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ESA Working Paper No. 11-18

October 2011

Agricultural Development Economics Division

Food and Agriculture Organization of the United Nations

www.fao.org/economic/esa

Effects of Global Warming on Vulnerability to Food Insecurity in Rural Nicaragua[1]

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September 2011

[1] The authors are economists in the Agricultural Development Economics Division (ESA) of the Food and AgriculturÅ Organization of the United Nations (FAO), based in Rome, Italy. This paper was prepared with the financial contribution of the FAO Multi-Donor Partnership Programme (FMPP). We thank Fransen Jean, Christian Derlagen, Gero Vaagt, Leonardo Chavez, Jean Balie, Anna Ricoy and James Tefft for their comments and suggestions. The findings, interpretations and conclusions expressed in this report are entirely those of the authors and do not necessarily represent the views of FAO and its member countries. All errors and omissions remain the responsibility of the authors.

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1. Introduction

There is growing evidence that global warming will have a substantial negative impact on agricultural yields, in particular in developing countries. This constitutes a risk for rural households, and unless these households are able to manage this risk, they will become increasingly vulnerable to food insecurity. In using data on Nicaragua, this paper demonstrates how an econometric model can be used to inform decision makers on the likely impact of global warming on the food security status of different types of households, the geographic distribution of these households and factors influencing households' ability to fend for themselves. The paper also discusses what could be done to reduce household vulnerability to future food insecurity.

Between 1971 and 2010, the average temperature in Nicaragua increased by 1.1 degrees Celsius and has become increasingly unpredictable, with large swings from year to year. In rural Nicaragua, 25 percent of farming households are extremely poor, while experiencing chronic or temporary food insecurity. A significant proportion of their income is generated through farming (more than 50% on average) and agriculture is almost completely rain-fed, with less than 2 percent of households reporting the use of irrigation. In this context, the impact of global warming could be severe. It is therefore important to be able to assess the likely impact of rising temperatures on food security and use this understanding for informing policy decisions.

In this report, we simulate the impact of expected temperature changes on farm level productivity, and subsequently, on household food consumption in Nicaragua. Time series data on temperature changes are combined with survey data from rural farming households to compute household vulnerability to food poverty[2]. We apply the model proposed in Capaldo, Karfakis, Knowles and Smulders (2010), where vulnerability is defined as a household's probability to fall below a food security threshold in the near future. Here, we express both consumption and the food security threshold in monetary terms. Hence, we develop a forward-looking measure of food deprivation, which provides information on each and every household's probability of falling below a food poverty threshold in the near future. By comparing this with data on households' current food poverty status, we are able to make a distinction between households that are experiencing either chronic or transitory food insecurity. Such a distinction is important when targeting and designing food security interventions, as it allows decision makers to prioritize and adapt interventions accordingly.

[2] A household is extremely or food poor if it is unable to cover her/his very basic needs.

Results indicate that the impact of climate change on increased vulnerability to food insecurity is quite significant. A small reduction in temperature can generate moderate benefits in terms of land productivity. However, given that average temperatures in Nicaragua have risen over the years, even minor increases in temperature can significantly reduce farm productivity through reductions in crop yields. Simulations further indicate that farm-level adaptation strategies and social protection measures can considerably reduce – but not eliminate - vulnerability. Special attention is given to municipalities in the department of Chinandega, the focus of interest of the FAO Multi-Donor Partnership Programme (FMPP) that partially funded this study.

Section 2 of the paper provides a rationale for the need to assess the effects of climate change on food security. Section 3 describes the data used and section 4 reviews climate patterns in Nicaragua; section 5 discusses the methodology to compute vulnerability and section 6 discusses the regression results, while section 7 contains the analysis of vulnerability to food insecurity. In section 8, we present some simulation results and discuss possible policy implications. Concluding remarks are given in section 9.

2. Rationale

Studies have shown that changes in climate patterns affect harvests negatively in many countries, causing an increase in local food prices, and leading to a reduction of rural incomes, while raising poverty rates (Schlenker and Lobell 2010, Hertel et. al. 2010). The size of the multiplier effect of this impact is directly related to the relative importance of the agricultural sector in the economy (Tol, 2009 and references therein). Based on these and similar findings, the impact of climate change is expected reduce the capacity of many countries to achieve their food security and economic development objectives.

According to a report of the Intergovernmental Panel on Climate Change (IPCC, 2007) in low latitude regions, a one or two degree Celsius increase in temperature is expected to have negative effects on the yields of major cereals[3]. Moreover, projected changes in the frequency and the intensity of extreme events (e.g. droughts, fires, pest or other infestations) will lead to a further deterioration in the production of food and forest products. Overall, smallholder and subsistence farmers, pastoralists and fisher-folk in affected regions are expected to experience severe negative climate change impacts.

[3] Mid to high latitude regions, on the other hand, are likely to see productivity gains resulting from moderate increases in the temperature (mainly in North America and Northern Europe).

A distinctive feature of the effects of temperature and rainfall on agriculture is their non-linearity. At low levels of temperature or low rainfall, increases of either or both variables normally improve agricultural productivity. As levels increase, a substantial rise in rainfall may cause flooding, while marginal increases in average temperature may alter plant growth. Studies have found that higher temperatures increase agricultural productivity of many crops, but only up to 30°C (Schlenker *et al*., 2006). Beyond this threshold, yield levels decline rapidly. Similarly, a small reduction in rainfall may be harmless in a normal year, but as rainfall levels keep declining, even a small additional decrease may trigger an agricultural drought. Equally, or even more important, is a change in the distribution of rainfall throughout the agricultural season. Unfortunately, we are not able to capture changes in rainfall distribution with our model.

3. Data

The PRECIS model was used for downscaling regional temperature data in Nicaragua to grid points covering the entire country, with a distance of 0.5 degrees in latitude and longitude between each point. We constructed a temperature shock by expressing temperature data in terms of relative variations between the year in which household survey data were collected, and the long-term averages. This allowed us to more fully exploit continuous information on temperatures, than if we had constructed shocks using binary variables.

We matched temperature data to geographical information from the household surveys (i.e. departments and municipalities), which allowed us to associate specific households with temperature data. This was done by assessing the proximity between grid points and administrative units. This choice had the disadvantage of possibly assigning different climate values to locations that are very close to each other, while assigning the same values to locations that are further away from each other.

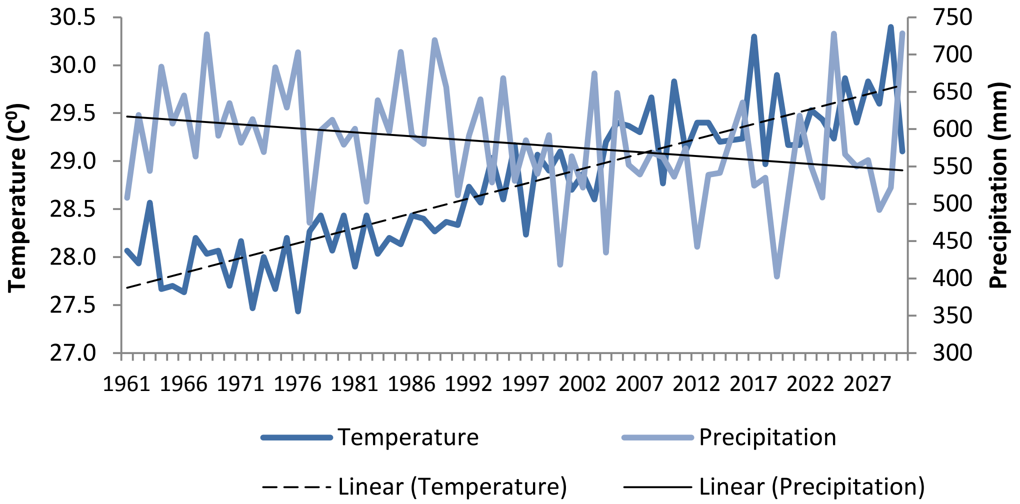
Household level data were drawn from the 2001 *Encuesta Nacional de Hogares Sobre Medición de Nivel de Vida*[4]. The sample consists of 1,242 Nicaraguan households that operate farmland which represent 68 percent of all rural households in the survey. We used the value of food consumption and the value of agricultural production per acre, the latter being a monetary measure of land productivity. Data on land ownership, crop and total farm income were treated for outliers replacing extreme values with the median of that variable.

[4] National Household Living Standards Measurement Survey. A series of the household level variables used in the analysis is taken from the Rural Income Generating Activities (RIGA) project, a project managed by FAO.

4. Past and future climate changes in Nicaragua

The mean temperature in Nicaragua increased by about 1.4°C between1971 and 2000[5]. This is markedly higher than the global average increase of 0.6°C over the same period. Average temperatures at national level reached 29°C in 2000 and are expected to continue to rise through 2030. Annual variability in temperatures is expected to be relatively constant between the two thirty year periods[6]. During the same 60-year period, both historical and future (estimates of) precipitation do not show marked differences, both in terms of levels and variability. The relative stability in rainfall was evident when a rainfall shock[7] included in the subsequent analytical steps showed no significant effects in crop yields (see Figure 1).

Figure 1: Past and future climate patterns in Nicaragua - marked increases in temperature but normal rainfall patterns



Source: Computed by authors: downscaled data on temperature and rainfall produced by the Instituto de Meteorología de la Republica de Cuba with the PRECIS-ECHAM3 model for Nicaragua.

Table 1 shows average and predicted rainfall precipitation and temperatures during the 1971 to 2000 period relative to the 2001 to 2030 period. The significant decline in the correlation between precipitation and temperature between the two periods (from
-0.54 to -0.34) is noted. The spatial distribution of temperature changes across the country is particularly important. In the departments of Granada and Managua, temperature variations have been substantially higher than the national average. Only the department of Leon has

[5] In climate studies, variations of variables over time are often compared to an "international standard period". This is a three-decade long time span which is usually shifted forward by one decade for comparison purposes. The reference period for this study spans from the 1971s through the 2000s and is compared with the 2001 to 2030 period (table 1).
[6] To factor in common skepticism about policy responses to climate change, these projections refer to the "A2 scenario". The IPCC defines this as a situation of high potential economic growth which is accompanied by low international cooperation (i.e. inadequate adaptation and mitigation efforts) in response to climate change challenges (IPCC, 2000).
[7] A rainfall shock was constructed as the relative difference in precipitation during the survey year in comparison with the long term average.

experienced a mild decline in temperature (in the range of minus 4%), relative to the long run average (see figure 2). During the survey year, in four of the six municipalities of the department of Chinandega (figure 3), rainfall fell by about 10% relative to the long run average (it fell by about 5% in the other two municipalities).

Table 1: Mean Annual Temperature and Rainfall over Reference and Future Periods

	Mean (1971-2000)	Standard deviation (1971-2000)	Mean (2001-2030)	Standard deviation (2001-2030)
Temperature	28.3	0.45	29.4	0.42
Rainfall	595.8	68.86	557.2	74.03
	Correlation (1971-2000): -0.54		Correlation (2001-2030): -0.34	

Source: Computed by authors

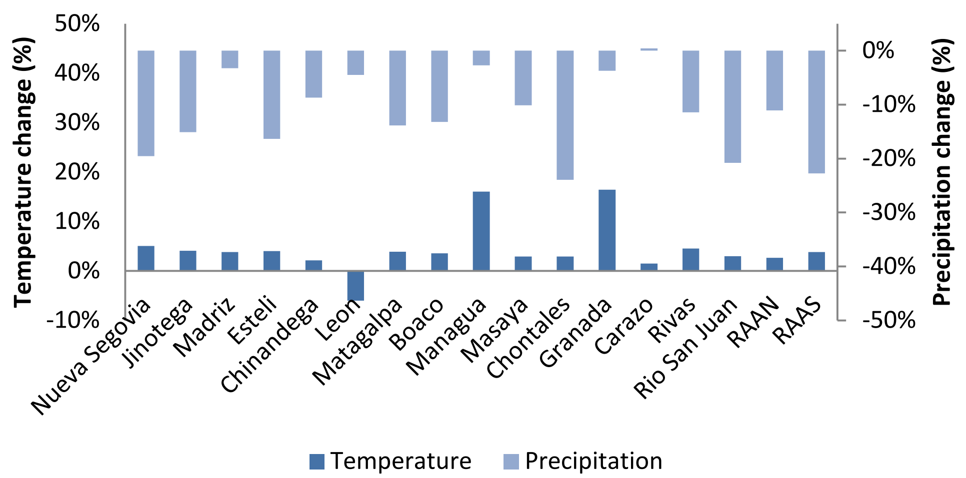


Figure 2: Climate Change in Nicaragua as of 2001 (% changes on the 1960-1989 average)

Source: Computed by authors

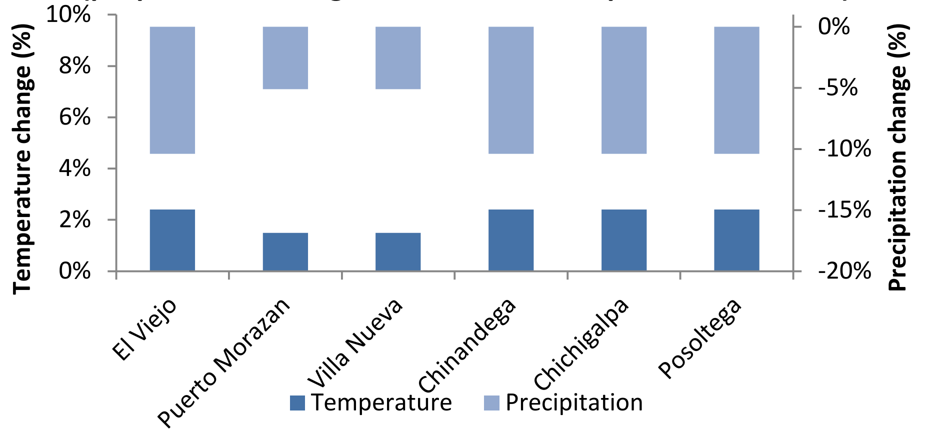


Figure 3: Climate Change in Chinandega municipalities (proportional changes in 2001 from ref. period 1960-1989)

Source: Computed by authors

Agriculture and rural households

Importance of agriculture and agricultural productivity

On average, farming households in rural Nicaragua earned 9,695 cordobas per acre in 2001, while farming income constituted 51% of total household income (table 2). The contribution of farming income to total household income and agricultural productivity varied widely across the country. In the Departments of RAAS, RAAN and Jinotega, farming contributed to more than 70% of total household income, whereas in Carazo, Chinandega, Managua, Madriz and Masaya, it accounted for less than 40%; in the latter locations, productivity was below the national average. Agricultural productivity was highest in peri-urban areas of Managua and Masaya, even though dependence on agriculture was moderately low (on average, income from farming contributed 40% and 21% to total household income in Managua and Masaya, respectively). This is explained by the relatively small number of farming households producing high value crops in these Departments, while being well-connected to urban markets.

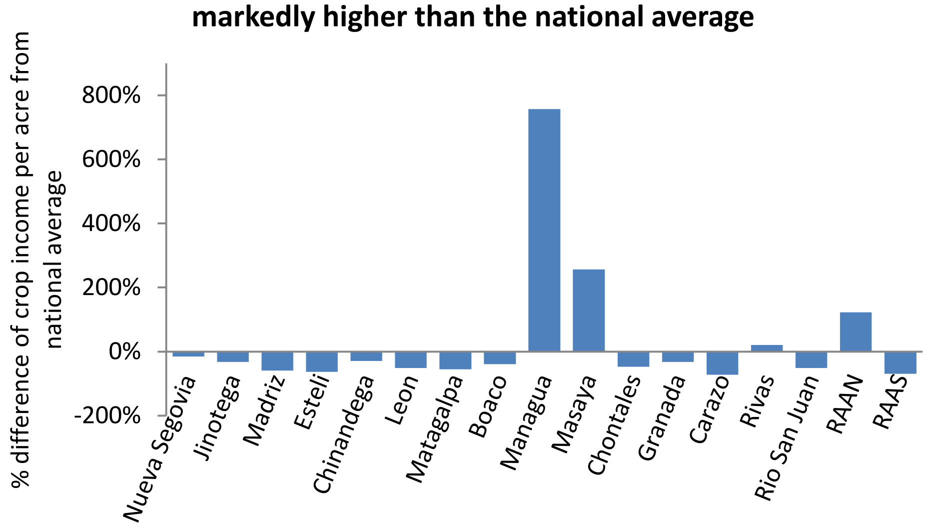
Table 2: Importance of agriculture in total household income varies widely across farmers in the country

	Share of Income from Farming (%)
Nueva Segovia	49
Jinotega	74
Madriz	36
Esteli	41
Chinandega	35
Leon	41
Matagalpa	47
Boaco	46
Managua	40
Masaya	21
Chontales	57
Granada	18
Carazo	31
Rivas	53
Rio San Juan	69
RAAN	85
RAAS	72
Total	**51**

Source: Computed by authors

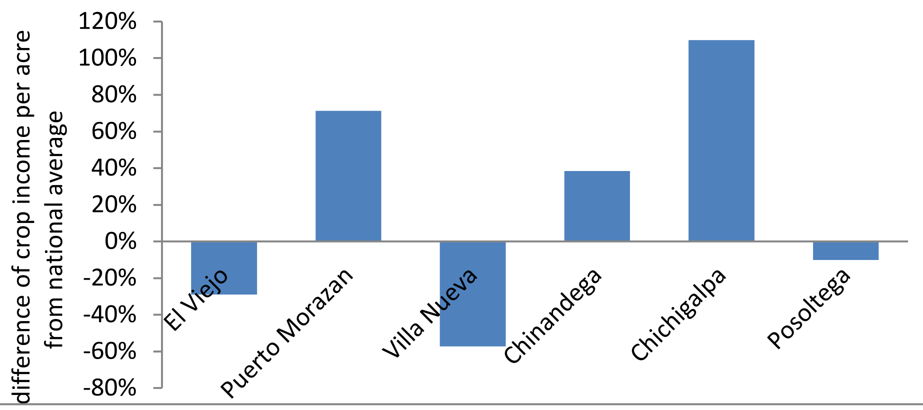
Productivity was found to be unevenly distributed also within the department of Chinandega (Figure 5). Puerto Morazan, Chinandega and Chichigalpa had farming incomes far above the departmental average, while the municipality of Posoltega, El Viejo and Villa Nueva fell below the average. No clear relationship was detected between productivity and climate change in the department. However, farmers in Chichigalpa were able to achieve high levels of productivity, in spite of important changes in climate patterns, possibly indicating successful adaptation and mitigation strategies. On the other hand, in Villa Nueva, where the incidence of climate change has been mild, productivity remained very low. Evidently, in more urbanized communities where the production of exportable cash crops dominates and knowledge diffusion is easier (like Chichigalpa), productivity is higher, in contrast with communities with low population density like Villa Nueva, in which staple food production is the norm.

Figure 4: In peri-urban areas, crop income per acre is markedly higher than the national average



Source: Computed by authors

Figure 5: Income from farming per acre, Chinandega, 2001 (% difference from department average)

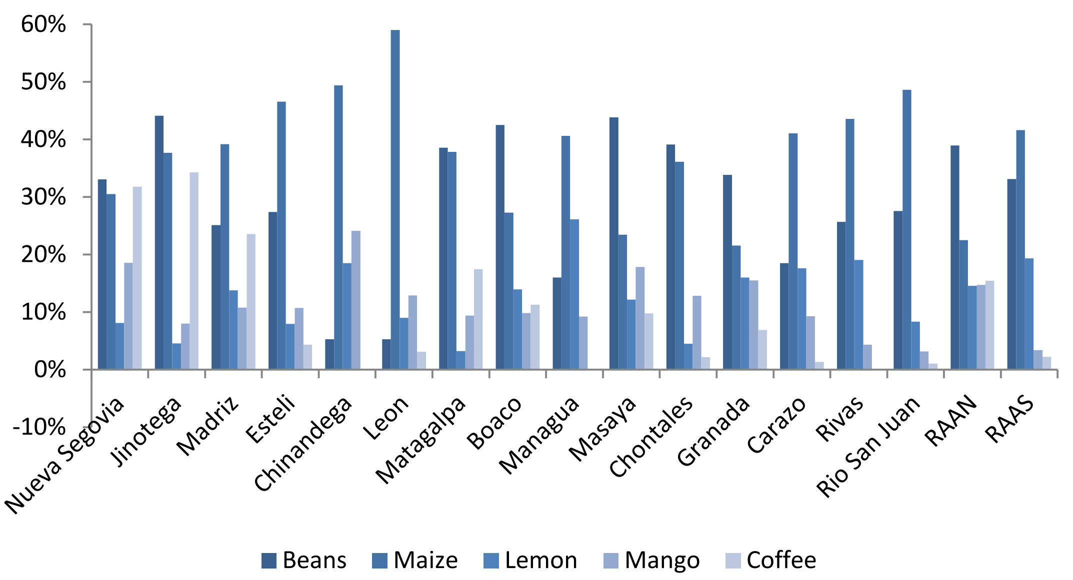


Source: Computed by authors

There is a clear pattern of mixed cropping and diversification across the country. Staple crops (e.g. beans and maize) are more prevalent than cash crops (e.g. coffee, lemon and mango). Maize is the most commonly cultivated crop in most parts of the country, with the highest frequency of about 55 percent of households in Chinandega and Leon cultivating maize. Beans follow closely, while lemon and mango are produced by fewer farming households (see figure 6). Coffee, finally is mainly produced in Nueva Segovia, Jinotega and Madriz as more than 25 percent of sampled farmers report producing coffee in those departments; 10 to 20 percent of the farmers produce coffee in Matagalpa and RAAN and a smaller proportion in the rest of the departments.

Also, it has been difficult to assess whether the level of crop diversification is sufficient for mitigating and adapting to the impacts of climate change. On the other hand, the great reliance on the consumption of maize and beans in the country, along with the high proportion of households that produce these crops, indicates that current levels of crop diversification may be insufficient to reduce the threats to food insecurity faced by subsistence farmers.

Figure 6: Main Crops in Nicaragua's Departments (% of farming households)



Source: Computed by authors

As can be seen in table 3, rainfall and temperature changes in 2001 in comparison with their long run averages, displayed a significant degree of variability across farm households in rural Nicaragua. However, a rather small proportion of the sampled households (about 11 percent) suffered a drought, defined as a decline in precipitation of more than 20 percent. On the other hand, about 75 percent of the households were confronted with relative temperature increases of more than 2.5 percent when compared with the long term average.

Table 3: Household exposure to temperature and rainfall changes in 2001

Class	Percent	Class	Percent
Rainfall change < -20%	11	Temperature change < 0%	11
-20% < Rainfall change < -15%	22	0% < Temperature change < 2.5%	15
-15% < Rainfall change < -10%	29	2.5% < Temperature change < 5%	57
-10% < Rainfall change <-5%	16	Temperature change > 5%	17
-5%< Rainfall change< 0%	18		
Rainfall change > 0%	4		
Total	**100**		**100**

Source: Computed by authors

5. Methodology

This study represents a follow-up to previous work conducted, in which we used the term 'vulnerability' as the likelihood of a household experiencing *food insecurity* in the future (Capaldo et al, 2010). In the analysis presented below, rather than estimating levels of food insecurity through a measure of food deprivation, the vulnerability analysis conducted involves estimating the probability that each and every household will experience *extremely poverty*[8] in the near future. To measure the vulnerability status of different households, we used econometric techniques (generalized least squares econometric methods), which has allowed us to approximate the expected distribution of household consumption.

To estimate the impact of climate change on household vulnerability, we first estimated the effects of climate change on land productivity (step 1). In a second step, we correlated expected land productivity (results from step 1), plus other socio-economic characteristics and constraints, with food consumption. As discussed in more detail below, we used the Instrumental Variables estimator (IV) to address problems of endogeneity.

To estimate vulnerability, our empirical analysis was articulated into two further distinct steps. To estimate expected household food consumption (measured through household expenditure per adult equivalent on food) and its variance, we used: (a) the results from the second regression above to obtain a consistent estimate of the expected food consumption and its variance for each household; and (b) the estimation of households' vulnerability to extreme poverty (a measure of insufficient economic access to food). In step (b) we calculated the probability that total consumption will be lower than a minimum threshold of food deprivation

[8] Extreme poverty implies that households are not able to cover basic needs, including food. We use this measure as a proxy of food insecurity (or food poverty).

for each household. In this latter step expected food consumption predicted from the regression analysis is added to non food consumption expenditures reported by the household.

Hence, in steps (1) and (2), we employed a set of linear regressions to estimate the impact of each variable on land productivity and food consumption. In steps (a) and (b) we built on the results from steps (1) and (2), to estimate each household's vulnerability indicator, where we defined vulnerability as the unconditional probability that household *h* may suffer a shortfall in consumption:

$$V_h = P[(ln\overline{K}_h - lnK_h) > 0]$$

Assuming that the logarithm of consumption is normally distributed, vulnerability is given by:

$$V_h = \frac{1}{\sqrt{2\pi\sigma_h{}^2}} exp\left\{-\frac{ln\overline{K}_h - lnK_h}{2\sigma_h{}^2}\right\}.$$

In this paper, we employ an approach that makes it easy to compare our results with those obtained by the World Bank in its calculations of extreme poverty and food insecurity. Instead of comparing a food expenditure threshold with each household's actual food expenditure, we compare the extreme poverty threshold to total household consumption expenditure (Coudouel et al., 2002). The probabilities calculated are to be interpreted as relative vulnerability to insufficient economic access to food (food poverty) and not as vulnerability to overall poverty, as we do not allow for stochastic changes in non-food expenditure. In other words, we estimate total consumption but we only consider future variations of food consumption (expenditure).

In order to obtain robust estimates of food consumption, we have to deal with endogeneity and heteroskedasticity. Endogeneity arises from the fact that the value of total agricultural production – which is essential for explaining consumption of farming households – is correlated with food consumption itself. We address this problem by adopting the standard solution of the Instrumental Variables (IV) estimator[9] and by choosing as instruments a proxy set of variables, namely (i) agricultural infrastructure, (ii) access to fertilizers and (iii) temperature[10]. With this technique, we run two linear regressions, estimating first the impact of all variables – including the instruments – on land productivity and then the impact of productivity and the remaining variables on consumption expenditures.

[9] We have tested this choice for robustness by calculating vulnerability under two different consumption estimates (IV and OLS). The results do not vary significantly, confirming the appropriateness of our choice (see Appendix).

[10] All variables are "instruments" in the estimation of agricultural production but these three are "specific instruments" that are not used in the consumption regression. We have evaluated our choice of instruments with statistical tests reported in the Appendix. All tests suggest that chosen instruments are statistically valid.

In order to address heteroskedasticity we use weighted least squares. Essentially, we implement the IV estimation in a recursive way, whereby we use the results of the first iteration to estimate the relationship between our explanatory variables and the variance of consumption. In a second iteration of the IV estimation, variables are weighted in accordance with the estimated variance.

6. Results: the determinants of farm income and consumption

We have two sets of results: estimates of the correlates of land productivity and estimates of the correlates of food consumption expenditure. The former define the relationship between land productivity and all other variables, plus changes in temperature, the use of inputs and participation in producers' organizations. The latter variables are employed as instruments in the first stage regression. The correlates on food consumption define the relationship between consumption, productivity and all other socio-economic variables.

As discussed above, our estimates are focused on the effects of global warming on agricultural productivity and thereby on food consumption of rural households. Both sets of results are in line with underlying theory and commonly observed facts. Table 4 includes the results of both steps of the IV regression. The first column refers to the regression of land productivity on all variables (including the specific instruments identified above), while the second and third columns show the results of the food consumption regression and its variance, respectively. Instruments (listed between the two gray lines) are selected so that they are correlated with land productivity, but not with food consumption.

The cornerstone of our results is the positive effect of productivity on food consumption. An increase in land productivity by 10% is associated with a 2% increase in consumption expenditure. All other variables can be grouped into two major categories: demographic characteristics and assets (including infrastructure variables and coping capacity information). These are discussed below.

6.1 Demographic characteristics

Household size is positively correlated with land productivity (the coefficient is significant at the 10% level), suggesting that all household members contribute to total farm income. On the other hand, the relationship between household size and per capita food consumption is negative, indicating that in larger households each member of the household has less access to food. Nevertheless, a quadratic term in this regression would assist in improving our understanding of the relationship.

Table 4: Estimation results (Instrumental Variables Estimator) – all variables in logs but shares and dummies

	Log value of ag production per acre		Log food consumption value per adult equivalent		Variance of log of food consumption value per ae	
	Coefficient	t-stat	Coef.	Coef.	Coef.	t-stat
Log value of ag production per acre			0.204***	(5.33)		
Log hh size in adult equivalent units	0.173*	(1.84)	-0.699***	(-21.42)	-0.0544	(-0.33)
Log age of hh head	0.160	(1.13)	-0.112**	(-2.28)	0.170	(0.69)
Log years of education of hh head	0.0373	(0.89)	0.0427***	(2.94)	-0.0651	(-0.90)
Single head	0.0450	(0.31)	-0.0185	(-0.36)	-0.349	(-1.37)
Female headed hh	0.00816	(0.05)	0.0544	(1.01)	-0.119	(-0.44)
Indigenous household	0.788***	(3.42)	-0.0610	(-0.79)	-0.372	(-1.06)
Access to hh migration network	0.157	(0.74)	-0.0347	(-0.47)	-0.230	(-0.67)
Log no of rooms	0.0153	(0.14)	0.194***	(4.98)	0.357*	(1.81)
HH has access to safe water	0.00408	(0.04)	0.0878***	(2.78)	0.0793	(0.50)
Log no of radios owned	0.190**	(2.34)	0.0425	(1.46)	-0.244*	(-1.74)
Log no of TVs owned	0.0896	(0.76)	0.0921**	(2.26)	-0.161	(-0.80)
Log dist. to nearest health facilities	-0.0111	(-0.77)	0.00530	(1.07)	0.0613**	(2.47)
Log dist. to nearest primary school	-0.0148	(-0.74)	0.000283	(0.04)	0.0157	(0.47)
Log km from hh to nearest major road	0.0217	(1.31)	-0.00541	(-0.97)	0.0280	(1.02)
Log no of bikes owned	0.136	(1.37)	0.0738**	(2.16)	-0.242	(-1.42)
Log land operated (ha)	-0.748***	(-21.96)	0.204***	(6.71)	0.0280	(0.50)
Log number of draft animals	0.354***	(6.66)	-0.00322	(-0.14)	-0.159*	(-1.78)
Log no of hh members partic. in com. org	0.116	(1.60)	0.0154	(0.61)	-0.140	(-1.14)
HH received loan	0.0608	(0.34)	-0.0101	(-0.17)	0.184	(0.63)
Log no of gov. assistance programs	-0.0593	(-1.01)	0.0217	(1.12)	0.0307	(0.32)
Log no of non-gov. assistance programs	-0.182**	(-2.34)	-0.000732	(-0.03)	0.114	(0.86)
Illness shock	0.360***	(3.31)	-0.0147	(-0.37)		
hh participates in ag producers organiza	0.382*	(1.91)				
HH used chemical fertilizer	0.235**	(2.27)				
HH used organic fertilizer	0.482**	(2.56)				
HH used pesticides	0.279***	(3.06)				
Temperature change < 0%	8.483*	(1.95)				
0% < Temperature change < 2.5%	-27.56***	(-2.61)				
2.5% < Temperature change < 5%	-27.34***	(-5.07)				
Temperature change > 5%	-2.586***	(-4.00)				
Constant	7.470***	(12.49)	7.528***	(21.75)	-4.382***	(-4.79)
R squared	0.34		0.38		0.03	
No of cases	1242		1242		1242	
F test	16.03		30.07		1.710	

*, **and *** indicate statistical significance at 1, 5 and 10 % levels, respectively. Department level dummy variables have been included in the regressions but the corresponding coefficients are not reported.
Source: Computed by authors

A range of characteristics of the head of household (age, education, civil status) are positively correlated with productivity but are insignificant. Also, the gender of the head does not significantly affect land productivity and food consumption. Strikingly, affiliation with an indigenous community is positively and very significantly correlated with land productivity. This result requires further exploration considering the very poor welfare status that usually characterizes indigenous households[11]. The age of the head of household and the civil status as single are associated with lower per capita food consumption; however, only the former effect is statistically significant.

[11] Less than 5% of the sampled households are indigenous; thus this result maybe spurious given the lack of sufficient variation.

6.2 Assets

Access to assets, as approximated using the number of draft animals, correlates positively and significantly with land productivity; similarly, the number of radios owned by a household is also positively correlated with land productivity. The latter indicates the value of access to information for these farming households.

Distances from health facilities and from primary schools are considered preference shifters, but we treat them as proxies of communication infrastructure. These two time variables are inverse measures: the longer the distance, the worse the road and transportation infrastructure. Infrastructure variables do not appear to have a statistically significant effect on land productivity; however, such effects it is likely that they are captured by the department level control dummy variables. The statistically significant negative correlation of the size of land under cultivation with productivity is an expression of the well-known negative correlation between farm size and productivity that typically motivates support for smallholders.

We consider assistance programs as assets, given that they are proxies of the social welfare infrastructure. The sign of the coefficients may be interpreted differently irrespective of if it is positive or negative. Assistance programs may be associated with lower productivity, if they are activated to increase productivity where this is low (correct targeting); on the other hand however a positive sign might indicate an effective response to their use.

Assets also have generally positive effects on food consumption. Here, all four exceptions feature very low coefficients and are not significant. The most important determinants of food consumption expenditure are the availability of farmland (operated land), the characteristics of the household's dwelling (approximated here by the number of rooms), access to safe water and access to household transportation (approximated by the number of bikes owned). All these variables indicate the importance of a strong asset base in achieving sufficient levels of household welfare.

6.3 Instruments

As explained above, an instrumental variables (IV) approach is employed to identify the correlates of food consumption. Instruments affect food consumption only indirectly, through their effect on productivity, while all other variables have both direct and indirect effects. All three instruments, namely the use of fertilizers, pesticides, and participation in producers' organizations have sizeable and statistically significant effects on increasing agricultural productivity.

For example, given that the use of chemical fertilizers (an instrument) is associated with a 24% increase in land productivity and increases in productivity are associated with a 20% increase in consumption, the effect of fertilizers on consumption is 5%.

To explore any non-linear effects of temperature changes on farm productivity, we constructed four variables that account for proportional reductions in temperature into categories of mild, moderate and higher proportional increases. The signs of the relevant variables are as expected. Current *declines* in temperature contribute to increases in productivity and significantly (at 10% level) whereas temperature *increases* have strongly significant negative impact on productivity.
Since the effect of temperature changes on productivity depends on temperature's level, the result seems to confirm the thesis of a non-linear relation between climate change and productivity which becomes evident past a threshold level of temperature (Schlenker, 2006). However, this level-dependence may not be entirely visible, given the proximity of average temperatures in Nicaragua to the 30 degree threshold. Observation of a longer historical path is expected to show that for low temperature values the impact of any increase on productivity is negligible.

In our model the impact of temperature changes on vulnerability to food poverty is indirect (i.e. a change in temperature in our model affects land productivity, which subsequently affects food consumption, total consumption and ultimately the degree of vulnerability of a farming household). As a consequence, it is difficult to measure the relationship between temperatures and vulnerability directly. A larger sample with richer information on land quality and crop yields would have certainly helped.

7. Effects of global warming on the likelihood of being food insecure

By applying the methodology described in section 5, we derive vulnerability indicators from the estimates of household expenditures on food consumption. We consider households with more than 50% probability of being food deprived in the future as 'vulnerable'.

7.1. Targeting: criteria and geographic distribution of vulnerability

Our analysis confirms that when targeting interventions, it is important to make a distinction between households that are food-poor[12] today and households that are likely to be so in the future. If we only use current food security status as the criteria for targeting, 25% of farming

[12] The food poverty, or extreme poverty line, for the Nicaragua LSMS 2001, has been computed by the World Bank and is equal to 2690 cordobas per capita, annually. For our analysis the line is adjusted so that it refers to adult equivalent household units.

households in rural Nicaragua are eligible. However, by applying a vulnerability analysis, we were able to identify a more strategic approach to targeting that takes into account likely changes in household food security status in the future, in part as a consequence of global warming. Importantly, possible errors of inclusion and exclusion in the design of interventions can be avoided, while different needs of chronically and transitorily food insecure households can be assessed. Our results show that:

- 18% of households (approximately 68 000 households) are estimated to be chronically food insecure (i.e. food insecure today and likely to be so in the future, unless assisted). These households are in need of assistance to help them break away from their food insecurity status;
- 5 % of households (approx. 19 000) are temporarily food secure (i.e. food secure today, but likely to be food insecure in the future unless assisted). These households are in need of assistance to avoid becoming food insecure in the future;
- 7 % of households (26 000) are temporarily food insecure (i.e. food insecure today, but likely to be food secure tomorrow without any assistance). These households do not need assistance, since they are likely to emerge from food insecurity with their own means; and
- 70 % of households (263 000) are considered permanently food secure (i.e. food secure today and likely to remain so in future, even without assistance). These households do not need assistance.

Table 5: Food poverty and vulnerability in Nicaragua (population shares in % and mean vulnerability probability in parenthesis)

	Not Vulnerable		Vulnerable		Total	
Not Food-Poor	70	[0.06]	5	[0.73]	75	[0.11]
Food-Poor	7	[0.27]	18	[0.82]	25	[0.67]
Total	77	[0.08]	23	[0.80]	100	[0.25]

Source: Computed by authors

Through this disaggregation we see that targeting based only on today's food security status would include 7 percent of households that are able to emerge from a state of insecurity without assistance, and excludes 5 percent of households that are food secure today, but likely to be food insecure tomorrow. At the national level, to effectively reduce vulnerability to food insecurity, about 22 percent of households (83 000) need to be targeted with different types of interventions to avert the impending threats to food security posed by global warming and/or other shocks. The nature of interventions targeted at chronically food insecure and transitorily food secure households, is further discussed below.

We see that also in Chinandega – the specific department of interest in this analysis - vulnerability analysis can improve intervention design and targeting (Table 6):

- 11% of households (2 400) are chronically food insecure (i.e. food insecure today and likely to be so in the future unless assisted). These households are in need of assistance to help them break away from their situation of food insecurity.
- 4 % of households (900) are temporarily food secure (i.e. food secure today, but likely to be food insecure in the future unless assisted). These households are in need of assistance to avoid becoming food insecure in the future.
- 9 % of households (2 000) are temporarily food insecure (i.e. food insecure today, but likely to be food secure tomorrow without any assistance). These households do not need assistance, since they are likely to emerge from food insecurity with their own means.
- 76 % of households (17 000) are permanently food secure (i.e. food secure today and likely to be so in the future, even without assistance). These households do not need assistance.

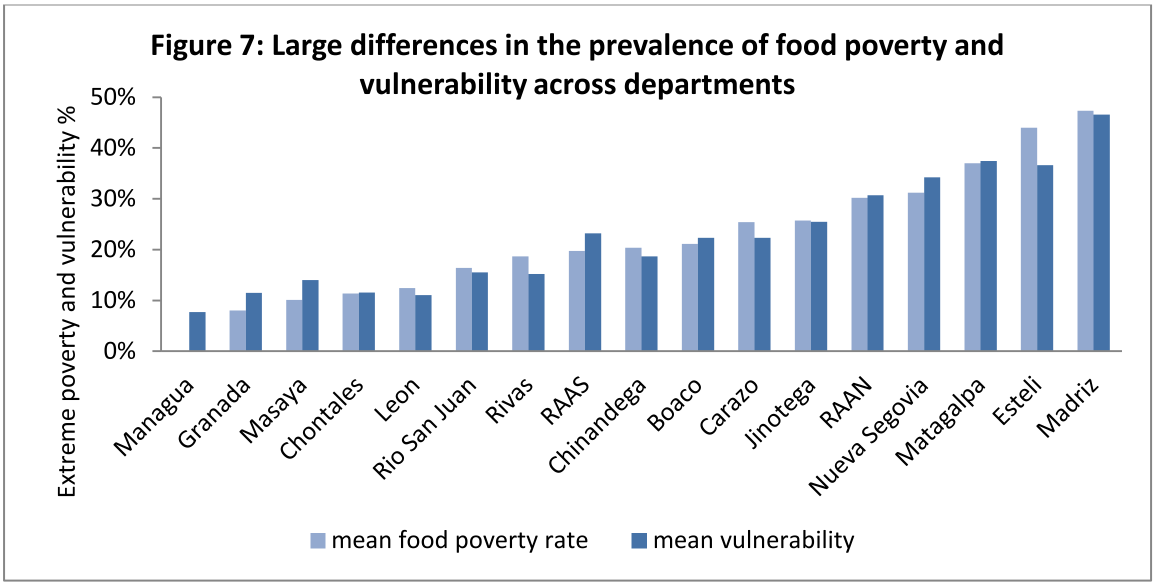
Table 6: Food poverty and vulnerability in Chinandega (population shares in % and mean vulnerability probability in parenthesis)

	Not Vulnerable		Vulnerable		Total	
Not Food-Poor	76	[0.06]	4	[0.71]	80	[0.09]
Food-Poor	9	[0.19]	11	[0.86]	20	[0.54]
Total	85	[0.08]	15	[0.82]	100	[0.18]

Source: Computed by authors

Compared to national averages, chronic food insecurity is less prevalent in Chinandega and a larger proportion of households are only temporarily food insecure, further emphasizing the benefits of targeting based on a vulnerability analysis. In fact, targeting based on a static measure of food insecurity would include 1 500 households that are likely to move out of food insecurity, even without assistance. Tables 5 and 6 provide additional information on average levels of vulnerability. Chinandega differs from the national sample in two ways: first, and most importantly, food poor, non-vulnerable farmers have a lower probability of losing access to food in the future (19% vs. 27%). Secondly, the probability is higher for food poor, vulnerable households, even though this latter difference is not significant (86% vs. 82%).

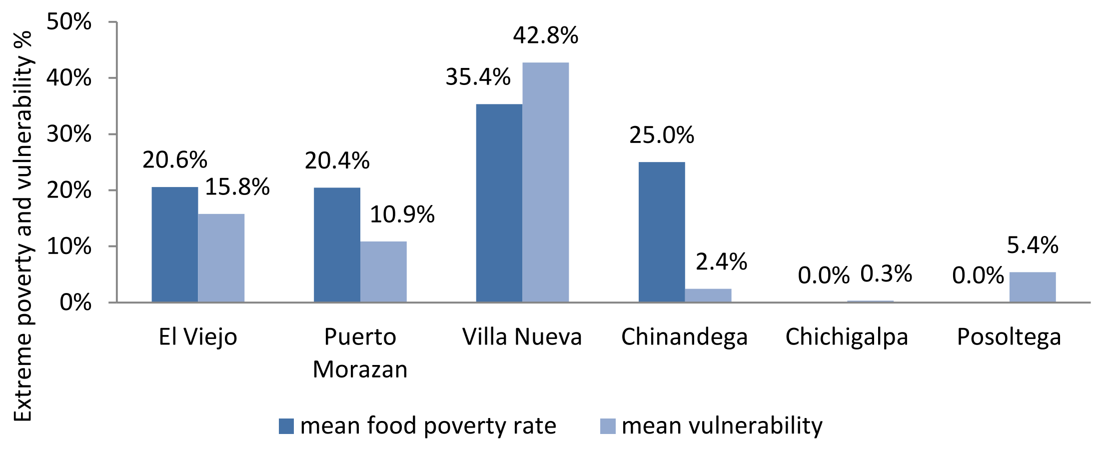
The spatial distribution of vulnerability is markedly uneven across the country (see figure 7), and as expected, highly correlated with food poverty. The probability of future food insecurity ranges from an average as low as 7.5% in Managua to an average of 46% in Madriz. When comparing current and prospective food poverty we see that in some departments these are quantitatively different from each other, thus confirming that the targeting of food security interventions is better informed by the complimentary use of indicators of current and prospective food security status. In Managua, there is virtually no food poverty, in spite of 7.5% being vulnerable to future food poverty, while in Madriz, where both the prevalence of food poverty and vulnerability are much higher, the difference between the two measures is just 1%.



Source: Computed by authors

Similarly, levels of vulnerability differ widely across municipalities in the Department of Chinandega. Among the six municipalities from which farming households were sampled, the probability of future food poverty ranges from almost zero in Chichigalpa to 43% in Villa Nueva. Differences between food poverty and vulnerability range between zero and 23% (Figure 8). Three municipalities (El Viejo, Puerto Morazan and Villa Nueva) face a higher probability of food insecurity (current and future) than the others, thus deserving greater attention in the design and targeting of food security interventions.

Figure 8: Food poverty and vulnerability in Chinandega's Municipalities



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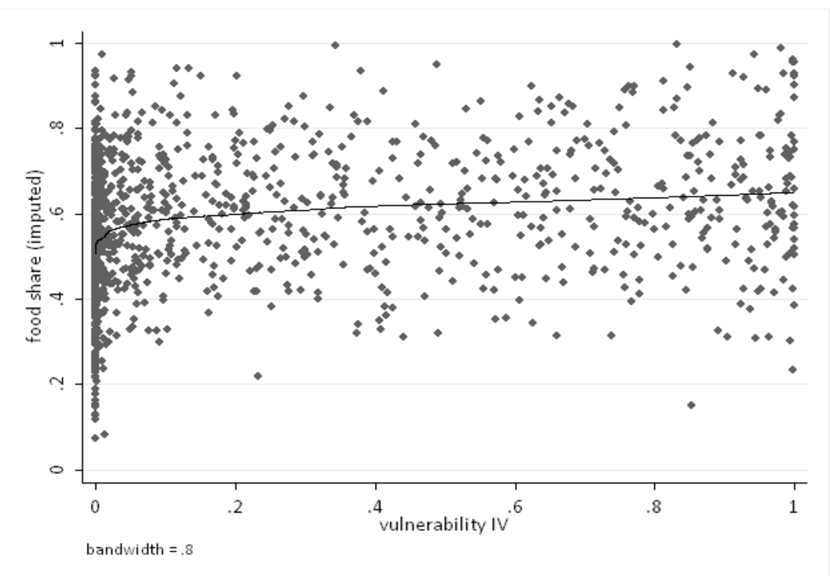
Lastly, a relevant feature of household preferences affecting vulnerability is the variability of the food share of total consumption (Figure 9). According to a common assumption in consumer theory, which is also an empirical regularity, the share of expenditure on food declines, as income increases. Our non-parametric calculations confirm this assumption indirectly, in the form of a positive relationship between the food share and the level of food consumption. This translates into a positive association between the share of consumption expenditure on food, and vulnerability.

Figure 9: Vulnerability and food share of total consumption



Source: Computed by authors

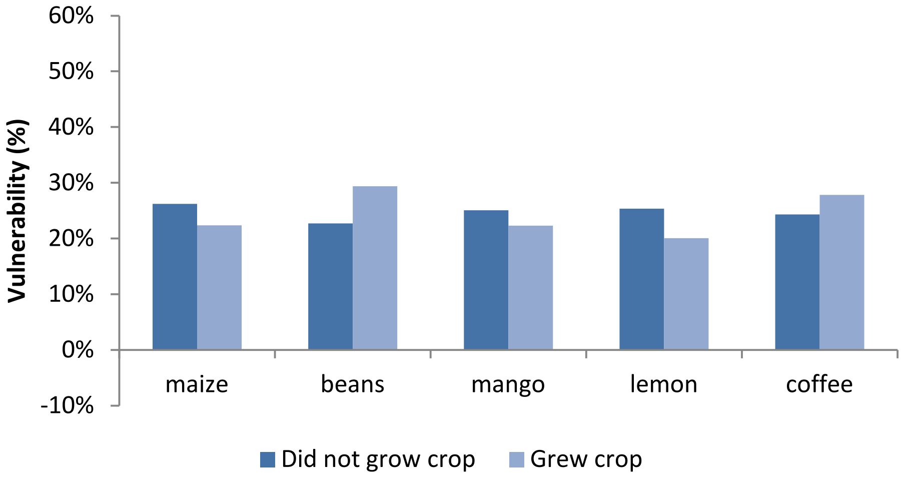
7.2. Characteristics of vulnerable households

The analysis of the characteristics of households provides useful information for defining the required nature of interventions when targeting households, and for the formulation of appropriate policies to reduce vulnerability to food insecurity. Given the close relationship between consumption and vulnerability, further investigation of demographics and assets provides similar findings as the above analysis of the estimates of consumption. The value added of the analysis presented below is that it enables us to define specific profiles of households that are more likely to find themselves in a situation of food poverty in the near future. A greater emphasis on cash crops, higher levels of overall productivity, and greater market participation, are all associated with lower levels of vulnerability.

- *Production of different crops and vulnerability*

Based on our analysis, bean growers are more likely to be food poor in the future (29% average probability) than farmers who do not cultivate beans or who produce another crop (maize, mango or lemon). At the other end of the spectrum, farming households that cultivate lemons are least vulnerable, compared to those who do not (25% versus 20%, respectively). The mean differences in vulnerability are statistically significant for maize and beans (at 1 and 10% level of significance), but insignificant for coffee, mango and lemon.

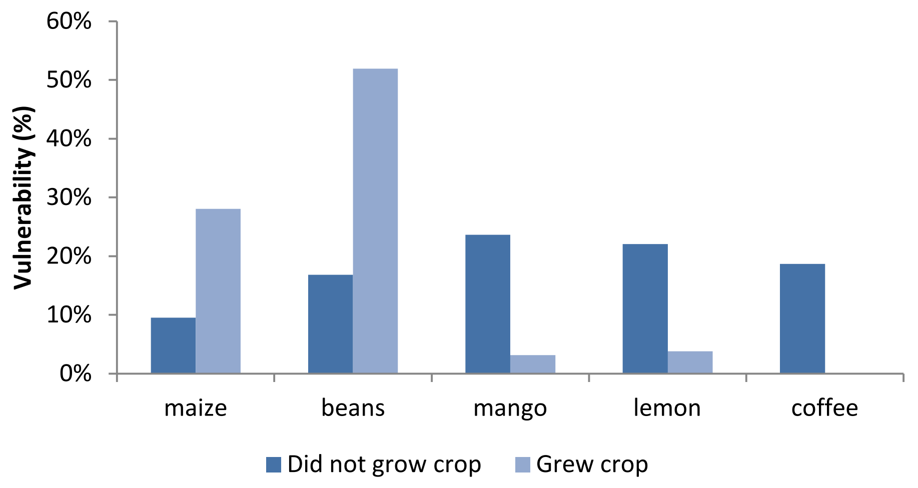
Figure 10: Crops grown and levels of vulnerability



Source: Computed by authors

In Chinandega, the relationship between farming systems and vulnerability is different (Figure 11) while generally, differences are more extreme. In this department, both bean and maize growers suffer from higher levels of vulnerability compared to farmers who do not grow these staple crops. In the case of beans, the difference is as large as 35%. More commercial crops, such as mango and lemon, are associated with substantially lower levels of vulnerability (21 and 18 percentage points, respectively). As at the national level, also in Chinandega, the cultivation of lemons is least sensitive to climate change, while the production of beans is associated with higher levels of average vulnerability. No farmer in the sample reported producing coffee in the department. The average differences in vulnerability for each crop are all statistically significant at the 5% level.

Figure 11: Crops grown and vulnerability in Chinandega



Source: Computed by authors

The relationship between vulnerability and the relative occurrence of each crop confirms these findings. When we associate vulnerability classes with the frequency with which farmers grow each crop (Table 7), we consistently observe a higher frequency of bean cultivation among more vulnerable classes (i.e 50-60% and 70-80% probability of being food insecure in the future) and low frequency of lemon cultivation across all classes. Finally frequencies of coffee producers are higher in mid to higher levels of vulnerability.

Table 7: Crops by classes of vulnerability (Nicaragua): Relative freq. with respect to total farming households

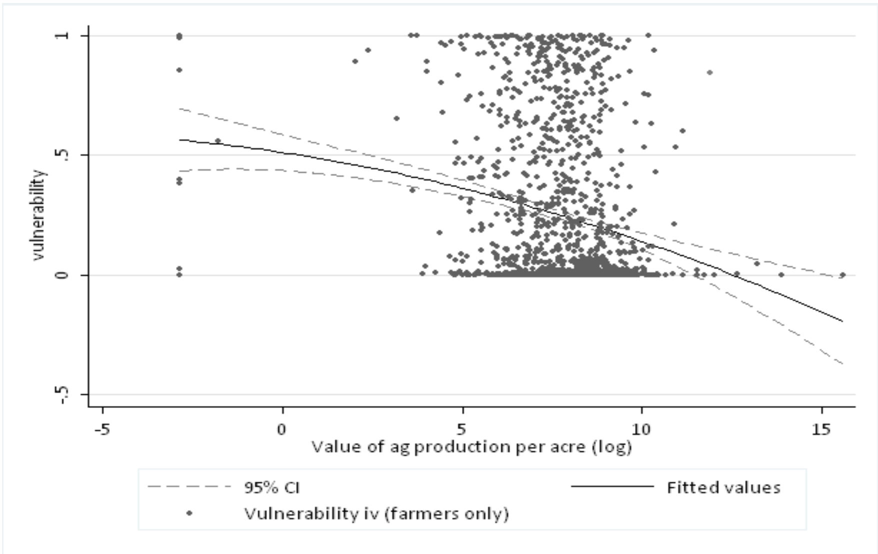
Vulnerability class	0-20%	20-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total
maize	0.41	0.36	0.31	0.40	0.18	0.39	0.37	0.39
beans	0.27	0.29	0.53	0.34	0.54	0.23	0.37	0.30
mango	0.11	0.12	0.15	0.10	0.10	0.10	0.09	0.11
lemon	0.13	0.11	0.01	0.07	0.05	0.09	0.11	0.11
coffee	0.11	0.15	0.11	0.18	0.17	0.12	0.13	0.12

Source: Computed by authors

- *Land productivity and sales*

Two more farm characteristics that are relevant for our analysis include land productivity and the share of farm production sold. Figure 12 shows a scatter-plot of vulnerability and productivity. The distribution of the data points does not exhibit any apparent pattern, but the quadratic fit we have estimated clearly shows a negative relationship between the two variables: higher productivity is associated with lower vulnerability.

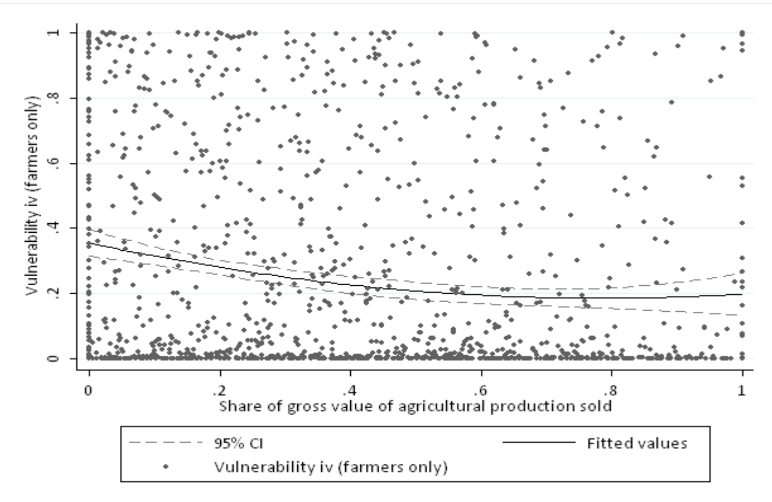
Figure 12: Vulnerability to food poverty and land productivity



Source: Computed by authors

Figure 13 shows the scatter-plot of vulnerability and the share of production sold. Once again, the wide distribution of the datapoints does not display any apparent relationship. By adding a non-linear fit, this time with non-parametric techniques (lowess smoothing), a relatively weak negative relationship appears between vulnerability and the share of production sold. According to our calculations, vulnerability is generally lower where access to markets is higher.

Figure 13: Vulnerability and farm sales



Source: Computed by authors

- *Demographic characteristics*

Age of the household head and household size appear to be positively correlated with vulnerability, while the relationship with the level of education is negative. From section 5, we know that this depends on the effects of these variables on consumption and farm productivity. Where education is higher, mean food consumption is higher (due to positive direct and indirect effects) and total consumption is therefore higher. Also, we know that higher education is associated with lower variance of consumption. In sum, a higher mean and lower variance determine a lower probability of falling below the minimum food expenditure compatible with food security. Farming housholds in higher classes of vulnerability are more likely to be indigenous and to be female-headed than households in the lower classes, while the civil status of the household head exhibits a clear non-linear behavior, with high frequency of singles in lower classes that decrease in central classes and increase again in higher ones.

- *Assets*

Most agricultural and non-agricultural assets have a negative relationship with vulnerability (table 8). The features of a household's dwelling (number of rooms, access to safe water, number of TVs and radios), private transportation (bikes), some agricultural assets (draft animals, fertilizers and pesticides) and certaintypes of social infrastructure (roads, community organizations and financial services), all have higher values in lower classes of vulnerability.

Table 8: Demographics, Assets and crops by classes of vulnerability add measurement unit

Class of vulnerability	unit	0-20%	20-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total
Proportion of hhs	%	60%	13%	3%	4%	4%	5%	11%	100
Age (head)	Years	47.28	47.47	47.79	47.96	39.88	51.00	45.90	47.15
Education (head)	Years	2.51	1.89	0.72	0.64	1.56	0.77	0.94	2.06
HH Size	adul. eq.	5.34	6.79	6.74	7.73	7.63	8.72	8.36	6.15
Single head	Bin.	0.21	0.14	0.11	0.10	0.09	0.23	0.17	0.19
Female head	Bin.	0.13	0.13	0.08	0.10	0.17	0.13	0.15	0.13
Indigenous	Bin.	0.07	0.07	0.00	0.06	0.02	0.07	0.07	0.06
Access to migr. Netw.	Bin.	0.05	0.01	0.03	0.00	0.01	0.03	0.03	0.04
# of Rooms		2.09	1.80	1.78	1.74	1.62	1.82	1.45	1.94
Access to safe water	Bin.	0.59	0.48	0.51	0.37	0.36	0.57	0.31	0.53
# of Radios		0.58	0.64	0.48	0.64	0.59	0.59	0.62	0.59
# of TVs		0.23	0.12	0.04	0.10	0.06	0.09	0.04	0.18
Time to health facility	Mins	13.41	14.36	18.41	14.00	15.69	11.81	11.12	13.54
Time to primary school	Mins.	14.88	13.78	13.58	12.72	14.43	17.33	17.17	14.89
Distance to major road	Km	54.45	60.41	23.54	57.55	37.88	54.93	56.90	54.04
# Bikes		0.39	0.19	0.23	0.20	0.09	0.05	0.06	0.30
Land operated	Acres	8.47	7.05	7.24	6.27	3.40	6.41	4.64	7.57
Land owned	Acres	10.88	8.68	8.09	7.61	2.64	5.29	6.02	9.44
# draft anim.		1.27	0.64	0.47	0.70	0.55	0.87	0.73	1.05
Community org.	Bin.	0.53	0.35	0.33	0.29	0.29	0.36	0.34	0.46
HH received Loan	Bin.	0.09	0.12	0.02	0.05	0.00	0.05	0.01	0.08
Gov't prog.	Bin.	1.56	1.35	1.18	1.24	0.96	1.86	0.99	1.45
NGO prog.	Bin.	0.41	0.40	0.45	0.45	0.15	0.38	0.38	0.40
Producers' Org.	Bin.	0.07	0.06	0.03	0.00	0.03	0.05	0.00	0.06
Chemical Fertilizer	Bin.	0.45	0.33	0.26	0.25	0.31	0.31	0.16	0.38
Organic Fertilizer	Bin.	0.08	0.03	0.04	0.02	0.00	0.09	0.02	0.06
Pesticides	Bin.	0.53	0.44	0.45	0.42	0.40	0.47	0.30	0.48
Temperature change	%	4	5	7	6	7	6	5	5

Source: Computed by authors

Notably, land variables and participation in governmental and non-governmental programs are positively associated with vulnerability. For land variables, once again, the inverse farm size-productivity relationship applies, while for governmental and non-governmental programs we can probably explain the relationship with reverse causality: vulnerability captures the fact that programs are activated where households are more exposed to risks.

8. Climate change and policy simulations

In this section, we use the estimates from section 6 to calculate vulnerability under different counterfactual hypotheses of climate change and potential policy responses. To simulate these impacts, we replace the actual values of the variables whose effect we are interested in with hypothetical ones. Different values generate different values of food and total consumption and ultimately different probabilities of food poverty. While instruments do not affect consumption variance in our model, all other variables (i.e. education) do, and in these cases the level effects may be amplified or reduced.

With the simulations, we do not repeat the estimation of consumption nor do we repeat the estimation of vulnerability. These simulations are an exercise in *comparative statics* (put differently, we assume a constant structure of the model). We compare current levels of vulnerability with the levels that would appear under different hypotheses without analyzing the process that leads to the new figures. Simulated figures must not be considered temporally subsequent to current ones but alternative, since in this paper we do not venture in the dynamics of vulnerability. In other words, the time dimension is essentially absent from this exercise.

8.1. Policies to reduce vulnerability

A rational approach to policy making suggests choosing policy instruments that are directly observable and have reliable relationships with target variables. From our estimates of the consumption model, it appears that we have two such instruments: education and agricultural inputs (specifically fertilizers and pesticides), which have statistically significant and positive impacts on consumption.

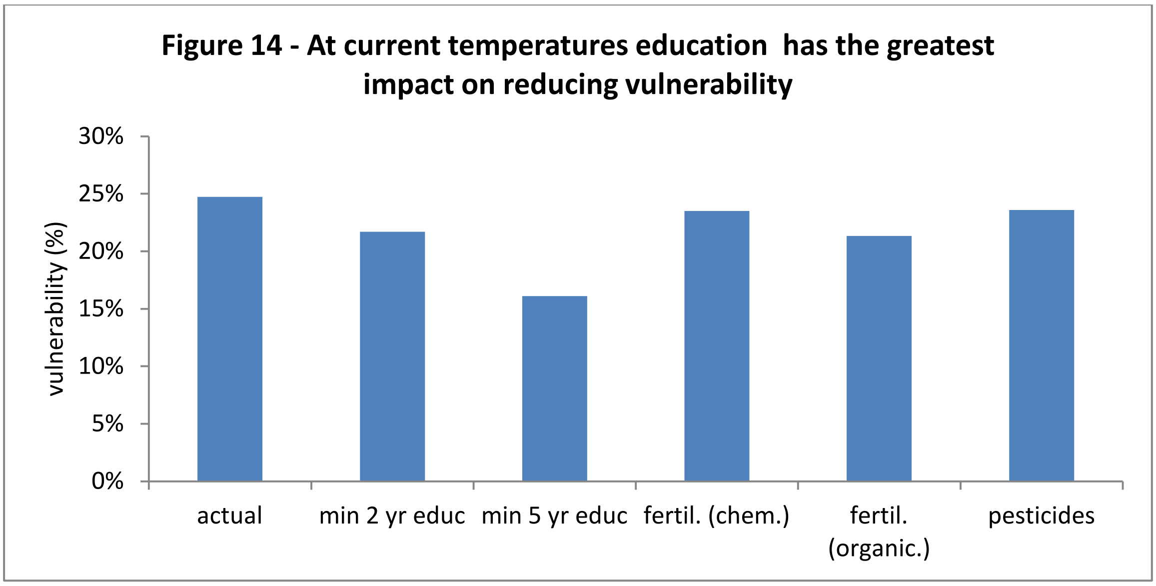
We consider five alternative hypotheses of policy interventions (figure 14) and estimate the impact of these on reducing vulnerability:

- Increase education of the household head to a minimum of two years
- Increase education of the household head to a minimum of five years (primary education completed)
- Access to chemical fertilizers for every farmer
- Access to organic fertilizers for every farmer
- Access to pesticides for every farmer

Increasing education of the head of household has the strongest effect (figure 14) on reducing vulnerability. By bringing education up to a two-year minimum for every household head, average vulnerability falls by approximately four percentage points. Raising the education level of the head of the household to a minimum of five-years, reduces vulnerability by 9 percentage points.

Universal access to chemical fertilizers or pesticides reduced vulnerability by one percentage point, while organic fertilizers have a stronger effect, approximately two percent.

As it is now clear, these effects depend on the responses of consumption. Education has positive effects on consumption, both directly and through productivity. Moreover, education reduces the variability of consumption (even though not significantly).



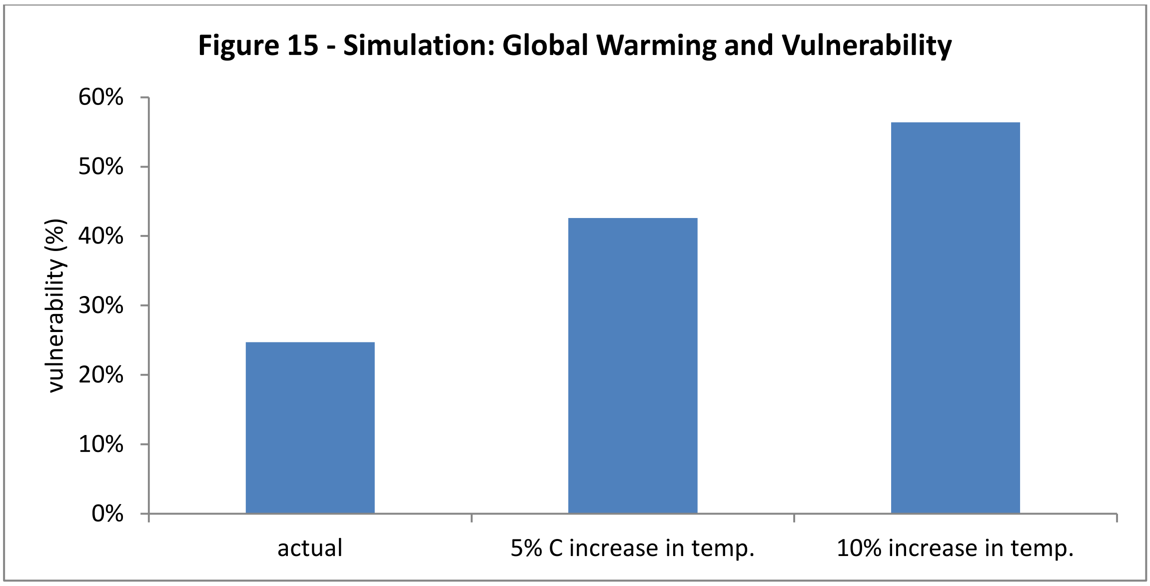
Source: Computed by authors

8.2. Global warming and policy responses

In order to simulate the effects of global warming, we calculated consumption and vulnerability under the assumption that average temperatures will increase by 5% or 10% (Figure 15). Both changes have large effects. A 5% increase in temperature (compared to the long run average for the period 1961-1990), brings vulnerability up to 43% and a 10 % increase more than doubles vulnerability (from 25 to 56%). In this case we do not have any variance effect. Temperature affects only the mean of consumption through its negative effects on productivity.

Figure 16 reports the effects of policy responses. Net effects in these cases depend on the interaction of several factors. On the one hand, increases in temperature reduce productivity and consumption, thereby increasing vulnerability. On the other hand, higher education has positive effects on consumption and productivity and facilitated access to fertilizers and pesticides further increases productivity.

In the case of a 5% increase in average temperatures, we estimate that ensuring that heads of households have a minimum education of two years, would reduce vulnerability levels from 43% down to 40%, while ensuring access to both fertilizers (chemical and organic) and pesticides would reduce vulnerability to 37%. The simultaneous application of both measures would bring vulnerability down to 34%. Thus, from the simulations, it is evident that there is a scope for policy measures that can smooth the negative impact of climate change.



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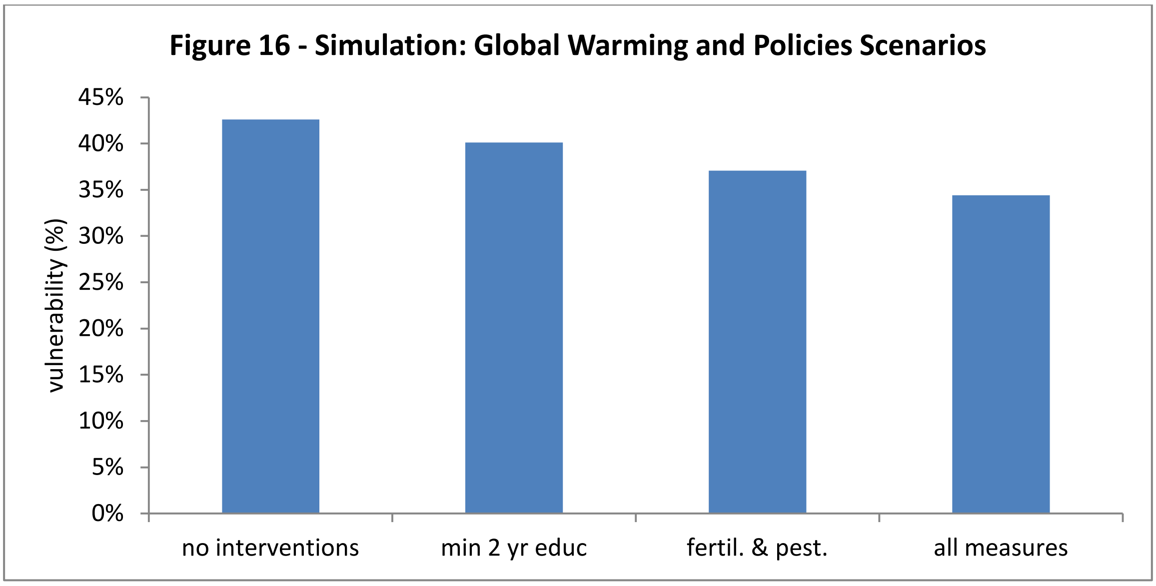

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9. Concluding remarks

The analysis carried out shows that climate change represents an important threat to the future food security status of rural households in Nicaragua. Changes in temperatures, and in their absolute levels, in addition to the ability to manage these changes, vary across the country. Hence, informing decision makers, based on the results of disaggregated analyses of climate changes and of the ability to manage these changes, is important and highly relevant to adapt – and possibly to mitigate – the impact of climate change.

The forward-looking lens of vulnerability analysis shows that in the context of climate change in Nicaragua, the design of food security interventions can greatly benefit from making a distinction between households that are transitorily food insecure and households that are chronically food insecure. These distinctions help avoid inclusion and exclusion errors and also support the design of interventions geared to the differing needs of chronically food insecure households. At the national level, conducting a static analysis of food security with vulnerability analysis, allows us to identify 26 000 households that are currently food insecure, but that are able to emerge from this state of food insecurity without external assistance, while 68 000 households that are found to be chronically insecure.

In addition to temperature changes, we analyzed the effects of demographic characteristics and of agricultural and non-agricultural assets on vulnerability to food insecurity. Location, asset holdings and propensity to sell agricultural produce on the market, have considerable effects on reducing the vulnerability levels of farming households.

We furthermore simulated the vulnerability effect of given changes in climate, and found that even small variations in temperature have heavy effects on farmers' future ability to access sufficient food. Policies that increase education and facilitate access to fertilizers and pesticides are effective means of offsetting the negative consequences of climate change. By increasing mean food consumption, both directly and through the effect on agricultural productivity, and by altering the variance of consumption, these policies help sustain total consumption and contain vulnerability to food poverty.

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11. Appendix

The following tables contain the results of statistical tests – all favorable – on the choice of the instruments and the robustness of our estimator.

Table A1: First stage regressions for agricultural production per acre

	Farmers only
Test for endogeneity of: Log value of ag production and wages	
Durbin-Wu-Hausman Chi-sq(1)	7.46
P-value	0.006
Over identification test of all instruments	
Sargan statistic Chi-sq(13)	18.39
P-value	0.143

Table A2: Vulnerability indicator (probability)

	OLS		**IV**	
	Mean probability	Standard deviation	Mean probability	Standard deviation
Vulnerability index	24.1	32.0	24.7	33.1

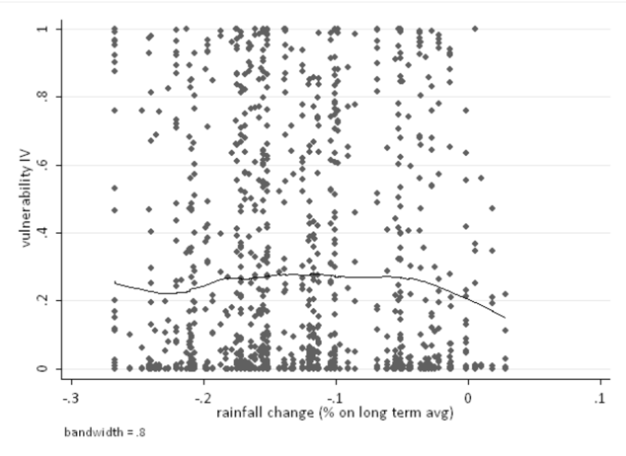
Table A3: Determinants of average food consumption per adult equivalent and its variance using OLS

	Log food consumption value per ae		Var. of log food consumption value per acre	
	Coef.	**t-stat**	**Coef.**	**t-stat**
Log value of ag production per acre	0.0947***	(10.26)		
Log hh size in adult equivalent units	-0.687***	(-22.12)	0.0424	(0.27)
Log age of hh head	-0.0912**	(-1.98)	0.368	(1.57)
Log years of education of hh head	0.0427***	(3.15)	-0.0566	(-0.84)
Single head	-0.0267	(-0.54)	-0.0317	(-0.12)
Female headed hh	0.0498	(0.93)	0.0339	(0.13)
Indigenous household	0.0869	(1.22)	-1.171***	(-3.27)
Access to hh migration network	0.0191	(0.26)	-0.121	(-0.39)
Log no of rooms	0.222***	(6.01)	0.376**	(2.02)
HH has access to safe water	0.0924***	(3.04)	0.190	(1.25)
Log no of radios owned	0.0573**	(2.15)	-0.327**	(-2.45)
Log no of TVs owned	0.107***	(2.85)	-0.149	(-0.81)
Log min from hh to nearest health facili	0.00491	(1.05)	0.0483**	(2.08)
Log min from hh to nearest primary schoo	-0.0000778	(-0.01)	-0.0168	(-0.51)
Log km from hh to nearest major road	-0.00265	(-0.52)	0.0733***	(2.99)
Log no of bikes owned	0.0967***	(2.97)	-0.158	(-0.99)
Log land operated (ha)	0.121***	(9.32)	0.0180	(0.34)
Log number of draft animals	0.0408**	(2.34)	-0.236***	(-2.83)
Log no of hh members partic. in com. org	0.0283	(1.24)	-0.271**	(-2.41)
HH received loan	0.0277	(0.53)	-0.100	(-0.38)
Log no of gov. assistance programs	0.0270	(1.44)	-0.0739	(-0.79)
Log no of non-gov. assistance programs	-0.0202	(-0.80)	0.208*	(1.70)
Illness shock	0.0277	(0.78)		
Rainfall change < -20%	-0.997***	(-2.69)	1.881	(1.08)
-20% < Rainfall change < -15%	-0.881*	(-1.85)	-0.293	(-0.13)
-15% < Rainfall change < -10%	-0.980	(-1.60)	-0.861	(-0.30)
-10% < Rainfall change < -5%	-1.138	(-0.98)	-2.261	(-0.41)
-5% < Rainfall change < 0%	-1.490	(-0.60)	-12.36	(-0.98)
Rainfall change > 0%	10.21**	(2.27)	-31.61	(-1.55)
Temperature change < 0%	2.232	(1.63)	-9.116	(-1.34)
0% < Temperature change < 2.5%	-0.605	(-0.17)	44.15**	(2.39)
2.5% < Temperature change < 5%	-0.102	(-0.06)	9.526	(1.17)
Temperature change > 5%	-0.0339	(-0.15)	2.542**	(2.07)
Constant	8.174***	(39.83)	-5.243***	(-5.51)
R squared	0.445		0.0615	
No of cases	1242		1242	
F test	27.68		2.398	

* p<0.10, ** p<0.05, *** p<0.01

Figure A1 shows the relationship between rainfall and vulnerability as it appears from non-paramtric estimates (Loess). Clearly, there is no monotonicity and it is not easy to interpret the behavior of the curve.

Figure A1: Vulnerability and rainfall changes



Appendix

Table 3: Model Variables (summary statistics)

Variable	mean	sd	variable	Mean	Sd
Value of food consumed per ae	3663	2700	Dist. to nearest major road (km)	54.04	109.8
Value of agric production per acre	9695	102924	Number of bikes in hh	0.3	0.62
Household size in adult equivalents	4.69	2.11	Land operated (imputed)	7.57	14.09
Age head of hh	47.15	15.76	No. of draft animal(s) hh owns	1.05	2.05
Years of education head of hh	2.06	2.79	Participation in community org	0.46	0.76
Single head	0.19	0.39	HH received loan	0.08	0.27
Female headed hh	0.13	0.34	# of govt programs accessed	1.45	1.64
Indigenous household	0.06	0.24	# of NGO programs accessed	0.4	0.76
Access to hh migration network	0.04	0.19	Illness shock	0.18	0.38
Number of rooms in dwelling	1.94	1.07	Particip in ag producers organization	0.06	0.23
HH has access to safe water	0.53	0.5	HH used chemical fertilizer	0.38	0.49
Number of radios in hh	0.59	0.55	HH used organic fertilizer	0.06	0.24
Number of tv sets in hh	0.18	0.39	HH used pesticides	0.48	0.5
Time to nearest health facility (min)	13.54	14.81	Proportional change in rainfall	-0.12	0.07
Time to nearest prim. School (min)	14.89	12.37	Proportional change in temperature	0.05	0.1
Irrigation access (%)	1.5	0.12			

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