Effects of global warming on vulnerability to food insecurity in rural Nicaragua

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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.

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

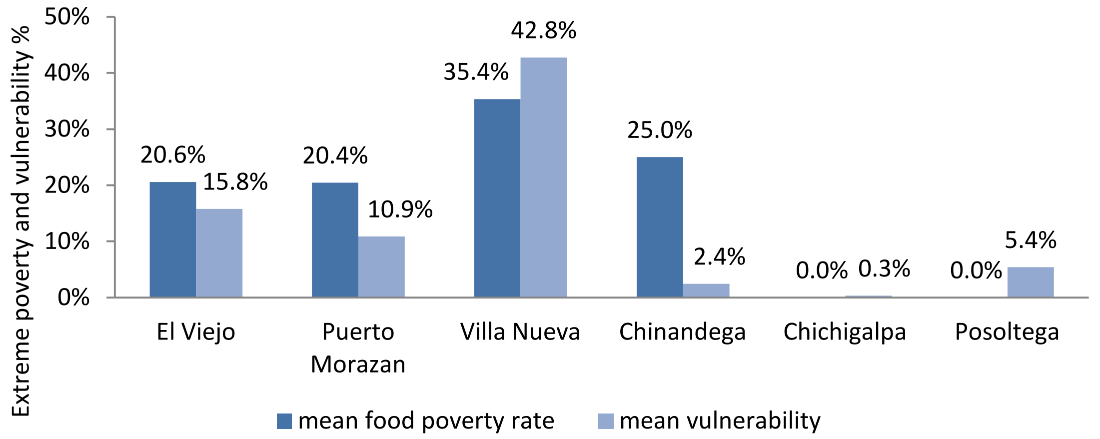
By applying the methodology described in section 5, we derive vulnerability indicators from the estimates of household expenditures on food consumption. We consider households with more than 50% probability of being food deprived in the future as 'vulnerable'.

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.

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



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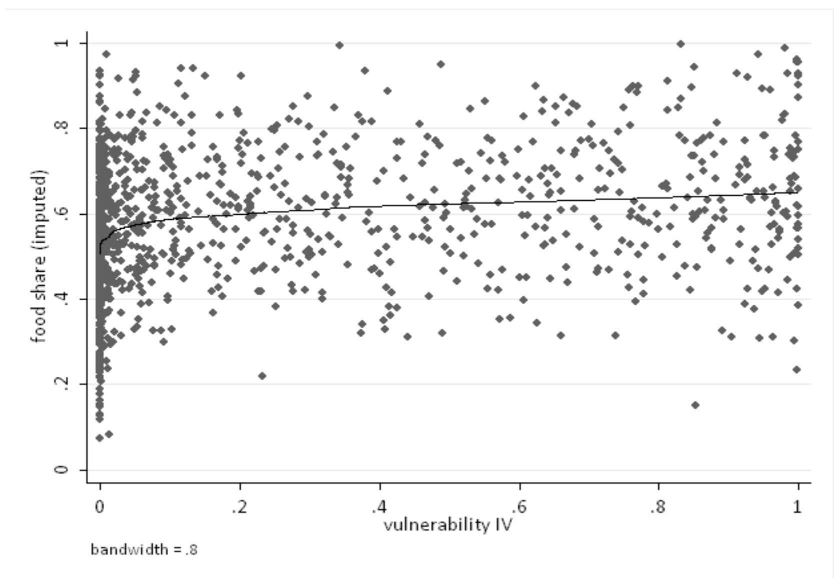
Lastly, a relevant feature of household preferences affecting vulnerability is the variability of the food share of total consumption (Figure 9). According to a common assumption in consumer theory, which is also an empirical regularity, the share of expenditure on food declines, as income increases. 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



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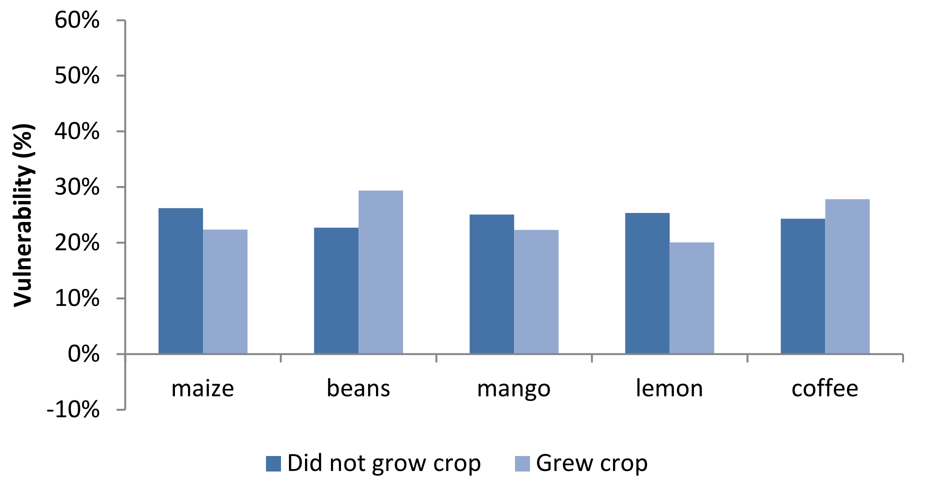
7.2. Characteristics of vulnerable households

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*

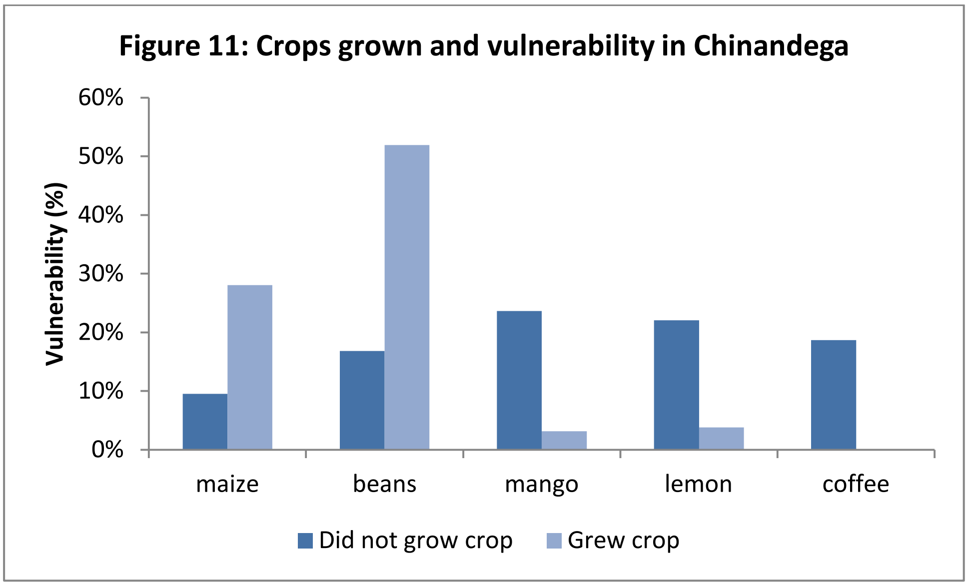
Based on our analysis, bean growers are more likely to be food poor in the future (29% average probability) than farmers who do not cultivate beans or who produce another crop (maize, mango or lemon). At the other end of the spectrum, farming households that cultivate lemons are least vulnerable, compared 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.



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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

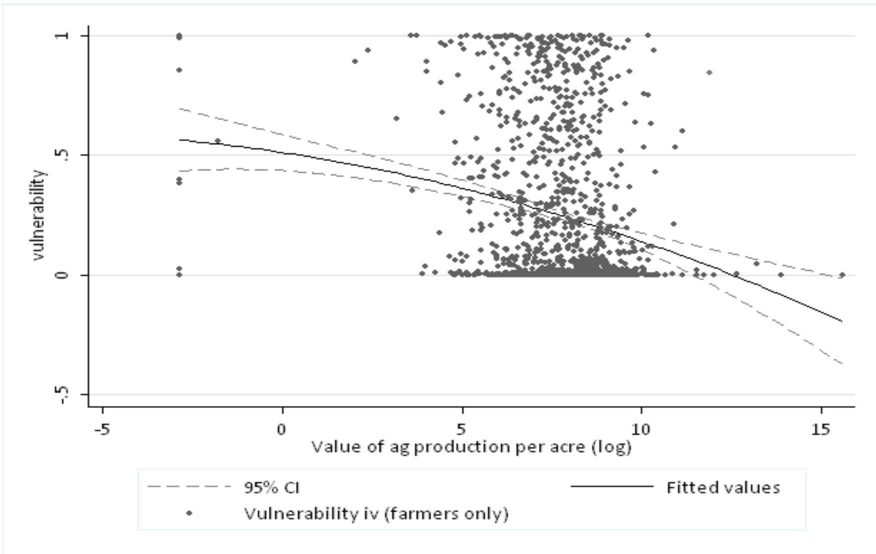

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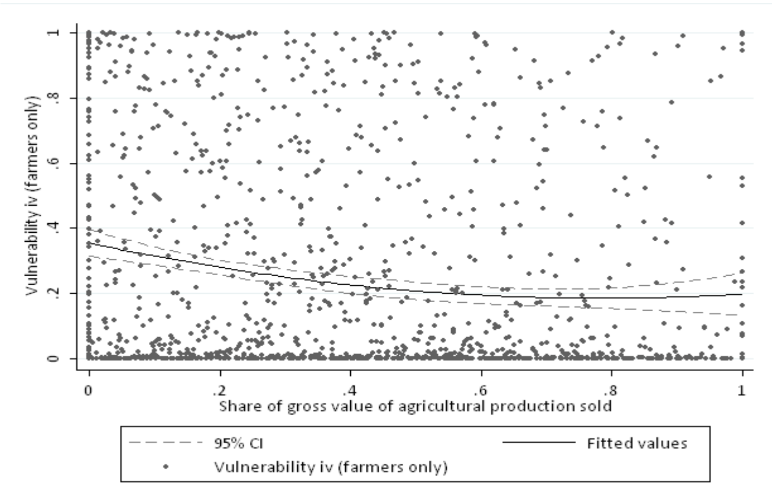
Figure 13 shows the scatter-plot of vulnerability and the share of production sold. Once again, the wide distribution of the datapoints does not display any apparent relationship. By adding a non-linear fit, this time with non-parametric techniques (lowess smoothing), a relatively weak negative relationship 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



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- *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.

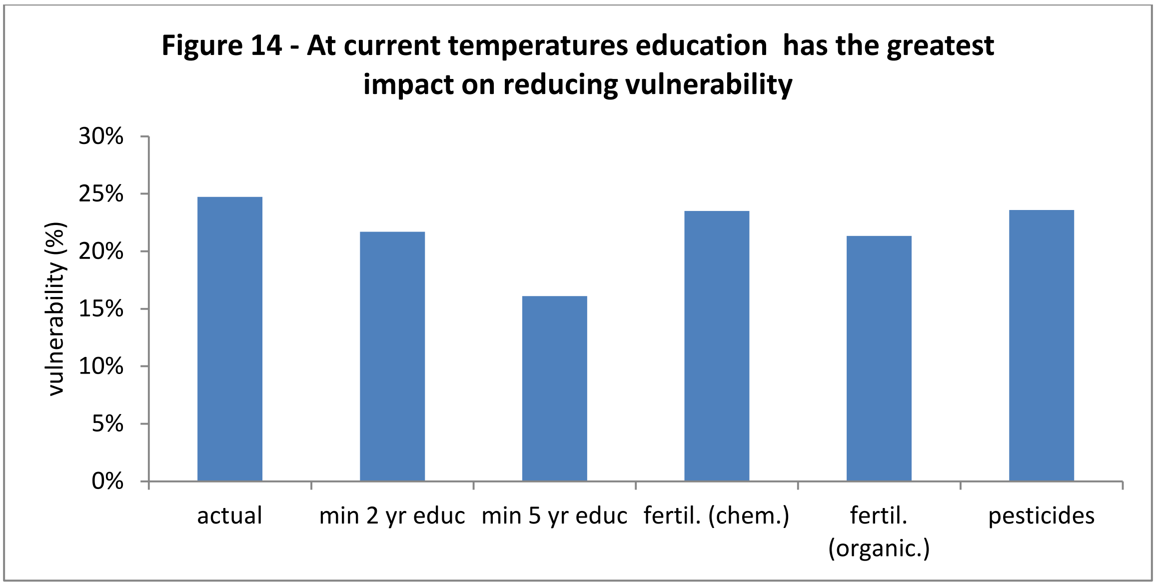
We consider five alternative hypotheses of policy interventions (figure 14) and estimate the impact of these on reducing vulnerability:

- 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).



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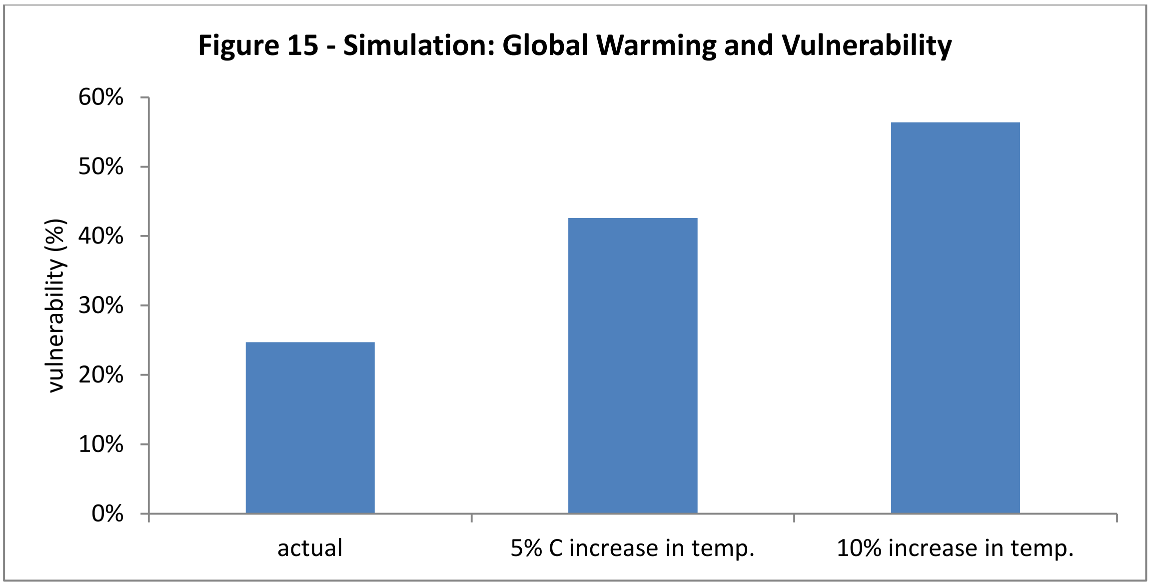
8.2. Global warming and policy responses

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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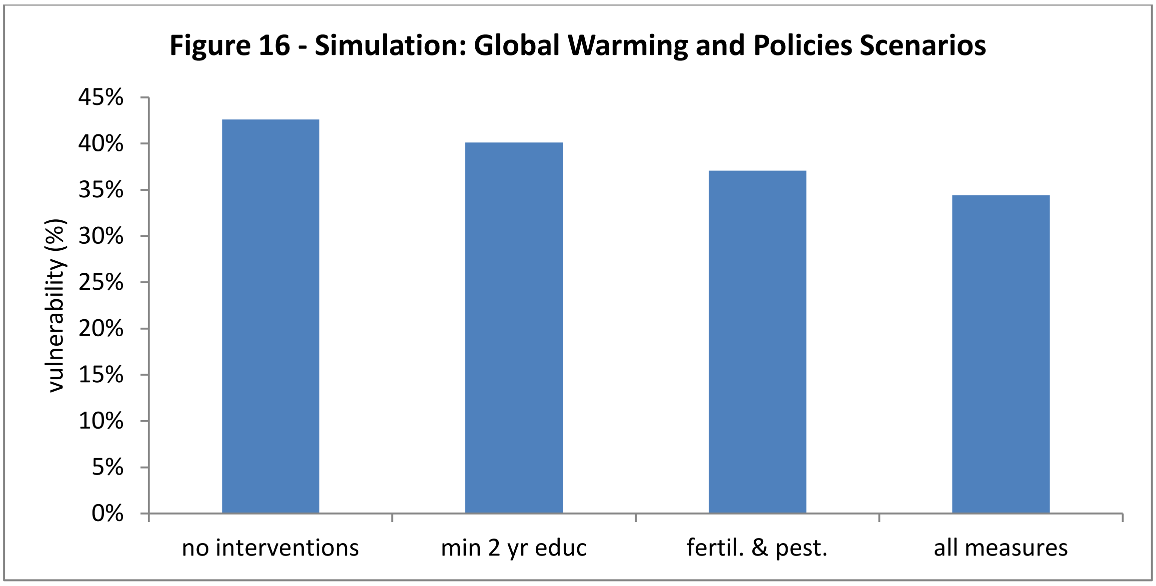

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9. Concluding remarks

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

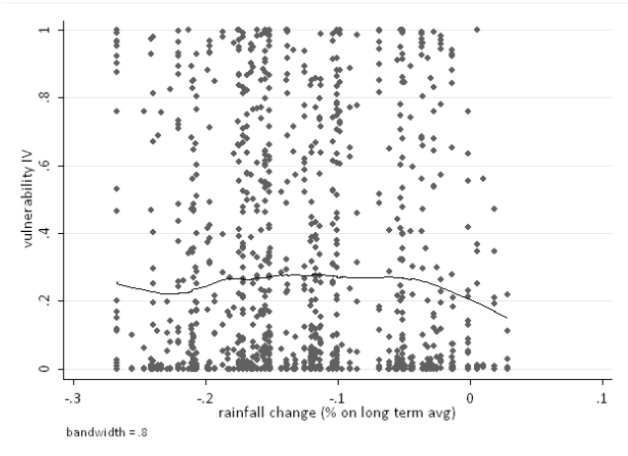
Table A3: Determinants of average food consumption per adult equivalent and its variance using OLS

	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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