Climate Change and Food Security in Uganda

Erika Munshi[1], Maia Call[2] and Clark Gray[3]
[1] Nicholas School of the Environment, Duke University
[2] National Socio-Environmental Synthesis Center, University of Maryland
[3] Department of Geography, University of North Carolina at Chapel Hill

Abstract

A large literature has shown that climate change is likely to have negative effects on agricultural production in tropical countries. However the trickle-down consequences of these changes for population well-being remain unclear. To address this issue, we examine how recent climate anomalies have affected food security, household expenditures, agricultural production and child health in Uganda. We draw on longitudinal household survey data collected by the World Bank, gridded climate data from the University of East Anglia, and multivariate approaches that account for the non-random occurrence of climate anomalies over time and space. Preliminary results indicate that exposure to prolonged heat reduces food security, expenditures and agricultural yields, suggesting that climate change will reduce population well-being.

Introduction

There is widespread interest in the effect of climate variability on agriculture productivity, specifically in developing nations where crop revenue serves as the base of the local economy. Both rising temperatures and increased rainfall variability have the potential to reduce agricultural productivity, compromising food security through agricultural and economic losses (Kurukulasuriya, 2006). While climate change is a global phenomenon, the distribution of climate change effects varies across geographic regions. The tropics and subtropics have been identified as regions expected to experience the most dramatic effects of climate change due to their proximity to the equator (IPCC 2014). East Africa, in particular, is vulnerable to climate change due to a heavy reliance on rain-fed agriculture (Kurukulasuriya, 2006) (Lobell, 2011). As climate variation increases, food security in East Africa may be compromised due to lower agricultural yields.

Research in this area has been primarily focused on agriculture vulnerability and yield reduction due to climate change (Muller et al 2011). Schlenker (2010) found that across Sub-Saharan Africa, there is a 95% probability of crop yield losses exceeding 5% due to climate change for maize, sorghum, millet, and groundnut. The relationship between climate change and food security in a broader context, however, has not been widely studied.

This paper aims to illustrate the effect of climate change on food security outcomes in Ugandan households by linking household-level survey data to gridded climate data. Food security outcomes were generated using survey responses from the LSMS- ISA longitudinal household survey collected in Uganda. Climate anomaly indicators were generated from gridded climate data collected by the Climate Research Unit (CRU). By linking survey responses of reported food shortage to observed climate patterns in the CRU data set, we were able to measure the impact of extreme temperature and precipitation events on food security in Ugandan households.

Background

As Uganda’s population rises, concerns for food security become more pertinent. Ugandans rely heavily on farming for subsistence and profit – with over 71% of land designated for agricultural use. Furthermore, over 84% of the population reside in rural areas where agriculture is the primary source of income. Low levels of urbanization suggest that the majority of Ugandans live and will continue to live in agrarian communities and remain reliant on rural food sources (CIA Factbook).

Uganda's varied topography suggests that climate change may impact certain areas more than others. The South and Southwestern regions have tropical climates with two dry seasons from December to February and May to August and rainy seasons during the rest of the year. The Northeast has a semi-arid climate with only one rainy season from July to September. Because Ugandan farmers in both climates rely heavily on rainfall for agriculture, is it likely that variations in precipitation – specifically drought – would be detrimental to crop yield. Climate variability may have particularly negative consequences on the productivity of smallholder farms in Northeast Uganda where rain is scarce.

This paper contributes to the body of literature that recognizes the vulnerability of Ugandan households in the face of climate change (Hisali 2011). By adding a longitudinal component, we are able to see how climate change has impacted households over time, specifically through an analysis of food security, agriculture, welfare, and child health outcomes from five survey rounds spanning eight years.

Data

To answer our research questions, we used GPS and survey data from the Uganda National Panel Survey (UNPS) and climate data from the Climate Research Unit (CRU). The UNPS is a household-level survey collected by the World Bank's Development Data Group as part of the Living Standard Measurement Study (LSMS). For the purpose of this project, UNPS survey data from 2005/2006 served as a baseline to which we compared four rounds of UNPS household level data (2009-2010, 2010-2011, 2011-2012, and 2013-2014). Households were selected for this study if they were present in the 2005/2006 round and appeared in at least one other round. The majority of households were present in all four rounds, meaning there were four observations per household (see Figure 1 below). Each household was surveyed up to four times; each survey response being treated as an individual observation. We used the 2005/2006 round as a baseline which allowed us to have a set of controls and include households that were not present in all rounds. During the 2013-2014 round, a randomly-selected sub-sample of households from the original sample were surveyed. In order to maintain the integrity of our longitudinal study, we restricted the analysis to households that appeared in the 2005/2006 baseline survey, resulting in fewer observations for the 2013-2014 round (see Figure 2 below).

Obs per Household	No. Households	Percent
1	105	4.38
2	158	6.59
3	835	34.84
4	1,299	54.19
Total	2,397	100

Round	No. Households	Percent
2009	2,377	29.27
2010	2,143	26.39
2011	2,160	26.59
2013	1,442	17.75
Total	8,122	100

The UNPS survey data is representative at the national and region levels, providing comprehensive information about Ugandan households both in rural and urban areas. To address our specific research objectives, we created a dataset for each of our outcomes (food security, agriculture, welfare, and child health) based on the UNPS Household, Agriculture, and Community surveys.

In order to link the survey information to CRU climate data, we used randomly-offset community GPS points collected in the 2009 UNPS round. The climate data used in the study was generated from the Climate Research Unit Time Series (CRU) gridded dataset (Harris et al 2014).

Methods

Food Insecurity

In order to gauge food insecurity in Ugandan households, we examined self-reported hunger captured in the household questionnaire by the question: "Have you been faced with a situation when you did not have enough food to feed the household in the last 12 months? In order to measure the impact of climate variability on food insecurity, we ran a logistic regression to compare reported food insecurity and drought conditions from each round (2009, 2010, 2011, 2013) to the baseline 2005/2006 UNHS to observe changes in reported food security due to climate variability over time. In order to capture both the agricultural season immediately preceding the interview date as well as long term agricultural productivity, we ran the regression using climate anomalies that occurred over both the 12 and 24 month periods preceding the interview date. Through this methodology, we were able to observe the impact of both short and long term climate variability on food security outcomes. We also generated a non-linear model using squared temperature and precipitation values to observe the relationship between both positive and negative temperature and rain anomalies on reported hunger.

Poverty

In an effort to provide context for the relationship between climate variability and reported food insecurity, we also examined the impact of temperature and rain anomalies on welfare. In order to measure welfare, we used a per capita expenditure (PCE) measure provided by the Ugandan Census Bureau. We conducted a linear regression to examine the changes in welfare due to climate variability over both 12 and 24 month periods preceding the interview date, similar to the food security analysis.

Agriculture

Our study also included an analysis of agricultural productivity and value as functions of climate variability. Productivity and value measures were generated from self-reported agricultural data collected by the UNPS Agriculture survey. The agriculture survey had two interview periods each year in order to account for the two agricultural seasons (January – June and July – December). As such, each household was interviewed twice per year. Because the agricultural data captures crop production and value over the course of the agricultural season, we generated standardized interview dates (January of the year of interview) to allow us to represent crop production and value for the whole year. For example, a household interviewed twice in 2009 was given an interview date of "January 2009", which we used to link the 12 and 24-month climate anomaly data. We created two measures for both crop productivity and value (average values and average values per acre) in order to account for land parcels of different sizes. Non-agricultural households were dropped from this analysis. A linear regression was used to examine the impact of climate variability on total production and value as well as production and value per acre.

Child Health

In order to provide context for food insecurity in households, we also conducted an analysis to determine the relationship between climate variability and child health. Our metric for child health was a weight for height measure which we generated using child heath data nested within the UNPS Household survey. We standardized height, weight, and gender values for children using Zanthro (Vidmar 2004). Households without children were dropped from this analysiz. A linear regression was conducted to examine the relationship between climate variability and child weight for height outcomes.

For all analyses, community-fixed effects were applied to control for differences between communities.

	Observations	Mean	Std. Dev.	Min	Max
Food Security and Poverty					
Self Reported Hunger	8,094	0.299	0.458	0.000	1.000
Per Capita Expenditure (ln)	8,078	10.738	0.785	8.126	15.061
Rain Anomalies 12 months prior	8,099	**0.649**	1.028	-2.039	**6.309**
Temp Anomalies 12 months prior	8,099	**0.873**	0.743	-0.675	**2.215**
Rain Anomalies 24 months prior	8,099	**0.741**	1.035	-1.714	**5.693**
Temp Anomalies 24 months prior	8,099	**1.021**	0.545	-0.401	**1.975**
Female Headed Household	8,099	0.271	0.444	0.000	1.000
Age of Household Head	8,099	43.056	15.117	13.000	99.000
Household size	8,099	5.809	3.067	1.000	29.000
Any education	8,099	0.811	0.392	0.000	1.000
Employed by non-farm	8,099	0.340	0.474	0.000	1.000
Employed by farm	8,099	0.730	0.444	0.000	1.000
Self-employed	8,099	0.362	0.481	0.000	1.000
Asset Value (ln)	8,099	13.262	1.679	6.553	19.985
Farm Size (ln)	8,099	1.141	1.495	0.000	8.189
Agriculture					
Crop Production (ln kg)	6,606	7.251	1.365	0.405	13.000
Crop Value (ln)	6,606	5.428	1.270	0.331	11.121
Crop Production per acre (ln kg)	6,097	5.294	1.209	0.010	10.159
Crop Value per acre (ln kg)	6,097	3.498	1.057	0.002	8.924
Legumes	6,606	0.810	0.392	0.000	1.000
Tubers	6,606	0.730	0.444	0.000	1.000
Banana	6,606	0.498	0.500	0.000	1.000
Cash crops	6,606	0.305	0.460	0.000	1.000
Cereals	6,606	0.812	0.391	0.000	1.000
Other crop	6,606	0.189	0.392	0.000	1.000
Child Health					
Weight for Height	4,786	0.010	1.148	-4.939	4.587
Child Age in months	4,866	33.597	14.726	6.000	59.000
Female	4,866	0.502	0.500	0.000	1.000

Table 1. Descriptive Statistics

Results

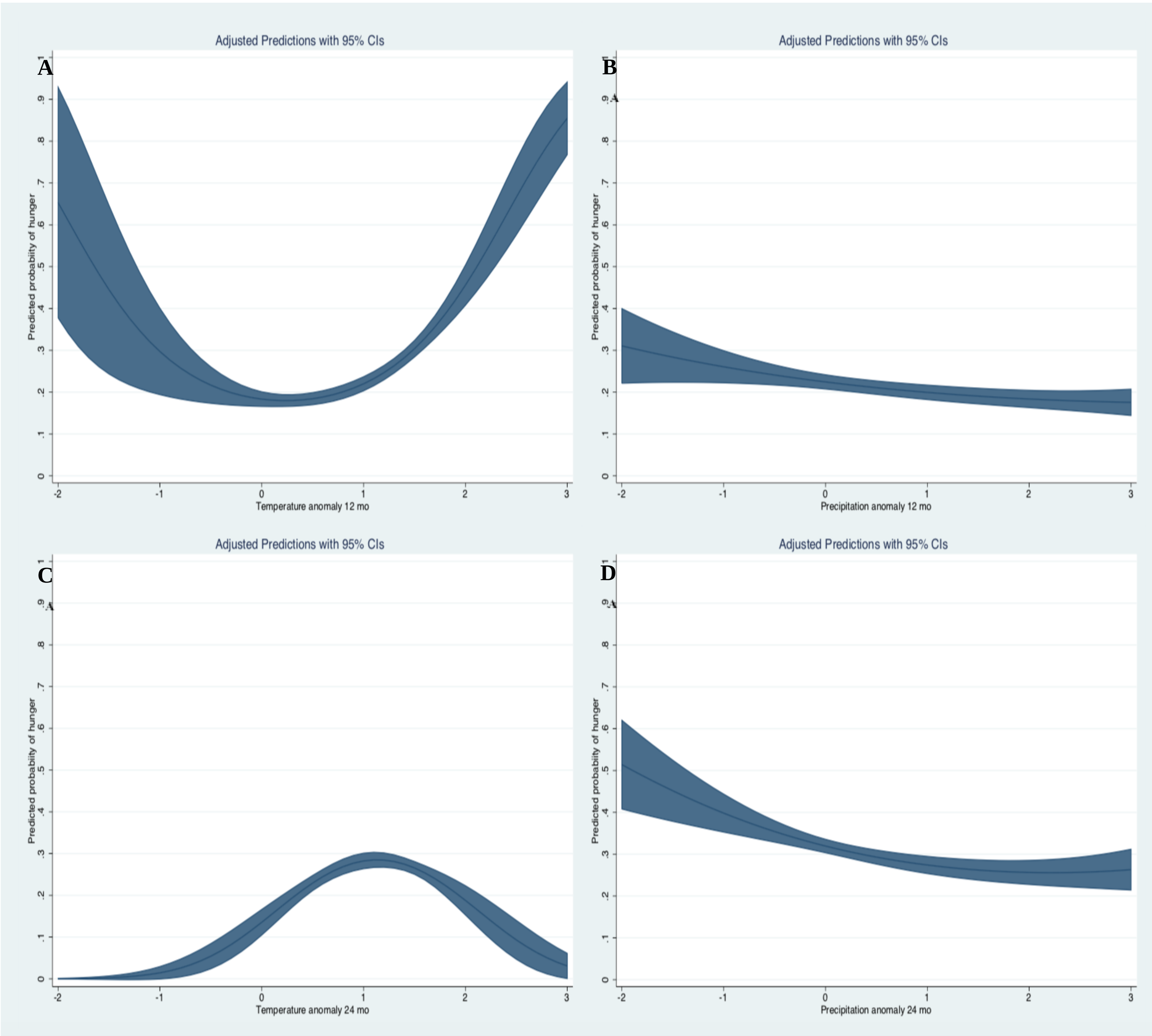

Figure 3. Nonlinear climate effects on self-reported hunger for 12 and 24 month periods. **A)** 12-month Temperature Anomalies. **B)** 12-month Precipitation Anomalies. **C)** 24-month Temperature Anomalies. **D)** 24-month Precipitation Anomalies

	Hunger 12month	lnPCE 12month	lnCropkg 12month	lnCropVal 12month	lnCropkg/acre12mo	lnCropVal/acre12mo	WFH 12month
Rain Anomaly 12 month	**0.9 ****	**-0.004**	**-0.011**	**0.03 ***	**-0.169 *****	**-0.124 *****	**0.013**
Temp Anomaly 12 month	**1.615 *****	**0.026 ****	**0.116 *****	**0.056 ****	**0.232 *****	**0.171 *****	**-0.044**
Female Headed Household	1.056	0.09 **	-0.198 ***	-0.173 ***	-0.142 **	-0.112 **	0.08
Age of Household Head	1.007 **	0.001	-0.004 **	-0.004 ***	-0.004 ***	-0.004 ***	-0.001
Household size	1.052 ***	-0.034 ***	0.046 ***	0.047 ***	0.017 **	0.019 ***	0.002
Any education	0.756 **	0.163 ***	0.175 ***	0.199 ***	0.01	0.037	0.082
Employed by non-farm	1.017	0.039	-0.08 *	-0.088 *	-0.06 +	-0.064 *	-0.112 +
Employed by farm	1.171	-0.167 ***	0.065	0.08	0.005	0.027	0.073
Self-employed	0.971	0.018	0.021	0.005	0.045	0.026	0.026
Asset Value (ln)	0.75 ***	0.161 ***	0.162 ***	0.163 ***	0.055 ***	0.055 ***	0.008
Farm Size (ln)	1.005	0.002	-0.001	-0.003	-0.007	-0.008	-0.013
Legumes			0.328 ***	0.556 ***	-0.083	0.127 *	
Tubers			0.691 ***	0.409 ***	0.452 ***	0.176 ***	
Banana			0.607 ***	0.433 ***	0.186 ***	0.015	
Cash crops			0.357 ***	0.438 ***	0.145 ***	0.201 ***	
Cereals			0.356 ***	0.352 ***	0.061	0.062 +	
Other crop			0.414 ***	0.445 ***	0.187 ***	0.208 ***	
Age of Child in months							0.01 ***
Female							0.028

Table 2. Model outputs for 12-month food security, welfare, agriculture, and child health outcomes.

	Hunger 24month		lnPCE 24month		lnCrop kg 24month		lnCrop Val 24month		lnCrop kg/acre24mo		lnCrop Val/acre24mo		WFH 24month	
Rain Anomaly 24 month	**0.805**	*******	**-0.028**	*******	**-0.009**		**0.022**		**-0.183**	*******	**-0.149**	*******	**0.049**	**+**
Temp Anomaly 24 mont	**1.215**	******	**-0.043**	******	**0.158**	*******	**0.162**	*******	**-0.146**	******	**-0.139**	******	**0.033**	
Female Headed Househol	1.055		0.089	**	-0.198	***	-0.175	***	-0.133	**	-0.106	*	0.078	
Age of Household Head	1.007	**	0.001		-0.004	**	-0.004	***	-0.004	***	-0.004	***	-0.001	
Household size	1.051	***	-0.033	***	0.046	***	0.047	***	0.017	**	0.018	**	0.002	
Any education	0.756	**	0.163	***	0.174	***	0.201	***	0.003		0.031		0.083	
Employed by non-farm	1.015		0.039	+	-0.079	*	-0.088	*	-0.06	+	-0.063	*	-0.11	+
Employed by farm	1.179		-0.165	***	0.065		0.081		0.001		0.024		0.069	
Self-employed	0.978		0.019		0.021		0.005		0.049		0.03		0.021	
Asset Value (ln)	0.753	***	0.161	***	0.162	***	0.164	***	0.052	**	0.052	***	0.009	
Farm Size (ln)	1.004		0.001		-0.001		-0.003		-0.008		-0.009		-0.013	
Legumes					0.317	***	0.549	***	-0.082		0.131	*		
Tubers					0.696	***	0.4	***	0.516	***	0.225	***		
Banana					0.606	***	0.43	***	0.2	***	0.027			
Cash crops					0.35	***	0.413	***	0.238	***	0.274	***		
Cereals					0.355	***	0.35	***	0.07		0.07	+		
Other crop					0.42	***	0.446	***	0.193	***	0.212	***		
Age of Child in months													0.01	***
Female													0.029	

Table 3. Model outputs for 24-month food security, welfare, agriculture, and child health outcomes.

Figure 3 represents the nonlinear climate effects of temperature and rain on self-reported food insecurity. Graph A (12-month temperature anomalies) indicates a strong relationship between extreme temperature anomalies in the short term and the greater odds of experiencing food insecurity are during the same time period. This is consistent with our expectations for the relationship between hunger and extreme temperatures. Graph C (24-month temperature anomalies) shows the opposite trend: temperature anomalies occurring over a 24-month period actually lower the odds of experiencing food insecurity in the 12 months preceding the interview. Graph B (12-month precipitation anomalies) indicates a strong linear relationship between reported food insecurity and rain. As rain increases, the odds of experiencing food insecurity decreases. Graph D (24-month precipitation anomalies) shows a similar trend to Graph B, a strong nearly-linear relationship between rain anomalies and reported hunger.

Table 2 shows the 12-month model outputs of linear and logistic regressions for food insecurity, welfare, agriculture, and child health. The hunger (food security) output, represented in odds ratios, indicates that rain anomaly exposure during the year decreases the odds of experiencing hunger during the same 12 months preceding the interview date. Temperature anomalies, on the other hand, increase the odds of experiencing hunger during the 12 months preceding the interview date. These results are consistent with the relationships identified in the nonlinear analysis. Welfare outputs, represented as coefficients, indicate that rain anomalies during the 12 months preceding the interview have a non-significant impact on expenditures while temperature anomalies increase per capita expenditure. Crop productivity outputs indicate that temperature anomalies during the 12 months preceding the interview increase total crop production as well as crop production per acre. Similarly, crop value outputs indicate that temperature anomalies increase crop value as well as crop value per acre. Rain anomalies, however, increase crop value but decrease crop value per acre. The impact of climate variability on child health was non-significant.

Table 3 shows the results of 24-month model outputs for hunger, welfare, agriculture, and child health outcomes. Similar to the 12-month analysis, the 24-month analysis shows that rain anomalies during the 24 months preceding the interview date reduce the odds of experiencing food insecurity while temperature anomalies increase the odds of experiencing food insecurity. This is consistent with the relationship identified in the nonlinear analysis. The welfare output indicates that both rain and temperature anomalies during the 24 months preceding the interview date lower per capita expenditure. The agricultural outcomes indicate that temperature anomalies increase crop production and value overall, but decrease crop production and value per acre. Rain anomalies have a non-significant impact on total production and crop value but a negative impact on production and value per acre. The child heath outcomes exhibited a marginally significant relationship between rain anomalies and greater weight for height.

Discussion

Food Insecurity

The results of both nonlinear and linear analyses indicate that short and long term rain anomalies reduced the odds of experiencing food insecurity. This is consistent with our expectations for the analysis because rain anomalies, particularly drought conditions, are often cited as a cause for hunger. We also found that in the short term (12-month) higher temperatures increased the odds of experiencing food insecurity, which is consistent with global climate trends. Higher temperatures may compromise food security through a number of mechanisms, including increased disease prevalence and reduced mobility due to heat waves. In the context of this study, the 12-month analysis results may be capturing more immediate hindrances, such as difficulties accessing food sources or limited economic freedom due to reduced mobility. The linear model suggested that temperature anomalies in long term (24-month) also increase the odds of experiencing food insecurity, which is consistent with the short term climate story. Our nonlinear temperature model for 24-month climate anomalies suggested that extreme temperature values may actually reduce the odds of experiencing hunger, which is not consistent with our other findings. A possible explanation for this is increased adaptivity in the long term which may allow households to make adjustments for extreme temperature values.

Welfare

The results of the welfare analysis indicate that rain anomalies during 12-months preceding the interview date reduces expenditure, while temperature anomalies increase expenditure. This could be indicative of rising food prices as a temperature increase might make both cultivation and distribution of agricultural products more labor intensive, resulting in higher food prices. In this case, higher expenditures could be interpreted as a negative consequence of climate change because households are having to spend more for the same amount of food. An alternative explanation could be that higher expenditure is actually a result of higher incomes and therefore relative economic prosperity. This narrative would not be consistent with the climate-hunger story. The relationship between climate and welfare is further complicated by the 24-month analysis which shows that both temperature and rain anomalies reduce expenditure in the long term. This may be because long term effects of rain and temperature anomalies on crop productivity are so severe that households are either unable to access agricultural products or purchase less due to reduced economic prosperity. Alternatively, reduced expenditure could be indicative of greater purchasing power due to lower agricultural prices if crop productivity has increased. Although per capita expenditures have historically been useful as a measure of economic welfare, the relationship between economic prosperity and food security in the context of climate change remains unclear. In order to better understand how climate is affecting food purchases specifically, our next step would be to isolate food expenditures to observe changes in purchasing power.

Agriculture

Our agricultural outcomes indicate that rain anomalies occurring during both 12 and 24-month periods preceding the interview date reduce crop productivity. This is inconsistent with the climate-hunger model output which showed that exposure to rain anomalies reduce the odds of experiencing hunger. A possible explanation for this could be increased pest presence as a result of increased standing water. Our agricultural outcomes also suggest that temperature anomalies increase crop production and value in the short term (12 month) but decrease both crop production and value in the long term (24 month). This suggests that crop productivity may be protected from climate effects in the short term by increased labor and short-term solutions, but negatively effected by temperature anomalies in the long run as farmers are unable to sustain their crops.

Child Health

Child health outcomes from our analysis were not significant. This indicates that children are relatively shielded from climate effects on food security, even when their household is experiencing food insecurity. This may be because parents choose to feed their children before themselves in times of food insecurity.

Conclusion

The findings of our study indicate that there may not be as clear a relationship between agriculture and reported food insecurity as we expected. In both the linear and nonlinear models, rain anomalies seemed to have a positive impact on food security, suggesting that rain may be good for communities. The impact of rain anomalies on welfare and agriculture, however, is inconsistent with this trend. Rain anomalies appear to decrease per capita expenditure as well as crop productivity and value per acre. Because many Ugandan farmers rely on crop production for sustenance as well as income, it seems the reduced expenditures may be a result of lower crop yields and subsequent lower income because crops are selling at lower prices. This suggests that increased rainfall actually negatively impacts farmers even though it appears to be beneficial for food security. Temperature anomalies, on the other hand, appear to increase the odds of experiencing food insecurity. This is consistent with the agriculture outcomes which show that while short term (12-month) crop productivity and value per acre increases with temperature, long term (24-month) crop productivity and value decreases. We also found that long term per capita expenditures decrease with temperature anomalies which is consistent with the idea that lower crop productivity and value compromises the purchasing power of farming households. The results of this study indicate that the relationship between food security and climate anomalies may be the result of factors beyond agricultural production. While the temperature anomaly results were more consistent across models than the precipitation results were, is it still unclear if the relationship between agriculture and temperature is related to food security. Further analysis of other food security drivers may better illustrate the mechanism for changes in food security as a result of climate change.

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