household consumption, income, poverty or health-related indicators. Hence, effects can be attributed to the varying returns to assets, their degree of diversification, location, and/or maintenance expenditures (Alderman 2010; Bizikova et al. 2009). Tol (2009) uses a comparative welfare model to demonstrate the effects of climate variability on income poverty in different affected regions, finding that the strongest effects are registered in regions where poverty abounds.[6]

In summary, the literature reveals a common agreement that – in the long term – climate variability and vulnerability tend to reinforce (rural) poverty. In the following section, we will assess the direct consumption effects of climate variability (both temperature and rainfall) and identify the household and regional factors that explain differences in poverty vulnerability. This will enable us to discuss possible alternative risk coping strategies that could be helpful to mitigate the heterogeneous effects of climate on poverty.

3. Poverty and vulnerability in Nicaragua

Statistical discussions about poverty only rarely reveal what it is like to be poor – the risks, limitations, hopelessness and pain. The gaps between poor and non-poor are generally considered to be determined by an inadequate distribution of wealth and consumption (Suryahadi and Sumarto 2003) and a low level of educational attainment.[7] The World Bank (2009) LSMS data show that the richest 20 percent of the population accounts for 47.2 percent of total consumption, whereas the poorest 20 percent only consume 6.2 percent. Consequently, Nicaragua is located in the upper quartile of countries with highest disparity in consumption (World Bank 2012).

Moreover, access to other infrastructure services by the poor is also limited. Investments in infrastructure mainly appear to show only modest gains in terms of population with access to services such as water, electricity and trash disposal, particularly in rural areas. Whereas 90 percent of households in urban centres have access to water and 98 percent have access to electricity, only one in four rural families have access to water supply and only 44 per cent of rural households have access to electricity.

In addition to inequality, Nicaragua is a country traditionally exposed to climate variability and with a long history of natural disasters. According to Ramírez et al. (2010), since the 1990 s the country has been impacted by a number of severe climate shocks. For example, the droughts that occurred in 2001, and Hurricane Félix and the tropical waves of 2007 caused GDP losses of 1.2 per cent and 5.2 per cent, respectively. Furthermore, indicators presented in the Climate Change and Knowledge Portal (World Bank 2014b) show that Nicaragua ranks high in Latin America and the Caribbean in terms of vulnerability.

Notwithstanding adverse climatic events, Nicaragua has experienced sustained moderate economic growth over the last 15 years. The 2007–08 food price crises and 2009 global financial crisis could have had a negative impact on the country's socioeconomic indicators, but a noteworthy reduction in poverty from 70.3% to 54.4% (see Table 1) was realized especially in the rural areas, by the end of the 2000 s.

The factors of poverty reduction in rural Nicaragua have been many; among the important are the increase of efficiency and effectiveness in domestic resources of small and medium producers, improved access to internal markets and more rewarding prices (IMF 2011). According to the World Bank (2012), poverty headcounts fell from 2005 to 2009 from 48.3 to 32.9 (see Table 1). Nicaragua also showed a decline in inequality as its Gini coefficient fell from 40.5 in 2005 to 37.1 in 2009.

Table 1. Poverty trends in Nicaragua (2005–09).

	2005			2009		
Indicators	National	Urban	Rural	National	Urban	Rural
Non-Poor	51.7	69.1	27.7	67.1	80.4	46.0
General Poverty	48.3	30.9	70.3	32.9	19.6	54.4
Extreme Poverty	17.2	6.5	30.5	9.7	4.4	18.2
Gini Coefficient	0.405			0.371		

Authors' calculations based on the World Bank (2005, 2009).

Table 2. Nicaragua–Poverty characteristics (2009).

	General Poverty	Extreme Poverty
Types of labour income		
Employed in agriculture	68.2	28.1
Self-employed in agriculture	63.7	28.1
Employed in non-agriculture	25.4	2.6
Self-employed in non-agriculture	27.5	7.3
Employment status		
Employed	42.3	14.5
Formal	18.9	1.2
Informal	46.2	16.7
Unemployed	40.6	12.7
Inactive	43.5	15.4

Note: Type of labour income and employment status correspond to the characteristics of the household head.
Data is presented as percentages of the total population considered poor.
Source: Authors' calculations based on the LSMS 2009.

Despite recent advances in the country's macroeconomic indicators and some progress in the fight against poverty, Nicaragua remains the second poorest country in Latin America (World Bank 2012). Furthermore, the Living Standard Measurement Studies (LSMS, 2009) show that extreme poverty still persists in rural areas. The World Bank (2012) notes that in the year 2009, 23.2 per cent of Nicaraguans living in rural areas were unable to meet their basic food needs coming from 28.1 percent in 2005, whereas in urban locations this number was only 4.4 per cent.

According to the World Development Indicators (World Bank 2014a), Nicaragua has a Gross National Income per capita of US$1,780.00 (Atlas method), second to last position in the continent with only Haiti behind. Hence, it is no surprise that approximately one-third of the population lives under the poverty line, with almost one out of every ten Nicaraguans living in conditions of extreme poverty (see Table 1). Although a simple assessment of poverty trends from 1993 to 2009 may suggest that extreme poverty has fallen around 30 per cent over the longer term, what is more worrying is the persistence of this high level of poverty in the society.

3.1 Poverty mapping: location & employment status

Various methodologies are used to categorize poverty, and understanding who the poor are. Detailed poverty map[8], for instance, describes the present condition of local economies and identifies the most deprived areas of the country presented in Appendix 1. It shows that the Central rural and Atlantic rural areas have the highest rate of general poverty and the highest incidence of extreme poverty in Nicaragua.

In terms of income, the poor usually obtain income from agriculture and are employed in the informal sector (see Table 2).

4. Methodology

Hoddinott and Quisumbing (2003) suggest there is little consensus amongst researchers on how to estimate poverty vulnerability. Gunther and Harttgen (2006) state that empirical texts on vulnerability are usually based on mix of approaches. On the one hand, several researchers concentrate their efforts on how to measure aggregate vulnerability within a population (Townsend 1994; Dercon, Hoddinott, and Woldehanna 2005; Mourdoch 2005). A common denominator in these studies is the use of panel data to examine if households are able to increase their consumption against income fluctuations over time. The main barrier is that panel data availability is very limited for most developing countries.

On the other hand, several studies focus on analysing the ex-post impact of shocks on household consumption (Paxon 1992; Gertler and Gruber 2002; Vakis and Davalos 2011). Their similarity in terms of methodology is that they use standard regression analysis to examine the relationship between adverse shocks and consumption. The empirical limitation of these studies lies in issues regarding omitted variable bias, risk of high correlation between the variables, no clear cut causality and risks of endogeneity.

Following Goldstein (1999), multilevel analysis could help overcome some of the limitations of previous studies and enables us to make a distinction between the unexplained variance at the household level (i.e. the impact of idiosyncratic shocks) and the unexplained variance at the community level (i.e. the impact of covariate shocks). Furthermore, Gunther and Harttegen (2006) show that multilevel analysis may correct for the inefficient estimators[9], which are likely to be observed in the results of standard regressions.

It is important to highlight the connection between theory and empirical analysis in terms of choosing relevant household categories with related individual (coping-capacity) characteristics (Filmer and Pritchett 2001). For this purpose, multilevel analysis provides robust standard errors and significance values (Goldstein 1999).

Additionally, Gunther and Harttegen (2006) show that multilevel models provide a breakdown of the error term; thus, decomposing the unexplained variance of consumption between household and community factors.

4.1 Model structure

Consequently, these hierarchical models address several limitations derived from the assumption of independency problems (Byrk 1986; Leeuw 2011; Greene 2003). Hence, multilevel models are considered particularly suitable to analyse household vulnerability poverty with reference to both idiosyncratic and covariate shocks.

For operating hierarchical models, we need to follow three essential steps:

1. Divide the variance of the dependent variable (poverty) into what it is explained by each level of analysis.[10]
2. Establish the determinants at the individual levels.
3. Establish the determinants of the secondary (regional) levels.

Gunther and Harttegen (2006) suggest that we could apply a two levels model in which the log of per capita household consumption of household i in community j is regressed on a set of household X and community/regional covariates Z. Our study tries to assess the effect of precipitation changes (years 2001-09) on the amount of goods consumed annually and ultimately on the probability of being poor. The change in precipitation and the percentage of people employed in agricultural activities constitutes a second level of analysis. It attempts to reflect the dependency on agricultural related income that exists in Nicaragua assuming that precipitation affects food production, and food production in turn affects income, and income affects consumption. Thus, we test the rainfall-production-income hypothesis. However, we do not use the income as the dependent variable, instead we use consumption because consumption tends to vary less than income, and also it is less subject to error measurements. In this case, the link would be, rainfall affects production and food production affects income and income affects consumption. We consider two possible effects: i) (direct) a reduction of food production reduces the edibles good for self-consumption, ii) (indirect)a reduction of food production reduces the goods to commerce hence less income is available and consumption drops.

Irrigation effects on production are truly visible and well-thought-out, however it is important to take into consideration that climate variability can cause long periods of drought and water resources need to replenish from precipitations, hence any positive effect of irrigation could disappear in the long run as water becomes scarce. Also, according to Zegarra and Chirinos (2016) it has existed historically a highly instability in the proportion of land under irrigation in Nicaragua, being the highest proportion 6% out of the total cultivated land. The high instability makes it difficult to account for the whole effect of irrigation. Furthermore, the number of farmers who have access to water is no higher than 5% and farmers with land extension less than 2 hectare have lesser access to water (see Appendix 5).

For the first level, the household variables used reflect three main factors: household assets, access to infrastructure and services, and demographic characteristics. Household assets include capital stock variables (savings accounts, remittances, stocks, dividends, rent and machinery). In addition, capital stock includes the valuation of household assets such as land, equipment (e.g. tractors), facilities (e.g. wells) and household goods (e.g. TV, blender, refrigerator, etc.). Households' assets are especially important to take into consideration since these variables can smooth consumption when covariate shocks are present, as savings can be used, land can be rented or equipment can increase productivity, therefore, reducing the vulnerability of the household. Proper infrastructure and services are important because they decrease the probabilities for inhabitants to get sick, allowing them to work and so increase their income. Demographic characteristics are used for control heterogeneities among households.

Infrastructure and household services include deprivation variables such as unsuitable floors, ceiling or walls, absence of basic services like water, electricity, fuel and sanitation, overcrowding (more than three people per room for sleeping) and information as to whether the household has access to communication media (televisions, newspapers, magazines, etc.).

For demographic characteristics, the variables of years of education of the head of household, household illiteracy and unemployment rate are considered. Finally, socioeconomic variables are included such as the household dependency ratio (individuals $<$14 years old and $>$60 years old as a proportion of working age people between 15 and 49 years old) and if the main sources of household income are the result of activities that could be affected by changes in international commodities prices (e.g. engagement in tradable sector, like coffee production).

At the second (departmental level), the two main variables are the precipitation change over the past eight years per department and the percentage of people employed in agricultural activities. We also use an alternative specification with temperature change as key climate variable (included in Appendix 2).

4.2 Model specification

In order to assess household vulnerability to climate variability, our study incorporates multilevel modelling based on equations that are assumed not to be correlated. First, it is assumed that cross-sectional variance can be used to estimate inter-temporal variance in consumption. Secondly, it is assumed that the impact of shocks on consumption variances are correlated with households' characteristics whereas error measurement is not. Therefore, according to this econometrical structure, this approach is suitable for assessing the effects of climate variability on household vulnerability to poverty. Hence the models are specified as follows:

Level 1:

$$Log(Consump\_pc_{ij}) = \beta_{0j} + \beta_1 Educ_{head}\ of\ household_{ij} + \beta_k X_{ki} + u_{ij} \quad (1)$$

Level 2:

$$\beta_{0j} = \alpha_{00} + \alpha_{01} Climate\_variability_j + \alpha_w Z_{jw} + \varepsilon_{0j} \quad (2)$$

where:

$Log(Consump\_pc_{ij})$: logarithm of consumption per capita of household 'i' in department 'j.'
$Education_{ij}$: educational level of the head of household 'i', in department 'j.'

X_{ij}:	other variables from the first level belonging to the household 'i', in
$Climate\_variability_j$:	changes in precipitation or temperature over the last eight years in department 'j.'
Z_j:	other variable from the second level in department 'j' (e.g. Percentage of Agricultural Occupancy).
β_{0j}:	average consumption per capita in department 'j.'
β_1:	effect of education on consumption per capita of the household.
β_k:	marginal effect of the X variable on consumption per capita.
α_{00}:	average consumption per capita for all departments.
α_{01}:	marginal effect of a change in precipitation of a department over the household consumption per capita.
α_w:	effect of the Z variable over consumption per capita.
u_{ij}:	random shocks for a household in the department 'j.'
ε_{0j}:	random shocks for department 'j.'

The first Equation (1) includes no cross-level interactions and therefore interaction terms were set to zero, following the usual procedure for multilevel models that compose the model in several steps. The second Equation (2) enables to estimates the error terms. We also estimated the effects of changes in temperature instead of precipitation/temperature maintaining the other factors presented in Equation (2). This analysis assumes that the error term at the $\varepsilon 0_j$ captures the impact of shocks over a specific area, whereas the error term u_{ij} captures the impact of covariate shocks on households (Gunther and Harttegen 2006). Thus, coefficients of climate will account for the direct impact on households 'consumption.

4.3 Operationalization of vulnerability to poverty

According to Chaudhuri, Jalan, and Suryahadi (2002), for estimating vulnerability it is necessary to assume first that the stochastic process generating consumption of a household h is given by:

$$lnc_h = X_h\ \beta + e_h \tag{3}$$

Where c_h is the per-capita consumption expenditure, X_h represents a vector of observable household characteristics, β is a vector of climate parameters and e_h is a mean-zero disturbance term that captures idiosyncratic shocks that contribute to different consumption levels for households. Equation (3) assumes that idiosyncratic shocks are identically and independently distributed over time for each household and that the parameters of β are relatively stable over time. This means that future consumption depends exclusively on uncertainty of idiosyncratic shocks, e_h (For an extended explanation see: Chaudhuri, Jalan, and Suryahadi 2002; p. 7).

Given the limitations of dealing with only cross-sectional data to identify the parameters driving the persistence in individual consumption levels or the stochastic process generating β, we can let the variance of e_h depend upon observable household characteristics by this function:

$$\sigma^2_{e,\ h} = X_h\ \theta \tag{4}$$

Using the estimates $\hat{\beta}$ and $\hat{\theta}$, we can directly estimate the expected log consumption:

$$\hat{E}\ [lnc_h \mid\ X_h] = X_h\ \hat{\beta} \tag{5}$$

and the variance of log consumption:

$$\hat{V}[lnc_h \mid\ X_h] = \hat{\sigma}_{e,h}2 = X_h\ \hat{\theta} \tag{6}$$

Assuming that consumption is log-normally distributed over households h, we can use these estimates to make an estimate of the probability that a household with some given characteristics X_h will be poor. If the cumulative density of the standard normal distribution is denoted by $\Phi(.)$, the estimated probability for poverty (or 'potential poverty') will be given by (see: Chaudhuri, Jalan, and Suryahadi 2002):

$$\hat{v}_h = \hat{Pr}(\ln c_h < z \,|X_h) = \Phi\left(\frac{\ln z - X_h\hat{\beta}}{\sqrt{X_h\hat{\theta}}}\right) \tag{7}$$

The results of vulnerability based on this model will assess for the influence of climate variability on the propensity of household to become poor; whether or not climate affects significantly on households ́ consumption. This will enable us to establish a link between changing climate conditions and the vulnerability to poverty, in other words, if ex-post conditions of households enable them to cope with such effects.

Thus, as presented in Table 5, the first two models are estimated using OLS in line with the methodology describe above we followed (the first model without the effect of change in precipitation and the second including such effects). The third and fourth model specifications are calculated with mixed effects, the latter includes an extra variable (Percentage of Agricultural Occupancy defined below) at the departmental level as a proxy for the importance of agricultural engagement in the particular geographical area, hence tracing the effects of climate variability on the income generation potential.

4.4. Data

We rely on the 2009 Living Standards Measurement Study (LSMS) to calculate the poverty and vulnerability effects.[11] The LSMS is used because it has national statistical representativeness in all of Nicaragua's three geographical macro-regions (Pacific, Central and Atlantic),[12] as well as in rural and urban areas. The main information provided by the LSMS survey includes housing characteristics, utilities, demographics, health, education, economic activities, basic food consumption, income, household assets, among others.

The 2009 Household Survey covers a representative sample of 6.515 households and 30.432 people nationwide. This allows us to extrapolate the results to the 5.763.628 people represented in the last Nicaraguan census published in 2005. The analysis is also adjusted to the population growth rate of 1 per cent. The LSMS data most used in this study are from section II on the composition and characteristics of households and employment and income data.

Official precipitation data (2001-2009) in Nicaragua is provided at department level, so even if a department has different altitudes, landforms and ultimately different temperatures, the geographical spatial approach corresponds to the second level (departmental level). Nicaragua is divided in 15 departments and two autonomous regions. The Institute for the Development of Statistics (INIDE) presents its annual statistics on climate data by department and autonomous region.

The Nicaraguan Institute of Territorial Studies (INETER) operates weather stations throughout the entire country, however, there are currently three departments – Boaco, Madriz and Carazo – that do not have weather stations yet, thus an average of the measures of other neighbouring departments are used to compute data for these three regions. For the specific case of Nicaragua, the climate change drought episodes (2001-2002), extreme hurricanes (Felix in 2007, Bertha in 2008) and precipitation/temperature effects on households are included in the analysis (see Appendix 4).

4.5. Variables

Household's consumption per capita[13] is calculated according to the methodology of the National Institute of Development's Information (INIDE) which takes all expenditure that households incur to obtain foods, goods and services for a specified period of time (one week prior the interview, last month, 6 months before, 12 months before). The annualized amount of expenditure is then divided by the numbers of members of each household.

Temperature and precipitation change are estimated by extracting the yearly average value of two individual years. The first year is subtracted from the most recent year, so we have annual variations of either temperature or precipitation during the specified period of time (8 years). In the case of Nicaragua, it is critical to understanding how climate variability may affect the incidence of poverty among specific groups or in particular areas.

Household income takes into consideration all payments that are mandatory by national labour law (commissions, vacations, thirteenth month, etc.), as well as the monetized edible goods or any other kind of earning that is given in form of payment, as well as goods that are taken from their own-businesses to provide food for members of the household. The variable is transformed into natural logarithm for technical reasons, such as the smooth of skewed distribution. We included the unsatisfied basic needs variables found in the LSMS 2009 into our models. Variables we use therefore are: basic services, overcrowding, housing condition, illiteracy rate, dependency rate and access to information. All these variables are expected to have a negative impact on consumption.

For the departmental level, the variables are: coverage of education; which measures the percentage of households that have benefited from government programs within a department. Health́s coverage; accounts for the percentage of households that have received health assistance or have participated in a disease prevention program. In both cases, when at least one person from a given household is beneficiary from one of these programs, such household was taken into consideration. Another variable is population density. This was calculated based on 2005 censuś population distribution and projected on 2009 population. It measures the number of inhabitants per km^2 in each department.

Some additional variables are constructed from the LSMS data. Access to basic services is a dummy that takes the value of 0 when the household does not have proper electricity and potable water infrastructure, uses firewood as combustion or does not have access to proper sanitation, and it is 1 when all these four conditions are met. Illiteracy rate is the proportion of members older than 8 years who can read or write. The dependency rate is the proportion of members who are between 0 and 13 or 60 and more years old, indicating the number of household members that are sustained by household workers.

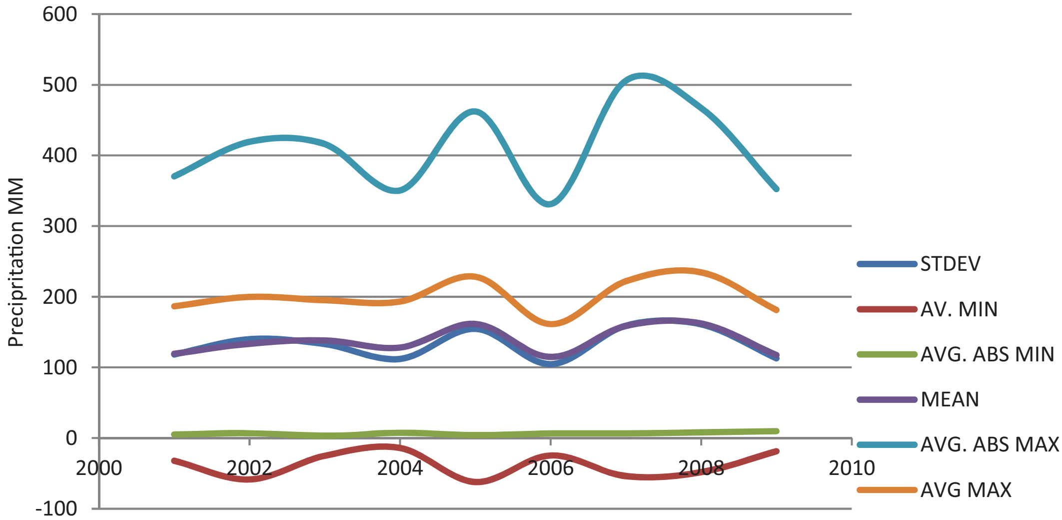
4.6 Descriptive statistics

Table 3 provides descriptive statistics of all major variables used in the model. The variables that show greatest disparities are: transfers, remittances, capital income, capital stock, consumption per capita and education, each showing highest variation between households.

Table 3 Descriptive statistics (values in Córdobas).

Variable	Obs	Mean	Std. Dev.	Min	Max
Transfers per Capita (Cord.)	6.515	2.021	14.599	0.00	813.665
Remittances per Capita (Cord.)	6.515	795	468	0.00	188,160
Capital Income per Capita (Cord.)	6.515	1.288	22.472	5,88	1,669
Capital Stock per Capita (Cord.)	6.515	2.161	125.571	0.00	999.998
Consumption per Capita (Cord.)	6.515	22.508	18.486	1,955.02	229.494
Education Household Head (yrs)	6.502	6,38	4,88	0,00	23,00
Household Unemployment Rate (%)	6.383	28,56	27,84	0,00	100
Household Dependency Ratio (ppl under 13 yrs and over 60yrs)	6.515	0,62	0,57	0,00	6,00
Household Illiteracy Rate (number of people who cannot read or write)	6.515	11,29	22,65	0,00	1,00
Lack of Access to Information (no spending on information; eg. newspapers)	6.515	0,25	0,43	0,00	1,00
Overcrowding (> 3 people/room)	6.510	0,52	0,49	0,00	1,00
Lack of Access to Basic Services	6.515	0,45	0,49	0,00	1,00
Rural Area (D = 1)	6.515	0,26	0,44	0,00	1,00
Precipitation Changes (Over 8 Years)	6.515	-3,90	7,44	−17,16	25,68
Agricultural Occupancy (%)	6.515	13,81	15,02	3,79	50,87

Source: Authors' calculation based on the LSMS 2009 and INETER 2000–2009.
Note: 2009 Exchange rate USD1 = COR 20,80.



Graph 1. Nicaragua – Precipitation National Averages (2001-09 periods). Source: Author's calculation based on INETER data.
Note: STDEV: Standard Deviaton of yearly precipitaton (mm).
AV. MIN: Average Minimum value of yearly precipitaton (mm).
AVG. ABS MIN: Average Absolute Minimum value of yearly precipitaton (mm.)
MEAN: Mean value of yearly precipitaton (mm).
AVG. ABS MAX: Average Absolute Maximum value of yearly precipitaton (mm).
AVG MAX: Average Maximum value of yearly precipitaton (mm).

Graph 1 presents the descriptive statistics in terms of changes in precipitation with national averages over the 2001–2009 period. National averages of precipitation were calculated as simple averages of all the departments. Each value was estimated by year considering the values of the 12 months. The purpose of Graph 1 is to show that changes from one year to the other are becoming more extreme so the impact of climate variability can increase eventually.

Based on the historical data, the trend shows a consistent and apparent continuous performance in yearly precipitation of Nicaragua with more significant variations in the period between 2004 to 2009. //. Starting in 2004, the ups and downs become more frequent and intensive. From 2004 to 2005 precipitation increased by 6,822.7 // 33.430 mm[14], and from 2005 to 2006 it decreased by 9,388.2 // 46.933 mm[15]. Hereafter, the pattern suggests that the country consequently started to experience a period of lower precipitation in 2009.

As a country that heavily relies on the production of agricultural raw materials, merely the agro-industry, this situation constitutes a negative picture for the future. This is because most of the agricultural practice of the country are rural and do not rely on sophisticated irrigation systems but on rainfall seasons, therefore, any variation in precipitation pattern either floods or low concentrations of precipitation over a period of time occur degradation of the outer layer of earth called 'Humus', which contains the majority of nutrients that make the soil fertile and suitable for farming. Either it is slowly 'washed away' thus, resulting in arid and degraded land or increases in the concentration of fertilizers to cope with constant washes.

Table 4 presents changes in temperature at department level over the same period (2001–09).

5. Results

Results of the analysis are presented in Table 5 and an additional review based on changes in temperatures rather than changes in precipitation is presented in Appendix 2.

Table 4. Nicaragua-Changes in temperature by department (2001–09 period).

Department	Temperature changes (2001–09)
Nueva Segovia	0.2083321
Jinotega	0.3750000
Madriz	0.2270832
Estelí	0.1000004
Chinandega	0.2250004
León	0.1333332
Matagalpa	−0.0291672
Boaco	0.2174995
Managua	0.291666
Masaya	−0.0375004
Chontales	0.4499989
Granada	0.2583332
Carazo	0.1552081
Rivas	0.1083336
Río San Juan	0.3500004
RAAN	0.2666664
RAAS	0.1166668

Source: Author's calculation based on INETER data.
Note: Temperatures are in Celsius Degrees.

The majority of variables report significant coefficients at the 1 and 5 per cent level among all the models. Years of education, capital income and remittances provide a positive feedback for consumption per capita, the rest of the variables related to poverty vulnerability (not taking into consideration income variables) report negative coefficients.

The high household dependency ratio along with overcrowding, and lack of access to information and to basic services lead to a decrease of at least 10 per cent in consumption per capita. It shows that whenever there are more dependent people in the household, it becomes harder to be able to provide enough food for family members. Capital income shows a higher variation compared with the importance of remittances in consumption per capita, whereas transfers (such as school lunch) are not significant at all levels of the model.

When testing our hypothesis, we found a significant negative impact of both precipitation and temperature variables. Models 2-4 include a second level of analysis (at a departmental level) which shows that changes in precipitation over an 8 years period have negative effect on consumption in all the households at any given location. This result holds true for all the models meaning that variations in precipitation of 1 mm over time will reduce at least 1.6 percent of households' potential consumption[16].

The data show an increase of volatility in precipitation during the period under study (see Graph 1). Departments that suffered drought episodes are those where climate variability has a negative effect on consumption. In other words, changes in precipitation have a negative impact at a departmental level by reducing average consumption. In the last model when the agricultural occupancy proxy is included, the significance of the effects of changes in precipitation on consumption is maintained even after controlling for unobserved factors. This confirms the robustness of the results.

Furthermore, the results of the departmental variables show that health programs coverage have a significant impact on households' consumption. Not being the case for educational programs. The interaction variable suggests that in departments where climate conditions are adequate and have proper health coverage, the combined effect is positive on consumption and vice versa. When analysing the random parts of the models, we found that there are no significant differences amongst the departments' curves, since variances are close to 0 for the intercept and for the slope. Nevertheless, coefficients of the parameters are as expected (negative) and significant at 1–5 percent level.

One interesting findings is related to temperature. We found a negative relationship between changes in temperature and consumption per capita. The third model presents a significant impact on consumption, with a reduction of 55.1 percent; moreover, the coefficient increases to 74.3 per

Table 5. Effects of precipitation change on households' consumption.

Explanatory variables	OLS MODEL		HIERARCHICAL MODEL	
	Model 1	Model 2	Model 3	Model 4
Fixed Part				
Household Characteristics				
Rural Area	0.013	−0.055***	−0.052***	−0.053***
	(0.01)	(0.01)	(0.02)	(0.02)
Years of Education Head of Household	0.022***	0.018***	0.018***	0.018***
	(0)	(0)	(0)	(0)
Household Unemployment Rate	−0.002***	−0.003***	−0.003***	−0.003***
	(0)	(0)	(0)	(0)
Household Dependency Rate	−0.100***	−0.098***	−0.096***	−0.095***
	(0.01)	(0.01)	(0.01)	(0.01)
Household Illiteracy Rate	−0.001**	−0.001*	0	0
	(0)	(0)	(0)	(0)
Lack of Access to Information	−0.135***	−0.079***	−0.079**	−0.079**
	(0.01)	(0.01)	(0.03)	(0.03)
Overcrowding	−0.111***	−0.059***	−0.061***	−0.061***
	(0.01)	(0.01)	(0.02)	(0.01)
Lack of Access to Basic Services	−0.115***	−0.054***	−0.052***	−0.052***
	(0.01)	(0.01)	(0.02)	(0.02)
Log (Capital Income)	0.286***	0.256***	0.258***	0.258***
	(0.01)	(0.01)	(0)	(0)
Log (Remittances per Capita)	0.015***	0.011***	0.011***	0.011***
	(0)	(0)	(0)	(0)
Log (Transfer per Capita)	0.001	0	0	0
	(0)	(0)	(0)	(0)
Main source of Income from a Tradable Sector	–	−0.085***	−0.085***	−0.085***
		(0.01)	(0.01)	(0.01)
Housing Conditions	–	−0.030**	−0.028**	−0.028**
		(0.01)	(0.01)	(0.01)
Log (Capital Stock)	–	0.076***	0.077***	0.078***
		(0)	(0.02)	(0.02)
Departmental Characteristics				
Change in Precipitation (8 years)	–	−0.016***	−0.022***	−0.022***
		(0.01)	(0.01)	(0.01)
% Agricultural Occupancy	–	–	–	−0.001*
				(0)
% Education Program Coverage	–	0.115	0.117	0.105
		(0.1)	(0.08)	(0.09)
% Health Program Coverage	–	0.361***	0.340***	0.271*
		(0.09)	(0.08)	(0.14)
Population Density	–	0.054	0.059	−0.039
		(0.07)	(0.17)	(0.23)
Interactions				
% Health P. Coverage* Change in Precipitation	–	0.022**	0.029***	0.030***
		(0.01)	(0.01)	(0.01)
constant	8.344***	7.638***	7.641***	7.728***
	(0.03)	(0.09)	(0.22)	(0.21)
Random Part				
Cons (Random intercept var)	–	–	0.001	0.001
			(0.001)	(0.001)
% of explained variance			0.009	0.009
Change in precipitation (Random slope var)	–	–	0	0
			(0)	(0)
% of explained variance			0	0
Goodness of fit				
−2*Log Likelihood	–	–	123605.12	123379.42
X2 – Change in comparison with previous models	–	–		−225.7
AIC	–	4029.83	123651.1	123427.4
BIC	–	4163.28	123804.6	123587.6
N (households)	6365	5839	5839	5839
N (departments)	17	17	17	17
r^2	0.65	0.696	–	–
Potential Poverty	40.59	47.30	47.09	47.14

Figures in parentheses are robust standard errors; $^{***}p<0.001$, $^{**}p<0.01$, $^{*}p<0.05$.
Note: No multicollinearity issue was registered in the models (see: Appendix 3).

cent when we add the agricultural occupancy variable in the fourth model specification. This may imply that climate variability effects on income generation from agricultural employment does not compensate from the negative (price) effects on per capita consumption. The random slopes present variances of at least 25.8 percent which suggests presence of differences amongst departments due to temperature variability. On the other hand, the random intercept has a variance of 0, similar to the previous models.

In contrast with the precipitation models, the significance effect of the interaction (health program*change in temperature) on household's consumption is no longer significant when agricultural occupancy is added. This result is expected since the program does not aim to mitigate adverse effects from climate variability.

It is also worthwhile to note the effect of climate variability on vulnerability to poverty when controlling for climate differences, as illustrated in the second model specification. Following the Chaudhuri, Jalan, and Suryahadi (2002) methodology on potential poverty assessments (as outlined in Section 4), our study finds that changes in precipitation can have an adverse effect on potential poverty outcomes, estimated at 47.30 percent compared with 40.6 percent of the first model. Hence, whereas at the national level 32.9 percent of households are observed to be poor in 2009 (see Table 1), our analysis estimates that 14.4 percent more households can become vulnerable to poverty due to the effects of climate variability.

These results show a projected probability of experiencing poverty in the future, which turns out to be far greater than the current general level of poverty in the population. These estimates reveal that the observed incidence of poverty treats the data on the fraction of the population that is vulnerable to poverty too lightly. Thus, there may be some households whose vulnerability level may be low (usually the non-poor); on the other hand, there may also be households that are observed to be non-poor and whose vulnerability level is high, pushing them into a cycle of poverty (being income and asset poor and thus staying poor forever).

It is important to mention that the spatial variability is included at the department level since we present precipitation and temperature data at this level. The study itself cannot estimate the future variability of climate. However, most literature on subject forecast more extreme climate conditions as presented in our literature review. Hence, we see plausible that the variability of climate will continue or increase.

Two main messages can be derived from these analyses. First, the portion of the population that is measured as vulnerable to climate variability is significantly higher than the portion which currently faces poverty. Second, even though poverty and vulnerability are usually considered as separate albeit related concepts, important linkages that reinforce individual effects have to be considered.

5.1 Goodness of fit

We conducted a series of tests in order to provide fit statistics of the models. According to the results, the most robust model is the second specification. In this case, the variable of climatic variability is added and treated as a one level model. The effects of this variable on consumption remain significant. Both AIC (Aikake Information Criterion) and BIC (Bayesian Information Criterion) tests agree on the preferred model. Their respective tests' results for the second model are 4029.83 and 4163.28 respectively, in comparison with 123651.1 and 123427. of the third model. In the last examination, when we add the percentage of agricultural occupancy, the model improves by 225.7 deviances. As expected, the variances explained by the existing differences at the departmental level are very low; the interclass relation in this level is 0. These results support our analysis regarding the impact of climate variability that is most visible at the individual level rather than the departmental one. The -2-log likelihood ratio test is used to see if the random slope incorporation improves the model fit in comparison to the model where it is not included. At last, the variation inflation factor (VIF) suggests no multicollinearity issue was registered in any of the models (see: Appendix 3).

6. Conclusion and policy implications

Climate variability has important consequences for households in Nicaragua, and therefore the topic should be seriously considered. Despite the general trend of reduction of poverty in the country, evidence of climate effects is still concentrated mostly in rural areas where it is a potential threat to welfare. Results of this study show the negative impact of changes in precipitation and temperature over the last eight years on household income and consumption per capita in Nicaragua. This study shows that temperature change has a negative effect on households' consumption and there is a need for a policy to reduce its impact. We also found evidence of regional differences on the effects caused by temperature variability. For this reason, policy-makers, when executing development strategies, should carefully assign the resources to mitigate this threat. In other words, those departments where climate variability affects more the consumption of households, they should be the ones with a higher priority in both national and regional policies.

Although, the results of change in precipitation suggest that there exists no such difference among departments. We did find that precipitation affects consumption of household in general. This means that changes in precipitation reduce household's production and income generating capacity and that rising food prices may further reduce household income and consumption opportunities. For extremely poor households this implies that their future consumption possibilities also depend on today's capability to handle climate risk. If they are not able to cope with these risks, they probably have to face a sustained decline in their consumption, thus perpetuating a poverty cycle.

Furthermore, this investigation raises concerns regarding the potential threat of climate variability to a considerable share (47 percent) of Nicaraguan households in terms of vulnerability to poverty. Climate variability could thus diminish the advances in poverty reduction or worse, it can increase the poverty levels. In terms of potential poverty, our analysis confirms that 13.4 percent more households can become vulnerable to poverty due to the effects of climate variability.

Nevertheless, not all types of climate variability will increase vulnerability if prudential policies to adaptation to its effects are established at a convenient time (Eriksen et al. 2007). In some cases, these policies could focus on the reduction of the vulnerability of particular groups, e.g. through targeted investment for enhancing rural employment and non-farm income generation. Before it becomes more difficult and costly to adapt rural households to the long-term effects of climate variability, assistance programs (e.g. social protection, prevention and management of disasters, climate adaptation and land rights) for targeting regions and disadvantaged population groups (Alderman 2010) could enhance their climate variability resilience and thus further contribute to structural poverty eradication objective.

The social programs such as education or health care have certainly contributed to improve household's income (Osypuk et al. 2014); however, is significant that adaptation decisions and policies be developed with a thorough base in the best existing knowledge on climate variability and its effects (Portier et al. 2010). Given the long-term climate variability risk that Nicaragua holds, it is necessary to reduce the effects of temperature and precipitation change. For this reason, our study suggests that any development strategy should consider climate variability as a persistent vulnerability to poverty. Policies should aim to secure access to water and reduce global warming. Furthermore, focusing on risk factors that prevail in particular regions and for specific categories of households might enable more effective and better targeted poverty reduction policies.

Notes

1. We prefer to use the term 'variability' (short-term changes) instead of climate 'change' which refers to any long-term change in Earth's climate, or in the climate of a region or city. This includes warming, cooling and changes besides temperature.
2. The Global Climate Risk Index (2014) analyses the extent to which countries have been affected by the impacts of weather-related events. The Climate Risk Index may serve as a red flag for existing vulnerability that may further increase in regions where extreme weather events will become more frequent or more severe because of climate change (Kreft and Eckstein 2014).

3. Poverty is defined as whether households or individuals have sufficient resources or abilities today to meet their needs (World Bank 2010).
4. I.e. individual or household level shocks, such as death, illness, injury, unemployment, loss on investments, indebtedness.
5. I.e. community or regional shocks, such as natural disasters, epidemics or climate change.
6. The analysis consisted of the comparison between different temperature changes and their direct effect on GDP change.
7. According to the World Bank (2012), educational attainment and welfare outcomes are closely related in Nicaragua. Findings show that lack of education is one of the main explanatory factors for poverty. Broadly speaking, welfare gains are associated with increased schooling. On average, households headed by individuals with secondary education are able to consume 32 per cent more per capita than similar households headed by someone with no education. Furthermore, a household head with technical education raises household consumption by 37 per cent. Households headed by individuals with a tertiary education account for only 12 per cent of Nicaraguan households and show a 93 per cent gain in consumption per capita. Additional findings show that households with heads who have attained less than complete secondary education are very likely to be living in poverty if the head is the only source of family income.
8. Poverty maps provide reliable diagnosis on poverty dynamics obtained by inferring consumption and income values from survey data estimations and extrapolating them to census data (Elbers, Lanjouw, and Lanjouw 2003).
9. Which might occur whenever the proposed methodology is applied to hierarchical data structures, i.e. whenever variables from various levels (e.g. from the household and regional level) are introduced in the regressions (Gunther and Harttegen 2006).
10. The ICC (interclass correlation) presents the percentage that is explained by a second level of analysis "level 2"; usually when the value is greater than 10 per cent, the use of an explanation of the dependent variable in more than one level is required.
11. The World Bank (2012) also relied of LSMS data to assess the effects of the commodities crisis on the Nicaraguan economy.
12. INIDE (2009) General Household Survey Report measuring the standard of living.
13. Some of the advantages of using the consumption rather than income as a measure of wellness are: less fluctuation and information is more reliable.
14. Calculated by Serial "MEAN" Points "2004" and "2005" From Authors Graph Calculation (161.6065062 in 2005, –161.6065062 in 2004)
15. Calculated by Serial "MEAN" Points "2005" and "2006" From Authors Graph Calculation (161.6065062 in 2005, - 114.6736185 in 2006)
16. This is in line with the Clausius-Clapeyron physical law that states that the water-holding capacity of the atmosphere increases by about 7 percent for every 1 °C rise in temperature. Because precipitation comes mainly from weather systems that feed on the water vapour stored in the atmosphere, this has generally increased precipitation intensity and the risk of heavy rainfall. Basic theory, climate model simulations and empirical evidence all confirm that a warmer climate, owing to increased water vapour, lead to more intense precipitation events even when the total annual precipitation decreases slightly, and have prospects for even stronger events when the overall precipitation amounts increase. Warmer climate therefore increases the risks of both drought – where it is not raining – and floods – where it is – but at different times and/or places (IPCC 2011).
17. Used to quantify the severity of multicollinearity in the analysis. A general interpretation is that if VIF is greater than 10 then multicollinearity is high.

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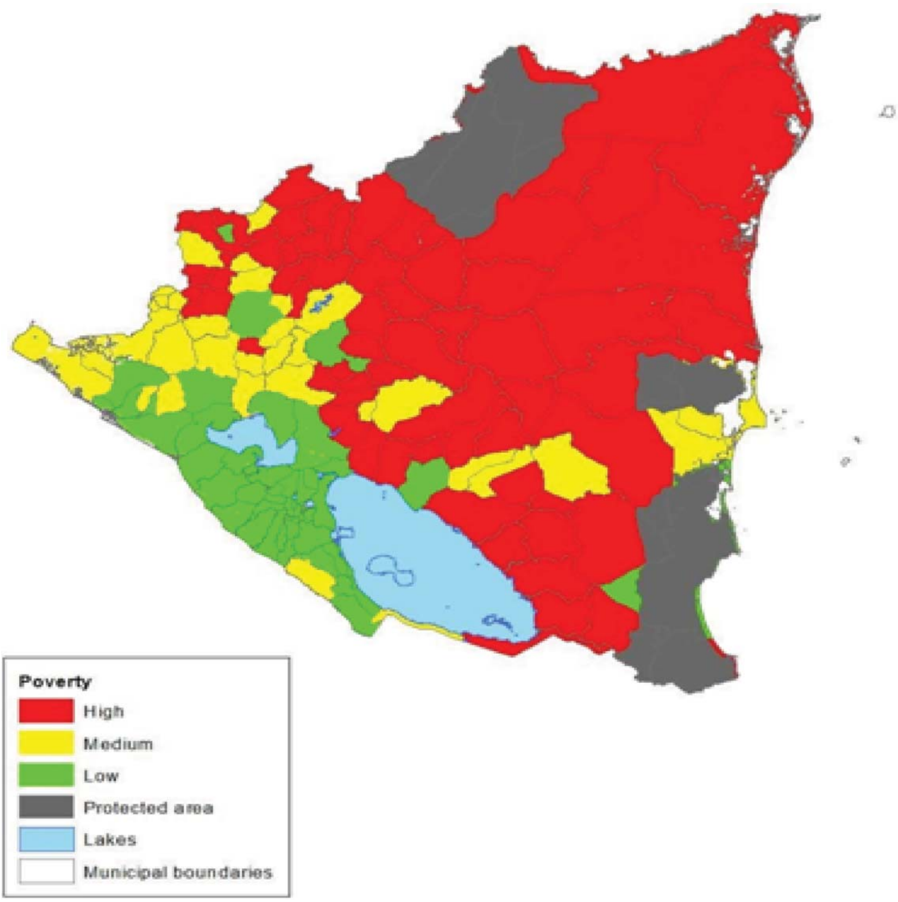
Online Resources:

www.bcn.gob.ni
www.inide.gob.ni
www.ineter.gob.ni

Appendix 1: Poverty Map of Nicaragua

The Nicaragua poverty map shows that poverty is more severe in rural areas and in the Caribbean coast, notwithstanding the economic potential in those regions'. This contrasts with rural areas in Western Nicaragua, which experienced poverty reduction in the period 1993–2009.

Because of the strong heterogeneity between macro-regions and for the illustrative purposes of this study, we present a poverty map that shows the critical areas in terms of poverty: areas of extremely high incidence of poverty (red), medium incidence (yellow) and low incidence (green). The map also presents environmentally protected areas. Key policies in these high and medium poverty level areas focus on identifying and resolving major bottlenecks to facilitate a better use of land, as well as on optimizing natural resources potential through adequate use of technological advancement and water supply management.



Source: World Bank (2013) based on the LSMS 2009.

Appendix 2: Model with Temperature Change

Explanatory variables	OLS Model		HIERARCHICAL MODEL	
	Model 1	Model 2	Model 3	Model 4
Fixed Part				
Household Characteristics				
Rural Area	0.012	−0.058***	−0.056***	−0.055***
	(0.01)	(0.01)	(0.02)	(0.02)
Years of Education Head of Household	0.021***	0.018***	0.018***	0.018***
	(0)	(0)	(0)	(0)
Household Unemployment Rate	−0.002***	−0.003***	−0.003***	−0.003***
	(0)	(0)	(0)	(0)
Household Dependency Rate	−0.099***	−0.096***	−0.094***	−0.093***
	(0.01)	(0.01)	(0.01)	(0.01)
Household Illiteracy Rate	−0.001**	−0.000*	0	0
	(0)	(0)	(0)	(0)
Lack of Access to Information	−0.135***	−0.088***	−0.087**	−0.088**
	(0.01)	(0.01)	(0.03)	(0.03)
Overcrowding	−0.112***	−0.060***	−0.061***	−0.061***
	(0.01)	(0.01)	(0.01)	(0.01)
Lack of Access to Basic Services	−0.118***	−0.058***	−0.056***	−0.057***
	(0.01)	(0.01)	(0.02)	(0.02)
Log (Capital Income)	0.287***	0.256***	0.257***	0.257***
	(0.01)	(0.01)	(0)	(0)
Log (Remittances per Capita)	0.015***	0.010***	0.011***	0.011***
	(0)	(0)	(0)	(0)
Log (Transfer per Capita)	0.001	0	0	0
	(0)	(0)	(0)	(0)
Main source of Income from a Tradeable Sector	–	−0.088***	−0.088***	−0.089***
		(0.01)	(0.01)	(0.01)
Housing Conditions	–	−0.029**	−0.028**	−0.028**
		(0.01)	(0.01)	(0.01)
Log (Capital Stock)	–	0.075***	0.076***	0.076***
		(0)	(0.02)	(0.02)
Departmental Characteristics				
Temperature Change (8 years)	–	−0.688**	−0.551*	−0.743*
		(0.31)	(0.34)	(0.41)
% Agricultural Occupancy	–	–	–	0.001
				(0)
% Education Program Covered	–	0.161*	0.138**	0.126
		(0.09)	(0.07)	(0.08)
% Health Program Covered	–	0.241***	0.276***	0.173
		(0.09)	(0.07)	(0.15)
Population Density	–	0.012	−0.035	−0.2
		(0.09)	(0.31)	(0.25)
Interactions				
% Health P. Covered* Change in temperature	–	0.770*	0.488	0.841
		(0.42)	(0.5)	(0.67)
cons	8.344***	7.747***	7.731***	7.836***
	(0.03)	(0.09)	(0.21	(0.14)
Random Part				
Cons (Random intercept var)	–	–	0	0
			(0)	.
% of explained variance			0.000	0
Temperature Change (Random slope var)	–	–	0.04	0.038
			(0.013)	(0.013)
% of explained variance			0.258	0.248
Goodness of fit				
−2*Log Likelihood	–	–	129924.72	129707.2
X2 - Change in comparison with previous models	–	–	–	−217.52
AIC	–	4189.77	129968.70	129753.70
BIC	–	4323.96	130116.30	129907.50
N (households)	6365	5839	5839	5839
N (departments)	17	17	17	17
r^2	0.649	0.698	–	–
Potential Poverty	40.59	42.8	42.93	42.58

Figures in parentheses are standard errors; $^{***}p<0.001$, $^{**}p<0.01$, $^{*}p<0.05$

Appendix 3: Variance Inflation Factor (VIF)[17]

	Variance Inflation Factor			
	Model 1		Model 2	
Variable	VIF	1/VIF	VIF	1/VIF
Lack of Access to Basic Services	1.87	0.5347	1.96	0.5099
Log (Capital Income)	1.68	0.5939	1.85	0.5408
Years of Education Head of Household	1.64	0.6111	1.65	0.6047
Rural Area	1.52	0.6558	1.77	0.5655
Household Illiteracy Rate	1.4	0.7123	1.41	0.7078
Lack of Access to Information	1.32	0.7566	1.33	0.7524
Overcrowding	1.31	0.7623	1.42	0.7043
Household Dependency Rate	1.13	0.8857	1.14	0.8757
Log (Remittances per Capita)	1.07	0.9316	1.06	0.9433
Log (Transfer per Capita)	1.05	0.9569	1.05	0.9511
Household Unemployment Rate	1.03	0.9665	1.04	0.9589
Main source of Income from a Tradable Sector	–	–	1.27	0.7875
Housing Conditions	–	–	1.50	0.6687
Log (Capital Stock)	–	–	1.33	0.7519
Population Density	–	–	2.12	0.4712
% Education Program Covered	–	–	3.46	0.2894
% Health Program Covered	–	–	2.76	0.3621
% Health P. Covered* Change in Precipitation	–	–	77.38	0.0129
Change in Precipitation (8 years)	–	–	72.13	0.0139
Mean VIF	**1.37**		**9.35**	

Appendix 4: Chronology of climate events in Nicaragua (1997–2014)

Year	Event
1997	El Niño
1998	Hurricane Mitch
2001	Drought
2002	El Niño
2004	El Niño
2006	El Niño
2006	Tropical storms
2007	Hurricane Felix
2009	Drought
2011	Tropical storms
2014	El Niño

Source: Author's analysis based on INETER data. INETER is referenced as an online source.

Appendix 5: Irrigation index by land exploitation size (2011)

	# of Farmers		Access to water	
	Numbers	%	Has access	Uses water
0–1 Ha	57,588	22%	1.80%	1.50%
1–2 Ha	31,694	12%	3.90%	3.40%
2–5 Ha	49,528	19%	5.10%	4.40%
5–20 Ha	60,020	23%	5.90%	5.20%
20–100 Ha	51,781	20%	4.60%	4.10%
>100 Ha	11,932	5%	6.90%	6.00%
Total	262,543	100%	4.40%	3.84%

Source: Zegarra and Chirinos (2016), *p*. 19.