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# Weather variability and food consumption
# Evidence from rural Uganda

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# Table of Contents

## Abstract

This study examines the impact of weather variations on food consumption in rural Uganda. The paper relies on two-period panel data (2005/06-2009/10) combined with data on rainfall, number of rainy days and maximum and minimum temperatures. We find that higher temperatures have an adverse effect on food consumption. In contrast, food consumption is not substantially affected by rainfall variations. While evidence from qualitative interviews and trends in agricultural production suggest that households are adopting mitigation measures, the conclusion from the evidence assembled in this paper is that higher temperatures are associated with a decline in crop yields and food consumption.

### Keywords

Weather variability; risk; food consumption; Uganda.

**JEL classification:** I31; O12; O44; Q12; Q54.

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# 1. INTRODUCTION

In the wake of current debates on the effects of climate change on poor households in developing countries, analyses of the effects of extreme weather events and weather variations on household welfare and coping strategies continues to attract academic attention. It is likely that due to their high degree of vulnerability (Cooper et al., 2008: 25) combined with their high dependence on rain-fed agriculture (Skoufias et al., 2011: 2), individuals and households in developing countries are more likely to be affected by changes in weather patterns. However, to the extent that individuals and households are able to appropriate or develop technologies and adjust their behavior to mitigate the impacts of changes in weather, they may be able to cope with or as the literature on climate change states, *adapt*, to shocks (Nordhaus, 1993: 14). While a review of the multiple channels through which climatic shocks may affect household welfare is needed to assess their potential effects, case-specific analyses are needed to understand the set of behavioral and technical changes that households may adopt to counteract welfare losses.

Building on these premises, this paper engages with findings from various disciplines and the existing microeconomic literature to discuss the multiple channels through which extreme weather events and weather variations may affect the welfare of rural households. This discussion is then used to develop a framework to analyze the effects of weather variability (rainfall, number of rainy days, maximum and minimum temperatures) on household food consumption in rural Uganda. The focus on Uganda is motivated by increasing concerns about the potentially adverse effects of climate change (Magrath, 2008; NAPA, 2007) which may exacerbate the already high vulnerability to weather changes of rural Ugandan households (MAAIF, 2010; Okori et al., 2009), recent concerns about food security (Shively and Hao, 2012) and limited knowledge of the actual effects of weather variability on household consumption in rural Uganda.

The paper is based on a household level panel dataset constructed from two rounds of the World Bank's Living Standards Measurement Surveys (LSMS) covering the period 2005/06-

2009/10. We concentrate on households living in rural areas and in order to rule out seasonal patterns restrict our attention to households interviewed in the same season in both survey rounds. The LSMS subsample is merged with rainfall and temperature data obtained from the Department of Meteorology of the Ugandan Ministry of Water and Environment (UDOM). To interpret and underpin the empirical results we draw on qualitative interviews and an analysis of recent developments in Uganda's agricultural sector.

To preview our results we find that weather variations, especially higher temperatures, have an adverse effect on food consumption. While the amount of land owned by a household works towards mitigating the effects of higher temperatures the protective effect is quite small. In contrast, food consumption doesn't seem to be substantially affected by rainfall variations. However, we find that non-food consumption expenditures such as expenditure on funerals and social functions and outgoing remittances experience a reduction when there is a decline in precipitation. While the evidence from qualitative interviews and recent developments in the agricultural sector suggest that households are adopting mitigation measures, the unerring conclusion from the evidence assembled in this paper is that higher day time temperatures are associated with a decline in crop yields and food consumption.

The remainder of this paper is organized as follows. Section 2 characterizes weather shocks, analyzes the channels through which such shocks affect household welfare and engages with the existing literature. Section 3 describes the socio-economic and weather characteristics of rural households in Uganda. Section 4 discusses the data and the empirical model. Section 5 reports the results. Section 6 concludes the paper.

## 2. WEATHER VARIABILITY AND WELFARE

### (a) Theory

Significant weather variability, a marker of climate change, may be classified into simple or complex extreme events (Wilkinson, 2006; IPCC, 2001). An increase or a decrease in maximum and minimum temperatures, respectively and/or an increase or decrease in the intensity of precipitation as compared to a long-term mean are examples of extreme simple events. Increasing occurrence of droughts and floods, especially when precipitations are associated with El Niño events, or storms and tropical cyclones and greater variability in the monsoon season are examples of extreme complex events.[1]

To identify the potential effects of weather variability on household welfare, we follow Skoufias *et al.* (2011) but tailor the discussion to our needs. Figure 1 provides a visualization of the potential chain of effects. The solid lines represent direct effects while the dashed lines represent indirect effects.

>>Figure 1 about here<<

First, the close link between the agricultural sector and nature and the importance of agriculture in developing countries suggests that weather variations are likely to have a greater impact on developing countries as opposed to developed, and in the first instance on rural households relying on subsistence agriculture in developing countries. Weather variations may be expected to have a direct impact on agricultural productivity and income as higher temperatures and changing rainfall patterns are likely to modify the hydrological cycle, ultimately affecting crop yields and total factor productivity (IPCC, 2001: 31). Weather changes may affect crop yields through changes in temperatures when they exceed the optimal thresholds at which crops develop (Lansigan *et al.*, 2000; Prasad *et al.*, 2008). Similarly, mismatches between the amount of water received/required and its potential evapotranspiration during the growing and harvesting seasons, and the timing of

[1] Complex extreme events may be considered an extension of simple extreme events that occur in a more disruptive way, due to their particular duration and intensity (Anderson, 1994: 555).

water stresses faced by the crops may affect agricultural productivity (Wopereis *et al.*, 1996; Otegui *et al.*, 1995). On the other hand, when there is excess water or a shortage of water (floods or droughts) its potential impact can be very high due to loss of life and infrastructure (IPCC, 2001: 29). Moreover, even if there is no effect on yields, erratic weather may stress crops and lower the quality of the harvest.

Subsequently, instability or a decrease in agricultural income is likely to influence consumption through different channels depending on the nature of agricultural production. When households are engaged in subsistence agriculture, food consumption will be directly influenced through changes in output while in the case of commercialized agriculture the effect may occur through changes in production and crop prices. Especially in the case of commercialized agriculture it is possible that due to increases in the prices of agricultural products there is a positive net effect on household income and consumption (Singh et al., 1986). However, in the current case this seems unlikely as most farmers (about 75 percent) are engaged in subsistence agriculture and hence changes in weather variability may be expected to have a direct effect on their food consumption.[2]

In order to mitigate the effects of weather variability on crop output and on consumption, households may adopt *ex-ante* and *ex-post* coping strategies. For instance, on the production side, in a bid to respond pro-actively to weather shocks rural households may choose crops that are less sensitive to weather variations (Morduch, 1995: 104). While such an approach may mitigate the effects of weather variations, the cultivation of low-risk low-return crops may still exert adverse effects on household welfare.[3] Other approaches include intercropping (that combines mixed

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[2] This argument is also supported by Benson *et al.* (2008) who analyse the mechanism of global and regional prices transmission and its welfare effects in Uganda and argue that not many households would benefit from rising food prices. In fact, only 12 to 27% of the population appears to be a net seller of food (Benson et al., 2008).

[3] For example, in Shinyaga District of Tanzania, Dercon (1996) found that the absence of well-developed markets for credit combined with lack of accessibility to off-farm labor provided an incentive to cultivate low-risk, low-return crops (sweet potatoes). Households in this area may be in a poverty trap of low-income and assets ownership which induces low-risk, low-return crop choices and in turn low-income and low-levels of asset accumulation (Dercon, 1996).

cropping with field fragmentation) or adoption of new production technologies (like high-yielding varieties seeds and fertilizers) which may lower the risk of agricultural activities. Consumption smoothing or ex-post coping comprises borrowing and saving, selling or buying of non-financial assets, modifying labor supply and making use of formal/informal insurance mechanisms (Bardhan and Udry, 1999: 95).

### (b) Empirics

Drawing on the framework outlined above, there is a well-developed empirical literature which has examined the effects of weather variations on agricultural production, income, consumption and savings. There are three clearly discernible strands of literature depending on the methodology adopted and the scope of the studies.

First, there are a range of agronomic models for a variety of crops (land uses) which simulate crop growth, development and yields under different climate scenarios relying on empirical or experimental production functions representing soil-plant-atmosphere dynamics including relevant determinants of crop performance such as temperature, precipitation and carbon dioxide levels (Mendelsohn et al., 1994). These models incorporate the distribution of weather outcomes on a daily basis relying on interpolated gridded climate normal for current conditions (Rivington and Koo, 2010). Simulations of future rainfall and temperature elaborated by Atmosphere-Ocean Global Circulation Models (AOGCM) and emissions scenarios (SRES) have been fitted into agronomic models to estimate crop yield response to weather and climate change. Global assessments modeling wheat, rice, maize and soybean have emphasized that although global crop production might only decrease slightly, developing countries are more likely to be affected (Rosenzweig and Parry, 1994; Parry et al., 2004). On a regional basis, using two different crop models (CERES-Maize and BEANGRO-DSSAT), Thornton et al. (2009) simulate maize and beans yields in the East African region when grown in current climatic conditions and their yield responses to projected changes in temperature (an increase of 1.0 to 1.8 °C for a low-emission scenario and 1.6 to 2.8°C for a high-emission scenario) and rainfall (wetter and dryer AOGCM scenarios). Their simulations suggest a 1 to 15% decline in production depending on the temperature and rainfall scenario considered. In a subsequent study Thornton et al. (2010) adjust their simulations to account for climatic and topographic variability in East Africa and provide estimates for mixed rain-fed agricultural systems divided into three categories - temperate/tropical highland, humid-sub-humid and arid-semi-arid areas. Their estimates yield a 5 to 35% increase in maize and bean production (by 2030) in temperate/tropical highlands but production decreases in humid-sub-humid and arid-semi-arid areas. As far as Uganda is concerned, according to the authors, 68% of the Ugandan agricultural system is mixed rain-fed, of which 12% of the area is temperate/tropical highland, 64% is humid-sub-humid and 24% is arid-semiarid. Average scenario simulations (a temperature increase of 1.8$^{o}$ C) for Uganda for the dominant humid-sub-humid system show a 4.6% (12.9%) reduction in maize production and 3.7% (20.8%) reduction in bean production by 2030 (2050).

While useful, the application of agronomic models to developing countries has been criticized for relying on parameter calibration based on conditions in temperate systems. In addition, the models do not account for the ability of farmer's to adapt and apply technology and increased human capital in agricultural systems in developing countries, thus, overestimating reductions in agricultural production (Mendelsohn et al., 1994; Schlenker and Roberts, 2008; Di Falco et al., 2012).

A second strand, Ricardian (or hedonic) models assess the effects of weather variability on land values and/or agricultural revenues as opposed to crop-specific yields as is done in the case of agronomic models (Schlenker and Roberts, 2008). For the most part, applying regression analysis to cross-section data, Ricardian studies have attempted to identify the extent to which both rainfall and temperature variability determine crop choices (Kurukulasuriya and Mendelsohn, 2008; Minten and Barrett, 2008), crop yields (Schlenker and Roberts, 2008; Di Falco et al., 2012; Barnwal and Kotani, 2013) and net revenues from agriculture (Deressa, 2007; Deschênes and Greenstone, 2007;

Kabubo-Mariara and Karanja, 2007; Kurukulasuriya and Mendelsohn, 2008; Molua, 2009). Typically, such models capture weather variability in terms of the deviation between current precipitation levels and current (maximum and minimum) temperatures and long-term averages of these variables.[4] The regression estimates from such hedonic studies are subsequently used to assess the effect of changes in weather patterns (predicted by climate-change models) on net farm revenues (Di Falco et al., 2012).

The main concern with Ricardian models estimated using cross-section data is the potential correlation between the weather-related variables and time-invariant location-specific factors such as soil type or farmers skills (Schlenker and Roberts, 2008; Barnwal and Kotani, 2013). To address such issues, the more recent papers in this genre such as Deschênes and Greenstone (2007), Schlenker and Roberts (2008) and Barnwal and Kotani (2013) rely on panel data. For instance, Deschênes and Greenstone (2007) use a county-level panel dataset from the United States and county-specific annual weather deviations from county averages to examine effects on farm income. The authors find no statistically significant effects of weather on US agricultural profits in the short run and beneficial effects on profits and crop yields under climate change scenarios. Schlenker and Roberts (2008) also use US county-level panel data on crop yields and fine scale historical daily temperature which allows them to exploit within-county variation. In contrast to Deschênes and Greenstone (2007) they find large and negative (non-linear) effects of temperature changes (see Fisher et al. 2012 for a discussion and explanation of these different results).

The panel data approach adopted in these recent studies bridges Ricardian analyses with a third strand of literature which uses household level panel data to look at the effects of weather variability primarily on household income and consumption (Paxson, 1992; Reardon and Taylor, 1996; Jacoby and Skoufias, 1997; Fafchamps et al., 1998; Dercon, 2004; Kazianga and Udry, 2006;

[4] Long-term averages are calculated as the simple average of the monthly estimates for each season between a certain year (for example 1970) and two years prior to the time period under analysis (see Deschênes and Greenstone, 2007).

Thomas et al., 2010; Skoufias and Vinha, 2013). These papers tend to focus on the effects of rainfall variability which is operationalized in a variety of ways such as changes in rainfall between two time-periods (Dercon, 2004), rainfall deviations from long-term means (Kazianga and Udry, 2006), rainfall shock dummies - rainfall is one or two standard deviations above or below the long-term mean (Skoufias and Vinha, 2013) as well as self-reported shock measures.[5] The evidence is mixed and does not permit easy generalizations. For instance, Paxson (1992) and Jacoby and Skoufias (1997) report that households are able to smooth income in Thailand and India, respectively, while Dercon (2004) shows substantial negative effects of rainfall variation on household food consumption in Ethiopia. A notable aspect of this strand of the literature is that apart from Skoufias and Vinha (2013) who examine the effects of rainfall and temperature variability the rest of the papers in this genre tend to focus on the effects of variability in rainfall only.

This paper, which deals with Uganda, may be placed in the third strand of literature. We rely on panel data and use changes in rainfall and temperature to identify the effect of weather variability on household food consumption. While, as is discussed in the next section, this is not the first paper to examine the effect of changes in weather patterns in Uganda it is perhaps the first paper to do so using household panel data and is one of the few papers in this genre that studies the effects of both rainfall and temperature variability.

## 3. WEATHER VARIABILITY AND AGRICULTURE IN UGANDA

### (a) Background

Uganda, a landlocked country, relies heavily on the rain-fed agricultural sector for income and employment. Poverty in Uganda is high but has been declining in recent years. The percentage of

[5] Thomas et al. (2010) provide a discussion on the advantages and disadvantages of using subjective (self-reported) measures of climatic shocks versus objective measures derived from weather data. The main disadvantages with the latter are the low resolution of meteorological databases and heterogeneity in the manner in which weather data are assigned to households.

the population living on less than $2 a day (PPP) has declined from 86% in the mid-nineties to about 76% in 2006, reaching 65% in 2009 (World Bank, 2011). As Tables 1 and 2 show, although the share of the agricultural sector in GDP has more than halved since 1990-94, the sector still accounts for about 65% of employment (World Bank, 2011). Our survey data which is restricted to rural Uganda displays that the majority of rural Ugandans (about 77 percent) are engaged in subsistence rain-fed agriculture and only 2-3 percent are engaged in the market-oriented agricultural sector (see Table 3).

>>Table 1 about here<<

>>Table 2 about here<<

>>Table 3 about here<<

The most important crops in terms of output are plantains, cassava, sweet potatoes and maize. Details on production, hectares cultivated and yield for the period 2000 to 2010 is provided in Table 4.

>>Table 4 about here<<

Over these ten years, at least at the national level, for almost all crops there has been an increase in total output (about 8 percent). Output has increased mainly due to an increase in the amount of land (15.8 percent) brought under cultivation and has been matched by a decline in crop yield in the case of a number of crops. These modest increases in output have been matched by a population increase of about 38 percent leading to a decline in per capita production (Pender et al., 2004). Echoing these data, studies by Benin *et al.* (2007), James (2010) and Okoboi et al. (2013) reveal that government efforts to modernize agricultural practices have only been partially effective and the increase in production has come mainly from the progressive extension of land cultivated, especially for food staples - maize, potatoes, beans. Notably, coffee, a cash crop has witnessed a decline in amount of land cultivated. The increase in the share of land devoted to growing food staples seems to be an attempt to insure against food shortages. For instance, maize grows fast and can both be eaten or sold if cash is needed, sweet potatoes mature fast, require low labor input while beans are rich in proteins, are the first crop to mature after the dry season and can be stored until the following season (Bagamba et al., 2008; Kasente et al., 2002).

**(b) Weather and variability – evidence**

Uganda's climate is influenced by the Inter-Tropical Convergence Zone, whose position varies over the year. Between October and December the zone covers the southern part of the country while between March to May it returns to the northern part (McSweeney et al., 2007: 1). Consequently, the rainfall pattern is bimodal with two rainy seasons. Accordingly, the country has two agricultural seasons each of which are composed of a dry season and a rainy season. The first agricultural season runs from December to May, with December-January-February comprising the first dry season during which fields are prepared after the harvest for the coming first rainy season (March to May). The second agricultural season starts in June with the harvest and preparation of fields until August, leading to the second planting (rainy) season from September to November (Asiimwe and Mpuga, 2007: 10) (see Figure 2 for a graphical representation of the agricultural cycle).

The country is particularly vulnerable to climate change and weather variability due to its high dependence on rain-fed agriculture (Mubiru et al., 2012: 1). Uganda's disaster profile drawn from the Emergency Events Database (EM-DAT) shows that the Ugandan population is most likely to be affected by droughts and floods (EM-DAT, 2011). More than 10% of Ugandans are exposed to the risk of droughts and the country is listed as 19th out of 184 countries in the human exposure ranking for this type of hazard (ISDR, 2009).

Mimicking the discussion in Section 2, Uganda's National Adaptation Plan of Action (NAPA) developed in 2007 summarizes five channels through which climate change may potentially exert an impact on Uganda's development. While we return to the effects of changes later on in the section, the first issue is whether there have indeed been discernible changes in weather patterns.

A recent Oxfam report (Magrath, 2008), based mainly on qualitative interviews conducted with rural households, reported that the country is experiencing more erratic rainfall in the first rainy season (March to May/June), with the result that droughts are more frequent and crop yields and plant varieties are decreasing. In contrast, rains in the second rainy season (October to December) have become more intense and devastating, often causing floods, landslides and soil erosion (Magrath, 2008: 1). Even in the best case in which the quantity of rain is the same during the rainy and dry seasons, the distribution of the rain is concentrated in fewer days, shortening the rainy season (Magrath, 2008: 3). Moreover, the report claims that during the latest twenty years there has been an increase in average monthly temperatures.

The report's claims on changes in weather patterns are partially supported by Mubiru *et al.* (2012). The authors analyzed historical data on daily rainfall and temperatures and find that there is high variability in the onset of rainfalls across different parts of the country. However, the withdrawal dates remain quite stable, resulting in a shortening of the growing season. The first (March to May) rainy season seems to be affected both in terms of the quantity and distribution of rainfall while the October to December rainy season seems to be stable in terms of the distribution of rains (stable number of rainy days) but there seems to be an increase in the amount of precipitation. During the dry seasons the pattern of rainfall appears to be stable although the frequency of unusual events has increased in both the dry and rainy seasons (Mubiru *et al.*, 2012; Jennings and Magrath, 2009). With regard to temperature, according to Mubiru et al., (2012) maximum and minimum temperatures have increased across the country causing warmer days and nights.

For the current purposes, the level of relevant weather variables for the season immediately preceding the surveys is reported in Table 5, while Table 6 presents information on the weather variables as deviations from their long-term means. For the rainfall related variables (amount of precipitation and number of rainy days) the period used to calculate the long-term means is 1960 to

1990 and for temperature we use the period 1980 to 2010. Uganda's Department of Meteorology (UDOM) uses these time-periods to compute long-term means and treats these measures as an estimate of "normal" weather conditions. We follow this established convention.

>>Table 5 here<<

>>Table 6 here<<

Consistent with the patterns pointed out by Mubiru et al. (2012), a careful scrutiny of the long-term means and the weather data for 2005/06 and 2009/10 suggests that minimum temperatures have risen in both the survey years as compared to the long-term means. The increase is between 6 to 11 percent (about 1 to 2 Celsius degrees higher) in 2005/06 and 5 to 8 percent (0.8 to 1.3 Celsius degrees higher) in 2009/10. Maximum temperatures also show an increase, although smaller in magnitude (about 1 to 4 percent). While the increase in the maximum and minimum temperatures seems clear, changes in rainfall patterns and changes in the number of rainy days as compared to the long-term means do not display a clear pattern.

**(c) Effects of weather variability on rural households**

Overall, based on the qualitative and quantitative assessments of weather patterns there seem to be two consistent patterns (i) greater rainfall instability in the first rainy (agricultural) season and a shortening of the growing season and (ii) an increase in maximum and minimum temperatures. A number of recent papers have analyzed the consequences of changing weather patterns in Uganda and the coping strategies that may have been adopted to deal with these changes.

Magrath (2008), based mainly on qualitative interviews conducted with rural households, report that due to erratic rainfall in the first rainy season (March to May/June), droughts are more frequent and crop yields and plant varieties are declining. Employing a similar methodological approach, Okori et al. (2009) argue that farmers in Lira and Kitgum districts of Northern Uganda perceived the decline and unexpected timing of rainfall as major causes of decreased food production and famines. Mwerera et al. (2010) find that 89% of the surveyed farmers in Kabale and

Nakasongla districts (in Western and Central Uganda respectively) experienced droughts leading to a 39.2% decrease in crop yield and 35.1% decline in income.

At the microeconomic level Asiimwe and Mpuga (2007) analyze the effect of variations in rainfall on the income and consumption of rural Ugandan households. The authors work with repeated cross section survey data (1999/2000 and 2002/2003) and rainfall data from the Statistical Abstract of the Uganda Bureau of Statistics. Using rainfall deviations from the long-term means they find a 51.7 percent decline in income of rural households during the first rainy season.[6] However, they do not find a clear cut effect on consumption. The authors argue that the decline in income with no effect on consumption suggests the use of consumption smoothing strategies (Asiimwe and Mpuga, 2007: 18).[7]

## 4. DATA AND MODEL SPECIFICATION

### (a) Data

Based on Figure 1, an assessment of the effects of weather variability should commence by considering the impact of weather variations on agricultural productivity and subsequently on household income and consumption. However, due to the different reference periods for which the consumption and crop output data are collected we cannot consistently trace the effects of weather variations on crop yield and subsequently on consumption, although these could be presented as separate stand-alone analyses. For instance, for households surveyed in July 2010, the consumption

[6] Rainfall changes were measured as the difference between current seasonal rains and the long-term mean, divided by the long term mean, for the planting and harvesting seasons in the six months preceding the date of interview of the household (Asiimwe and Mpuga, 2007: 11)

[7] The estimations could be downward biased in the case the survey years were particularly different from the others. For example, if 1999/2000 was a year of massive rains as compared to the usual rainfall pattern, the long-term mean calculated including the 1999/2000 data would spread the effect of that particular year on the other data, lowering the magnitude of the shock in the analysis and compromising the ability of the model to capture the effects of the shock on the outcome variable.

data refer to the week or the month (depending on the type of good) preceding the survey while the data on agricultural production is based on crop output in 2009. Since consumption in July 2010 is likely to be based on output in the season immediately preceding this period (December to May 2010) we cannot provide a consistent analysis linking the effects of weather variations on crop output in 2010 on consumption in 2010. However, since most households rely on subsistence farming it is likely that assessing the effect of weather deviations on consumption, especially food consumption is likely to provide a valid assessment of the effects of weather variability on agricultural production.

Hence the paper focuses mainly on the impact of weather variability on household food consumption by constructing and combining a household level panel data set with meteorological data from synoptic stations spread around the country. The panel data are publicly available from the World Bank Living Standard Measurement Study (LSMS) website. The surveys conducted in 2005/2006 and subsequently in 2009/2010 cover 3,123 households distributed over 322 enumeration areas (EAs). In order to enhance comparisons the analysis is restricted to 488 rural households interviewed in the same season in both rounds.[8] The dataset contains information on the socioeconomic status of the households, with a detailed module on expenditure on food, non-durable, semi-durable and transfers. Descriptive statistics for the household variables of interest are reported in Table 7 and 8.

>>Table 7 about here <<

>>Table 8 about here <<

[8] Although we restrict attention to 488 households interviewed in the same season in both rounds, an assessment of the descriptive statistics of those included in the analysis and those who are excluded shows that differences between the two groups are minor (see Table A.3 in the Supplemental Appendix).

Weather data on precipitation and maximum and minimum temperatures were obtained from the Uganda Ministry of Water and Environment - Department of Meteorology (UDOM). These data are from 13 synoptic stations located around the country.[9]

Households are assigned to a synoptic station on the basis of their proximity to a specific station (the average household distance from a station is 32 Km with a standard deviation of 23 Km). After assigning households to a specific synoptic station we assigned each household a set of four weather variables - rainfall in millimeters, number of rainy days and maximum and minimum temperatures for the two seasons preceding the season of the interview. Hence, we assign two rainfall and two temperature variables for each household. One set pertaining to the first season preceding the interview and the second pertaining to the second season preceding the interview. For example, if a household was interviewed in June 2005 it is assigned weather information for the periods March-April-May 2005 and secondly the December-January-February 2004/05 variables. See Figures 2 and 3 for an illustration.

>>Figure 2 and 3 about here<<

### (b) Model specification

The availability of panel data allows us to control for a number of factors that may confound the relationship between weather variability and food consumption. Specifically, in addition to controlling for household fixed effects the specification controls for a number of time-varying household characteristics and other unobserved time-invariant variables. The latter includes controls

[9] We preferred the use of data from UDOM as opposed to data from the US National Aeronautics and Space Administration as data from UDOM is of higher resolution. Appendix Table A.4 and Map 1 show the distribution of the synoptic stations.

for the synoptic station to which households were assigned, regional fixed effects and season and round of interview effects to account for seasonality.[10]

The following model is estimated,

$$lnFCE_{h,s,r,\mathrm{p},t} = \alpha + \beta lnWV_{h,s,r,p,t-1} + \gamma X_{h,s,r,p,t} + \omega_h + \mu_s + \pi_r + \tau_p + \rho_t + \varepsilon_{h,s,r,p,t} \qquad (1)$$

where $lnFCE_{h,s,r,p,t}$ is the logarithm of the food consumption expenditures for household $h$ assigned to the synoptic station $s$, located in region $r$, in season $p$ and year $t$, while $WV_{h,s,r,p,t-1}$ is a vector of the various weather indicators. $X_{h,s,r,p,t}$ is a vector of time-varying household specific characteristics including sex, age (also squared) and education of the head of the household, the size and demographic composition of the household, ownership of house and number of rooms, and land (size and number of parcels). $\omega_h$, $\mu_s$, $\pi_r$, $\tau_p$ and $\rho_t$ are the household, synoptic station, region, season and time fixed effects while $\varepsilon_{h,s,r,p,t}$ is an idiosyncratic error term. This model is expected to yield consistent estimates of the effects of weather variability on food consumption, provided that the unobserved time-invariant fixed characteristics are not correlated with the idiosyncratic error term. To consider the linkages between changes in precipitation and changes in day time temperature we estimate a set of specifications with interactions between precipitation variables and maximum temperature. To explore the ability of households to deal with the potential effects of weather variability we also estimate models where we interact the weather variables with land ownership and amount of land owned. The idea is that households who own land or who own relatively larger plots of land may be able to deal with weather risks through crop diversification, amongst other possible risk mitigation strategies.

[10] If the unobserved effects were not correlated with the error term, a random effects model would be better in terms of consistency and efficiency of the parameters estimated because loss of some information lowers efficiency in the case of fixed effects models. However, a random effects estimation with clustered standard errors uses the additional orthogonality conditions that the group means are uncorrelated with the idiosyncratic error. Since clusters are of different size and comprehensive of households settled in different regions with different poverty patterns, the additional orthogonality condition is likely to be violated. Testing for overidentifying restrictions using the artificial regression approach of Wooldridge (2002: 290-91) to account for heteroskedastic- and cluster-robust standard errors confirms to use fixed effects estimations (p-value 0.000).

In addition, we also examine the persistency of weather variations on outcomes by estimating (2) which includes a set of two-season lagged weather variables. That is,

$$lnFCE_{h,s,r,\mathrm{p},t} = \alpha + \beta_1 lnWV_{h,s,r,p,t-1} + \beta_2 lnWV_{h,s,r,p,t-2} + \gamma X_{h,s,r,p,t} + \omega_h + \mu_s + \pi_r + \tau_p + \rho_t + \varepsilon_{h,s,r,p,t} \quad (2)$$

While the focus of the paper is on the effect of weather variability on food consumption, in an attempt to shed some light on the potential channels through which households might be able to smooth consumption, we also estimate variants of (1) with expenditure on non-food items as the dependent variable of interest.

## 5. RESULTS

A priori the manner in the rainfall-related variables is expected to influence food consumption is not clear since too much (many) or too little (few) rainfall (rainy days) may harm crop production and thereby food consumption. However, based on the existing knowledge of the effects of heat on the growth of crops such as maize and beans (see Thornton et al., 2009, 2010; Lobell et al. 2011) increases in both day time (maximum) and night time (minimum) temperature are expected to exert negative effects on crop yield and food consumption.

Estimates of the impact of weather deviations on food consumption are presented in Tables 9 and 10. To gauge the sensitivity of the results we first estimate variants of (1) which only include the rainfall variables, then only the temperature variables and finally both sets. The control variables for the odd numbered specifications in the tables are sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership and size of the house and a year dummy (taking value one when the year is 2009). In addition, specifications (13) and (15) and all the even numbered specifications also include ownership of land (value one when the household owns land) and amount of land owned.

Examining rows 1 to 8 we see that regardless of the specification, changes in the amount of rainfall do not exert a negative effect on consumption. Indeed the coefficient on the variable is positive although not statistically significant. To capture the idea that it is not the amount of rainfall that has a bearing on household welfare as opposed to the distribution of rainfall we use the number of rainy days in each of the relevant seasons. In all the specifications, the variable has a negative effect indicating that a 10 percent increase in the number of rainy days per season is associated with a 1.9 to 3 percent decline in food consumption. While it does appear that household consumption is more susceptible to the distribution rather than the amount of rainfall, in all the specifications the effect is not statistically significant. Overall, as far as the precipitation-related weather variables are concerned it seems that households are able to protect their food consumption.

An assessment of the effects of temperature yields a different picture. Increases in the minimum and maximum temperatures appear to be associated with a large, negative effect on food consumption. Jointly the temperature variables are statistically significant at conventional levels, with the larger effect emanating from an increase in the maximum temperature. The estimates indicate that a 1 percent increase in maximum temperature is likely to reduce food consumption by about 3 percent. Depending on the season the weather data show that in 2005/06 households experience a 1 to 4 percent increase in maximum temperature as compared to the long-term means (0.34 to 1.1 °C) which translates into a 3 to 12 percent decline in food consumption.

To explore the possible links between changes in precipitation and changes in day time temperature we estimate a set of specifications with interactions between the maximum temperature variable and the two precipitation related variables (see rows 9 to 12 of Table 9). While independently the effect of an increase in day time temperature continues to exert a large negative effect on consumption, the main point emerging from these specifications is that an increase in the number of rainy days or an increase in the amount of rainfall or more generally increased access to water works towards mitigating the negative effects of heat on food consumption. According to the estimates, a 4 percent increase in the number of rainy days or an 8 percent increase in the amount of rainfall is enough to undo the negative effects of rising day time temperature. Considering this from another perspective the estimates reveal that a 1 percent increase in temperature accompanied by a 4 percent decline in the number of rainy days is likely to translate into a 10 percent decline in food consumption as compared to a 5 percent decline in food consumption if the number of rainy days remains unchanged.

Estimates in rows 13 to 16 of Table 9 include two period lags of the weather variables controlling for land ownership and size. As far as the amount of rainfall is concerned there is no effect of either the one-period or two-period lagged variables on food consumption. As in the case of the earlier specifications, the number of rainy days, both the one-period and two-period lagged variables exert a negative effect although the effects of the more recent period are clearly more pronounced. In row 16, the effect of the distribution of rainfall is now statistically significant indicating that a 10 percent increase in the number of rainy days leads a 4 percent decline in food consumption. Based on the same set of estimates, we see that increases in the maximum and minimum temperature have a negative effect on food consumption. Once again the effect of an increase in the maximum temperature is large and a 1 percent increase is associated with a 3 to 4 percent decline in food consumption. In our most comprehensive specification (row 16) we see that the effects of the weather variables are not persistent. The sensitivity of consumption only to weather fluctuations in the season immediately preceding the survey suggests that while households are able to protect food consumption against weather fluctuations such adjustments take time.

>>Table 9 about here<<

To explore differences in household ability to cope with weather variations we run a series of models with interactions between household indicators of wealth (ownership of a house, land ownership and the amount of land owned) and each of the four weather indicators (see Table 10). There are several points which stand out. Regardless of the specification we find that food consumption remains sensitive to an increase in the maximum temperature, that is, day time warming as opposed to night time warming. In all the specifications, this variable remains statistically significant (see F-test for maximum temperature). While simply owning a house or owning land does not seem to provide any protection, the amount of land owned by a household does play a role, albeit quite small, in mitigating the negative effects of an increase in temperature. Based on the estimates displayed in row 28 of Table 10, a 1 percent increase in the maximum temperature translates into a 3.4 percent decline in food consumption for a household with average land holdings, while this effect falls to about 2.8 percent (3.4 - 0.068*8.3) in case household land holdings increase by one standard deviation (based on 2009/10 data).

>>Table 10 about here<<

While the aim of the paper is to identify the effect of weather variability on food consumption, it is possible that households protect food consumption at the cost of non-food consumption and a singular focus on food consumption may lead to an underestimate of the effects of weather variability on household welfare. In order to provide a more comprehensive assessment we also estimated models such as (1) to examine the effect of weather variability on other consumption aggregates – non-durables, semi-durables and transfers. There is no evidence that weather variability influences expenditure on non-durables. With respect to semi-durables there is some evidence that higher temperatures translate into a reduction in expenditures but the effect is not consistent across specifications. A relatively clear effect emanates from social transfers which are positively linked to rainfall or in other words, a reduction in rainfall limits the ability of households to provide transfers. However, overall, there is very little evidence that non-food expenditure is affected by weather variability or that households are cutting back on non-food consumption due to weather variability in order to protect food consumption. Indeed in the case of subsistence farmers it is perhaps to be expected that the brunt of the effects of weather variability will be manifested through effects on food consumption.

>>Table 11 about here<<

>>Table 12 about here<<

>>Table 13 about here<<

## 6. DISCUSSION AND CONCLUDING REMARKS

Motivated by concerns about the effects of climate change on household welfare in developing countries and the paucity of analysis on rural Uganda, this paper used two rounds of panel data to examine the effect of weather variability on household consumption. We find that variations in rainfall both in terms of the amount and the number of rainy days have a limited bearing on household food consumption, although there is some evidence that households reduce expenditure on transfers when there is a decline in rainfall. In contrast, there is a statistically discernible and large negative effect of an increase in day time (maximum) temperatures on food consumption. This effect persists in all specifications and depending on the specification we found that under normal rainfall conditions a $1^{o}$C increase in the maximum temperature is associated with a 10-12 percent reduction in household food consumption. The estimates also show that the effects of increasing temperatures may be mitigated by increases in rainfall or conversely effects of temperature on food consumption are exacerbated if there is a decline in rainfall. Effects are somewhat lower for households with larger land holdings which underlines the vulnerability of the poorest households in developing countries.

The sign and the magnitude of the effects that we find and the greater sensitivity of food consumption to heat when water is scarce is similar (see Table 14) to the effects of weather variability on crop yields based on climate change models (Thornton et al., 2010) and particularly analysis based on experimental data from field trials (Lobell et al., 2011).[11] While both these papers offer crop-specific analyses, they deal with crops (maize and beans and only maize, respectively) that are important in the Ugandan context. Our estimates are also consistent with the qualitative work on Uganda (see Magrath et al., 2008).

>>Table 14 about here<<

Despite these estimates, whether food consumption declines is clearly not a foregone conclusion. There are several measures which may be taken and have been taken to mitigate the effects of rising temperatures. For instance, it is possible to counteract the effects of increases in temperature by using heat-resistant crop varieties, changing the crop-mix, adoption of intercropping and using measures to preserve soil moisture. As discussed in the text (see Table 4), seemingly in an attempt to shield food consumption, there is evidence that households are increasing the share of land devoted to the production of food crops (maize, beans, cassava), while reducing land used to cultivate cash crops. Evidence of behaviour designed to mitigate the effects of weather changes is also provided by a number of qualitative studies (Magrath, 2008; Osbahr et al., 2011; Okonya et al., 2013).

For instance, a farmers' representative in Western Uganda's Kasese district states (see Magrath, 2008:7):

> "Because of the current weather changes the yields have completely gone down. We used to have much more rainfall than we are having now, that's one big change, and to me this area is warmer than 20 years ago. Until about 1988 the climate was okay... Now the March to June season in particular isn't reliable, which doesn't favour the crops we grow. Rain might stop in April. Because of the shortened rains you have to go for early maturing varieties and now people are trying to select these."

In Southern Uganda, to protect coffee, the traditional cash crop from heat Magrath (2008) reports that farmers are growing more trees around coffee bushes in order to provide shade and to conserve soil moisture and at the same time conserving and reusing water through measures such as

[11] Details on the crop science and the manner in which heat affects the growth of crops such as maize and beans are available in these papers.

terracing. Based on a survey in six of Uganda's agro-ecological zones, Okonya et al. (2013) report that in the last ten years about 45% of the 192 households in their study have started to plant trees, in part, to enhance soil fertility. About 35% have adopted quick-maturing crop varieties while about 25% have adopted new/high yielding varieties and/or drought-tolerant crops/varieties. Osbahr et al. (2011: 310) report that farmers are using swampy areas as fields, partly due to land pressure, and that they have changed to heat-resistant cassava and beans and adopted soil and water conservation methods.

While these measures may mitigate the effects of climate change and global warming on household welfare in Uganda and more generally in developing countries, the evidence assembled in this paper yields the unerring conclusion that rising temperatures are associated with a decline in crop yields and food consumption in rural Uganda.

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## TABLES

**Table 1** Per capita GDP (constant 2000 USD) and value added per sector (% GDP)

| | 1990-1994 | 1995-1999 | 2000-2004 | 2005-2010 |
|---|---|---|---|---|
| GDP per capita (constant 2000 UDS) | 193.99 | 239.11 | 273.38 | 345.13 |
| Agriculture [a] value added (% GDP) | 52.40 | 43.41 | 26.61 | 24.60 |
| Industry value added (% GDP) | 12.72 | 17.17 | 23.22 | 25.75 |
| Services value added (% GDP) | 34.88 | 39.42 | 50.17 | 49.65 |

*Source*: World Bank (2011b)

[a] Major changes in the share of agriculture in value added are due to the discovery of oil in the country (counted in the industrial sector).

**Table 2** Employment per sector (% of total employment) [a]

| | 2002 | 2005 | 2009 |
|---|---|---|---|
| Agriculture | 65.50 | 71.60 | 65.60 |
| Industry | 6.50 | 4.50 | 6.00 |
| Services | 22.00 | 23.20 | 28.40 |

*Source:* World Bank (2011b)

[a] Data on employment per sector is available only for the years presented in the table when a national household survey was conducted.

**Table 3** Occupational distribution in rural Uganda

| | Full sample NHS (2,248 rural households) | | Study sample (488 households) | |
|---|---|---|---|---|
| Occupation | 2005 | 2009 | 2005 | 2009 |
| Subsistence agricultural and fishery workers | | | | |
| Subsistence agricultural workers | 77.94% | 76.87% | 79.17% | 79.21% |
| Subsistence animal rearing | 2.80% | 3.69% | 1.93% | 3.55% |
| Subsistence fishery and related workers | 0.63% | 0.18% | 0.43% | 0.24% |
| Market-oriented skilled agricultural and fishery w. | 2.60% | 2.84% | 2.00% | 2.70% |
| Elementary occupations | | | | |
| Agricultural, fishery and related laborers | 3.39% | 2.46% | 3.00% | 2.22% |
| Other elementary occupations | 2.78% | 3.78% | 2.27% | 3.00% |
| Other job categories | 9.86% | 10.18% | 11.2% | 9.08% |
| Total | 100% | 100% | 100% | 100% |

*Source:* Authors' calculations based on LSMS 2005/06-2009/10 household panel.

**Table 4** Production, yields and hectares harvested for selected crops in selected years

| | Production (1000 Tonnes) | | | | Yield (Kg/Ha) | | | | Hectares harvested (1000 Ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2010 | *% change 2000-10* | 2000 | 2005 | 2010 | *% change 2000-10* | 2000 | 2005 | 2010 | *% change 2000-10* |
| Banana | 610 | 563 | 600 | *-1.64* | 4519 | 3976 | 4196 | *-7.15* | 135 | 142 | 143 | *5.93* |
| Beans | 420 | 468 | 455 | *8.33* | 601 | 577 | 489 | *-18.64* | 699 | 828 | 930 | *33.05* |
| Cassava | 4966 | 5576 | 5282 | *6.36* | 12384 | 14408 | 12728 | *2.78* | 401 | 387 | 415 | *3.49* |
| Coffee | 143 | 158 | 162 | *13.29* | 477 | 601 | 600 | *25.79* | 301 | 263 | 270 | *-10.30* |
| Groundnuts | 139 | 159 | 172 | *23.74* | 699 | 707 | 732 | *4.72* | 199 | 225 | 235 | *18.09* |
| Maize | 1096 | 1170 | 1373 | *25.27* | 1742 | 1500 | 1543 | *-11.42* | 629 | 780 | 890 | *41.49* |
| Plantains | 9428 | 9045 | 9550 | *1.29* | 5900 | 5400 | 5618 | *-4.78* | 1598 | 1675 | 1700 | *6.38* |
| Potatoes | 478 | 585 | 695 | *45.40* | 7029 | 6802 | 6814 | *-3.06* | 68 | 86 | 102 | *50.00* |
| Sorghum | 361 | 449 | 500 | *38.50* | 1289 | 1527 | 1515 | *17.53* | 280 | 294 | 330 | *17.86* |
| Sweet potatoes | 2398 | 2604 | 2838 | *18.35* | 4321 | 4414 | 4577 | *5.92* | 555 | 590 | 620 | *11.71* |
| Total | 20039 | 20777 | 21627 | *7.92* | 38961 | 39912 | 38812 | 0.38 | 4865 | 5270 | 5635 | 15.83 |
| Population (million) | 24.2 | 28.4 | 33.4 | *38.02* | | | | | | | | |

Source: FAO (2012) for data on agricultural sector and World Bank (2011) for population data.

**Table 5** Descriptive statistics of weather indicators: Long-term means and levels in 2005/06 and 2009/10 for the first season preceding the survey [a]

| Weather variable | Season | N | Long-term mean | | 2005/06 | | 2009/10 | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | St.D. | Mean | St.D. | Mean | St.D. |
| Rainfall (mm) | Dry 1 | 58 | 48.64 | 21.87 | 39.29 | 23.34 | 108.71 | 24.15 |
| | Rainy 1 | 262 | 147.31 | 37.56 | 150.88 | 44.18 | 152.79 | 46.59 |
| | Dry 2 | 168 | 87.64 | 41.56 | 98.10 | 36.64 | 66.75 | 38.02 |
| No. of rainy days | Dry 1 | 58 | 4.64 | 2.10 | 3.88 | 2.14 | 8.16 | 2.23 |
| | Rainy 1 | 262 | 11.75 | 2.20 | 12.31 | 2.56 | 11.97 | 1.56 |
| | Dry 2 | 168 | 7.19 | 3.04 | 7.88 | 2.32 | 5.93 | 2.72 |
| Max. temp. (°C) | Dry 1 | 58 | 30.24 | 2.63 | 31.35 | 2.71 | 29.91 | 2.77 |
| | Rainy 1 | 262 | 28.85 | 2.08 | 29.17 | 1.98 | 29.24 | 2.04 |
| | Dry 2 | 168 | 27.36 | 0.98 | 28.28 | 1.54 | 28.86 | 1.07 |
| Min. temp. (°C) | Dry 1 | 58 | 16 | 2.55 | 17.53 | 1.92 | 17.19 | 2.04 |
| | Rainy 1 | 262 | 17.29 | 2.09 | 18.33 | 1.68 | 18.02 | 1.75 |
| | Dry 2 | 168 | 16.21 | 1.32 | 17.14 | 1.15 | 17.16 | 0.92 |

Source: Author's calculations based on UDOM (2012) weather data.

[a] Long-term means are calculated as averages of the specific weather indicator in the specific season over the period 1960-1990 for rainfall and number of rainy days and 1980-2010 for maximum and minimum temperatures. For example, the long-term mean assigned to the 58 households who were surveyed in the first dry season is 48.64 mm of rain. In 2005-06 these households were assigned a mean of 39.29 mm of rainfall and in 2009/10 108.71 mm of rainfall.

**Table 6** Descriptive statistics of weather indicators between 2005 and 2010: Weather indicators reported as a percentage deviation from the long-term mean for the first season preceding the survey [a]

| Weather variable | Season | N | 2005/06 | | 2009/10 | | 2006/07-2009/10 | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | St.D. | Mean | St.D. | Mean | St.D. |
| Rainfall mm | Dry 1 | 58 | -18.74 | 31.00 | 159.65 | 92.21 | 29.34 | 17.35 |
| | Rainy 1 | 262 | 3.04 | 18.70 | 2.98 | 15.64 | -7.39 | 6.82 |
| | Dry 2 | 168 | 21.02 | 34.42 | -27.05 | 19.96 | 14.52 | 22.90 |
| No. rainy days | Dry 1 | 58 | -10.32 | 36.38 | 91.12 | 38.41 | 40.15 | 33.92 |
| | Rainy 1 | 262 | 6.52 | 21.30 | 3.40 | 10.74 | -1.57 | 12.49 |
| | Dry 2 | 168 | 18.66 | 25.79 | -19.28 | 10.73 | 17.79 | 18.33 |
| Max temp. (°C) | Dry 1 | 58 | 3.71 | 2.39 | -1.05 | 3.75 | 0.14 | 1.70 |
| | Rainy 1 | 262 | 1.17 | 2.88 | 1.39 | 2.29 | 1.17 | 1.80 |
| | Dry 2 | 168 | 3.42 | 5.10 | 5.51 | 2.13 | -4.24 | 10.32 |
| Min temp. (°C) | Dry 1 | 58 | 10.94 | 12.48 | 8.27 | 6.50 | 8.74 | 9.59 |
| | Rainy 1 | 262 | 6.69 | 8.37 | 4.80 | 6.37 | 3.75 | 6.80 |
| | Dry 2 | 168 | 6.07 | 6.59 | 6.26 | 6.71 | 4.92 | 6.93 |

Source: Author's calculations based on UDOM (2012) weather data.

[a] Weather indicators are expressed as a percentage deviation from the long-term mean. Long-term means are calculated as averages of the specific weather indicator in the specific season over the period 1960-1990 for rainfall and number of rainy days and 1980-2010 for maximum and minimum temperatures. For example, the 58 households who were surveyed in the first dry season in 2005/06 experience rainfall which is 18.74 % lower than the long term mean.

**Table 7** Descriptive statistics of selected variables for rural households in Uganda

| | 2005/06 | | | 2009/10 | | |
|---|---|---|---|---|---|---|
| Variable | *N* | Mean | St. Dev | *N* | Mean | St. Dev |
| Month survey | 488 | 8 | 1.6525 | 488 | 8 | 2.0737 |
| Year survey | 488 | 2005 | 0 | 488 | 2009 | 0 |
| Sex Head HH[a] (Female=1) | 488 | 0.2275 | 0.4196 | 488 | 0.2520 | 0.4346 |
| Age Head HH | 488 | 42.6783 | 15.2597 | 488 | 46.8504 | 15.5713 |
| Education head of the HH | | | | | | |
| (1) Don't know | 482 | 0.0000 | 0.0000 | 480 | 0.0042 | 0.0645 |
| (2) Never attended school | 482 | 0.1784 | 0.3833 | 480 | 0.2063 | 0.4050 |
| (3) Some schooling but not completed primary | 482 | 0.4502 | 0.4980 | 480 | 0.4479 | 0.4978 |
| (4) Completed primary | 482 | 0.1701 | 0.3761 | 480 | 0.1438 | 0.3512 |
| (5) Completed post primary specialization | 482 | 0.0353 | 0.1847 | 480 | 0.0250 | 0.1563 |
| (6) Completed junior high | 482 | 0.1286 | 0.3351 | 480 | 0.1313 | 0.3380 |
| (7) Completed secondary | 482 | 0.0062 | 0.0791 | 480 | 0.0104 | 0.1016 |
| (8) Completed post secondary specialization | 482 | 0.0290 | 0.1681 | 480 | 0.0292 | 0.1684 |
| (9) Degree or above | 482 | 0.0021 | 0.0455 | 480 | 0.0021 | 0.0456 |
| Household size | 488 | 5.8443 | 3.1349 | 488 | 6.3996 | 3.2937 |
| Share of males 0-5 | 488 | 0.1224 | 0.1439 | 488 | 0.0994 | 0.1269 |
| Share of males 6-11 | 488 | 0.0823 | 0.1150 | 488 | 0.1022 | 0.1150 |
| Share of males 12-17 | 488 | 0.0728 | 0.1176 | 488 | 0.0917 | 0.1312 |
| Share of males 18-64 | 488 | 0.2125 | 0.2015 | 488 | 0.1911 | 0.1844 |
| Share of males >65 | 488 | 0.0231 | 0.1150 | 488 | 0.0352 | 0.1398 |
| Share of females 0-5 | 488 | 0.0982 | 0.1375 | 488 | 0.0927 | 0.1254 |
| Share of females 6-11 | 488 | 0.0745 | 0.1033 | 488 | 0.0852 | 0.1091 |
| Share of females 12-17 | 488 | 0.0598 | 0.1028 | 488 | 0.0746 | 0.1148 |
| Share of females 18-64 | 488 | 0.2303 | 0.1749 | 488 | 0.2029 | 0.1383 |
| Share of females >65 | 488 | 0.0240 | 0.1122 | 488 | 0.0249 | 0.0969 |
| Own house (Yes=1) | 488 | 0.8955 | 0.3062 | 483 | 0.9296 | 0.2561 |
| No. Rooms | 488 | 3.9918 | 2.3615 | 483 | 2.9379 | 1.6970 |
| Own land (Yes=1) | 444 | 0.8581 | 0.3493 | 462 | 0.9177 | 0.2750 |
| Owned parcels size (Ha) | 446 | 5.7250 | 34.7912 | 474 | 4.3094 | 8.3383 |
| HH monthly food consumption[b] | 488 | 86,024.46 | 66,432.58 | 484 | 87,557.27 | 69,168.5 |
| HH monthly total expenditures[b] | 485 | 175,957.6 | 175,729.7 | 484 | 195,559.8 | 194,160.4 |
| Region 1 – Central | 488 | 0.2725 | 0.4457 | 488 | 0.2725 | 0.4457 |
| Region 2 – Eastern | 488 | 0.2459 | 0.4311 | 488 | 0.2459 | 0.4311 |
| Region 3 – Northern | 488 | 0.2951 | 0.4565 | 488 | 0.2951 | 0.4565 |
| Region 4 – Western | 488 | 0.1865 | 0.3899 | 488 | 0.1865 | 0.3899 |

*Source:* Author's calculations based on LSMS 2005/06-2009/10 household panel.

[a] HH stands for household.

[b] Real expenditures; Adjusted for monthly regional inflation. 1 USD=1,780 UGX in 2005

**Table 8** Consumption expenditure, 2005/06 and 2009/10

| | | Rural Uganda (UBOS-NHS) | | 488 households (LSMS sub-sample) | |
|---|---|---|---|---|---|
| | | 05/06 | 09/10 | 05/06 | 09/10 |
| Household total expenditures [a] | | 176,600 | 197,500 | 174,958 | 195,560 |
| Per capita total expenditures [a] | | 33,150 | 38,200 | 29,959 | 30,556 |
| **Shares of households expenditures by item groups (%)** [b] | | | | | |
| Food, drink and tobacco | | 50.00 | 51.00 | 55.66 | 52.34 |
| | *Food* | | | *(91)* | *(91)* |
| | *Beverages and tobacco* | | | *(6)* | *(5)* |
| | *Restaurants* | | | *(3)* | *(4)* |
| Non durable | | | | 30.75 | 31.56 |
| | *Rent, fuel Energy* | *15.00* | *15.00* | *(52)* | *(50)* |
| | *Non-durable and personal goods* [c] | *4.00* | *5.00* | *(12)* | *(9)* |
| | *Transport and communication* | *6.00* | *7.00* | *(11)* | *(16)* |
| | *Health and medical care* | *8.00* | *6.00* | *(23)* | *(22)* |
| | *Other services* [c] | *2.00* | *3.00* | *(2)* | *(3)* |
| Semi durable | | | | 11.41 | 13.82 |
| | *Clothing and footwear* | *4.00* | *3.00* | *(36)* | *(30)* |
| | *Furniture, carpet, furnishing* | | | *(9)* | *(8)* |
| | *Household appliances and equipment* | | | *(5)* | *(10)* |
| | *Glass/table ware, utensils* | | | *(4)* | *(3)* |
| | *Education* | *8.00* | *7.00* | *(42)* | *(45)* |
| | *Services not elsewhere specified* | | | *(4)* | *(4)* |
| Transfers | | 3.00 | 3.50 | 2.17 | 2.28 |
| | *Outgoing remittances, gifts and other transfers* | | | *(47)* | *(46)* |
| | *Funerals and other social functions* | | | *(36)* | *(43)* |
| | *Other (taxes, pensions, subscriptions, interests)* | | | *(17)* | *(11)* |

Source: Authors' calculations based on UBOS-NHS (National Households survey) and LSMS Uganda household panel 2005/06-2009/10.

[a] Adjusted for regional inflation, base year 2005.

[b] UBOS reported classification is slightly different from the more detailed breakdown allowed by the LSMS dataset. For the LSMS dataset we report in italics and parentheses the breakdown into more detailed expenditure items.

[c] In UBOS classification *Non-durable and personal goods* share include semi-durable furniture, households appliances and utensils while *Other services* includes *Services not elsewhere specified*.

**Table 9** Fixed effect estimate: Effect of Weather Variability on Food Consumption [a]

| | Rain(-1) | Days(-1) | Max(-1) | Min(-1) | DaysXMax | RainXMax | Rain(-2) | Days(-2) | Max(-2) | Min(-2) | Own land | Size land | Const | Rsqr | N | NHH | F-test temps | F-test prec.Xmax |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***(1)*** | 0.037 | | | | | | | | | | | | 9.726*** | 0.147 | 961 | 488 | | |
| | (0.060) | | | | | | | | | | | | (0.524) | | | | | |
| ***(2)*** | 0.050 | | | | | | | | | | 0.231** | -0.001 | 9.156*** | 0.159 | 896 | 472 | | |
| | (0.060) | | | | | | | | | | (0.093) | (0.001) | (0.569) | | | | | |
| ***(3)*** | 0.153 | -0.193 | | | | | | | | | | | 9.642*** | 0.151 | 961 | 488 | | |
| | (0.146) | (0.190) | | | | | | | | | | | (0.485) | | | | | |
| ***(4)*** | 0.174 | -0.207 | | | | | | | | | 0.223** | -0.001 | 9.03*** | 0.164 | 896 | 472 | | |
| | (0.154) | (0.194) | | | | | | | | | (0.096) | (0.001) | (0.556) | | | | | |
| ***(5)*** | | | -2.735*** | -0.271 | | | | | | | | | 20.07*** | 0.165 | 961 | 488 | 0.051 | |
| | | | (0.013) | (0.839) | | | | | | | | | (4.836) | | | | | |
| ***(6)*** | | | -2.730*** | -0.615 | | | | | | | 0.237*** | -0.001 | 20.52*** | 0.177 | 896 | 472 | 0.066 | |
| | | | (1.042) | (0.806) | | | | | | | (0.093) | (0.001) | (4.902) | | | | | |
| ***(7)*** | 0.128 | -0.281 | -3.266*** | -0.586 | | | | | | | | | 22.84*** | 0.172 | 961 | 488 | 0.036 | |
| | (0.121) | (0.182) | (1.122) | (0.953) | | | | | | | | | (5.548) | | | | | |
| ***(8)*** | 0.148 | -0.288 | -3.122*** | -0.860 | | | | | | | 0.228** | -0.001 | 22.50*** | 0.184 | 896 | 472 | 0.048 | |
| | (0.130) | (0.194) | (1.111) | (0.920) | | | | | | | (0.096) | (0.001) | (5.430) | | | | | |
| ***(9)*** | 0.092 | -4.711*** | -5.742*** | -0.415 | 1.314*** | | | | | | | | 30.93*** | 0.177 | 961 | 488 | | 0.003 |
| | (0.116) | (1.312) | (1.372) | (0.888) | (0.386) | | | | | | | | (6.549) | | | | | |
| **(10)** | 0.109 | -4.733*** | -5.573*** | -0.705 | 1.318*** | | | | | | 0.232** | -0.001 | 30.57*** | 0.189 | 896 | 472 | | 0.002 |
| | (0.126) | (1.391) | (1.226) | (0.849) | (0418) | | | | | | (0.094) | (0.001) | (6.126) | | | | | |
| ***(11)*** | -3.547** | -0.306* | -8.071*** | -0.448 | | 1.078** | | | | | | | 38.96*** | 0.178 | 961 | 488 | | 0.001 |
| | (1.284) | (0.169) | (1.502) | (0.953) | | (0.363) | | | | | | | (6.225) | | | | | |
| ***(12)*** | -3.629** | -0.310 | -8.016*** | -0.737 | | 1.106** | | | | | 0.239** | -0.001 | 39.01*** | 0.191 | 896 | 472 | | 0.000 |
| | (1.482) | (0.178) | (1.429) | (0.907) | | (0.415) | | | | | (0.090) | (0.001) | (6.161) | | | | | |
| ***(13)*** | 0.052 | | | | | | -0.026 | | | | 0.224*** | -0.001 | 9.24*** | 0.160 | 896 | 472 | | |
| | (0.055) | | | | | | (0.048) | | | | (0.088) | (0.001) | (0.64) | | | | | |
| ***(14)*** | 0.195 | -0.240 | | | | | 0.049 | -0.157 | | | 0.217*** | -0.001 | 9.128*** | 0.169 | 896 | 472 | | |
| | (0.142) | (0.189) | | | | | (0.090) | (0.122) | | | (0.083) | (0.001) | (0.576) | | | | | |
| ***(15)*** | | | -3.572*** | -0.305 | | | | | 1.554** | -0.391 | 0.241*** | -0.001 | 18.36*** | 0.182 | 896 | 472 | 0.002 | |
| | | | (0.907) | (0.514) | | | | | (0.774) | (0.667) | (0.093) | (0.001) | (6.03) | | | | | |
| ***(16)*** | 0.144 | -0.362*** | -4.139*** | -1. 252 | | | 0.160 | -0.082 | 1.107 | 0.484 | 0.226*** | -0.001 | 20.91** | 0.195 | 896 | 472 | 0.002 | |
| | (0.121) | (0.148) | (1.131) | (1.313) | | | (0.145) | (0.150) | (1.107) | (0.713) | (0.083) | (0.001) | (8.51) | | | | | |

*Source:* Author's calculations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

[a] The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications also include the number and size of the owned parcels of land. The weather variables are natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations in parentheses. *, **, ***, indicates 10, 5 and 1% level of significance, respectively.

**Table 10** Fixed effect estimates: Effect of Weather Variability on Food Consumption – Exploring Heterogeneity [a]

| House | Own House | Rain(-1) | Days(-1) | MaxT(-1) | MinT(-1) | RainxHouse | DaysxHouse | MaxTXHouse | MinTXHouse | Const | Rsqr | Ftest Rain | Ftest Days | Ftest maxt | Ftest mint |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***(17)*** | -0.481 | -0.037 | | | | 0.088 | | | | 9.57*** | 0.160 | 0.707 | | | |
| | (1.408) | (0.306) | | | | (0.310) | | | | (1.59) | | | | | |
| ***(18)*** | 0.448 | 0.539 | -0.776 | | | -0.383 | 0.596 | | | 8.48*** | 0.166 | 0.448 | 0.303 | | |
| | (1.748) | (0.576) | (0.575) | | | (0.587) | (0.614) | | | (1.94) | | | | | |
| ***(19)*** | -3.699 | | | -2.678 | -2.081 | | | -0.076 | 1.350 | 24.66** | 0.177 | | | 0.055 | 0.569 |
| | (9.783) | | | (1.554) | (1.936) | | | (1.534) | (1.985) | (9.67) | | | | | |
| ***(20)*** | -6.695 | 0.606 | -0.858 | -4.035 | -2.265 | -0.483 | 0.599 | 0.994 | 1.480 | 28.75** | 0.188 | 0.464 | 0.207 | 0.055 | 0.689 |
| | (11.397) | (0.623) | (0.602) | (3.408) | (2.776) | (0.615) | (0.621) | (3.015) | (2.750) | (12.10) | | | | | |

| Own Land | Own land | Size land | Rain(-1) | Days(-1) | MaxT(-1) | MinT(-1) | RainxLand | DaysxLand | MaxTXLand | MinTXLand | Const | Rsqr | Ftest Rain | Ftest Days | Ftest maxt | Ftest Mint |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***(21)*** | 0.615 | -0.001 | 0.126 | | | | -0.083 | | | | 8.76*** | 0.160 | 0.350 | | | |
| | (0.461) | (0.001) | (0.086) | | | | (0.095) | | | | (0.723) | | | | | |
| ***(22)*** | -0.053 | -0.001 | -0.141 | 0.346 | | | 0.347 | -0.610 | | | 9.166 | 0.167 | 0.417 | 0.242 | | |
| | (0.871) | (0.001) | (0.331) | (0.387) | | | (0.359) | (0.395) | | | (0.950) | | | | | |
| ***(23)*** | -1.884 | -0.001 | | | -3.828** | 0.032 | | | 1.210 | -0.671 | 22.26*** | 0.178 | | | 0.061 | 0.289 |
| | (5.061) | (0.001) | | | (1.773) | (1.248) | | | (1.445) | (0.685) | (7.47) | | | | | |
| ***(24)*** | -1.889 | -0.001 | -0.104 | 0.143 | -3.875** | -0.398 | 0.284 | -0.475 | 0.898 | -0.406 | 23.79*** | 0.188 | 0.389 | 0.159 | 0.050 | 0.359 |
| | (5.37) | (0.001) | (0.263) | (0.340) | (1.911) | (1.326) | (0.284) | (0.321) | (1.454) | (0.620) | (8.063) | | | | | |

| Land size | Own Land | Size land | Rain(-1) | Days(-1) | MaxT(-1) | MinT(-1) | RainxSize | DaysxSize | MaxTXSize | MinTXSize | Const | Rsqr | Ftest Rain | Ftest Days | Ftest maxt | Ftest mint |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***(25)*** | 0.239** | 0.013*** | 0.068 | | | | -0.003*** | | | | 9.076*** | 0.167 | 0.000 | | | |
| | (0.094) | (0.001) | (0.063) | | | | (0.001) | | | | (0.57) | | | | | |
| ***(25)*** | 0.231** | 0.013 | 0.195 | -0.212 | | | -0.003 | 0.0001 | | | 8.94*** | 0.171 | 0.518 | 0.562 | | |
| | (0.096) | (0.027) | (0.170) | (0.203) | | | (0.011) | (0.010) | | | (0.60) | | | | | |
| ***(27)*** | 0.257*** | -0.145* | | | -3.046*** | -0.823 | | | 0.082*** | -0.046*** | 20.98*** | 0.185 | | | 0.009 | 0.000 |
| | (0.094) | (0.077) | | | (1.108) | (0.823) | | | (0.022) | (0.008) | (5.06) | | | | | |
| ***(28)*** | 0.248*** | -0.155 | 0.155 | -0.292 | -3.393*** | -0.737 | 0.001 | -0.002 | 0.068** | -0.026 | 23.06*** | 0.193 | 0.481 | 0.309 | 0.014 | 0.537 |
| | (0.097) | (0.099) | (0.144) | (0.200) | (1.113) | (0.951) | (0.012) | (0.013) | (0.034) | (0.043) | (5.39) | | | | | |

*Source:* Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

[a] Number of observations is 896 and number of households is 472 for all specifications. The control variables included in the specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, land ownership and size of land, year dummy. Weather variables (-1) are calculated as natural logarithm of the weather indicator in the season preceding the survey. Robust standard errors clustered by synoptic stations are in parentheses. *, **, *** indicates 10, 5 and 1% level of significance, respectively.

**Table 11** Fixed effect estimates: Effect of Weather Variability on Consumption of Non-durable Goods [a]

| | Dependent variable: ln (monthly non-durables expenditures) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rain (-1) | Days (-1) | Max t(-1) | Min t.(-1) | Ownland | Landsize | Const | Rsqr | N | NH |
| **(29)** | 0.028 | | | | | | 12.177*** | 0.077 | 961 | 488 |
| | (0.197) | | | | | | (1.540) | | | |
| **(30)** | 0.103 | | | | -1.071*** | 0.002** | 9.652*** | 0.093 | 896 | 472 |
| | (0.137) | | | | (0.400) | (0.001) | (1.163) | | | |
| **(31)** | 0.182 | -0.259 | | | | | 12.064*** | 0.077 | 961 | 488 |
| | (0.431) | (0.675) | | | | | (1.578) | | | |
| **(32)** | 0.106 | -0.005 | | | -1.071*** | 0.002** | 9.649*** | 0.093 | 896 | 472 |
| | (0.281) | (0.433) | | | (0.407) | (0.001) | (1.291) | | | |
| **(33)** | | | 2.236 | 1.459 | | | 0.419 | 0.079 | 961 | 488 |
| | | | (2.798) | (1.661) | | | (7.504) | | | |
| **(34)** | | | -0.150 | 2.002 | -1.096*** | 0.002** | 4.817 | 0.095 | 896 | 472 |
| | | | (2.089) | (1.177) | (0.396) | (0.001) | (7.097) | | | |
| **(35)** | 0.204 | -0.145 | 2.916 | 1.767 | | | -3.359 | 0.080 | 961 | 488 |
| | (0.425) | (0.680) | (4.177) | (1.856) | | | (15.546) | | | |
| **(36)** | 0.118 | 0.087 | 1.061 | 2.628 | -1.096*** | 0.002** | -1.826 | 0.097 | 896 | 472 |
| | (0.270) | (0.423) | (3.095) | (1.799) | (0.403) | (0.001) | (13.44) | | | |

Source: Author's calculations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

[a] The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications also include the number and size of the owned parcels of land. Weather variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations are in parentheses. *, **, *** indicates 10, 5 and 1% level of significance, respectively.

**Table 12** Fixed effect estimates: Effect of Weather Variability on Consumption of Semi-durable goods [a]

| | Dependent variable: ln (monthly semi-durables consumption expenditures) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rain (-1) | Days (-1) | Max t(-1) | Min t.(-1) | Ownland | Landsize | Const | Rsqr | N | NH |
| **(37)** | 0.112 | | | | | | 6.518*** | 0.209 | 961 | 488 |
| | (0.154) | | | | | | (1.057) | | | |
| **(38)** | 0.107 | | | | -0.024 | -0.004*** | 6.778*** | 0.174 | 896 | 472 |
| | (0.150) | | | | (0.139) | (0.001) | (1.135) | | | |
| **(39)** | 0.367 | -0.426 | | | | | 6.332*** | 0.172 | 961 | 488 |
| | (0.312) | (0.441) | | | | | (1.104) | | | |
| **(40)** | 0.334 | -0.381 | | | -0.039 | -0.003*** | 6.547*** | 0.176 | 896 | 472 |
| | (0.367) | (0.519) | | | (0.149) | (0.001) | (1.269) | | | |
| **(41)** | | | -4.503 | -1.381 | | | 26.438** | 0.177 | 961 | 488 |
| | | | (2.739) | (1.138) | | | (11.536) | | | |
| **(42)** | | | -4.486 | -1.800 | -0.006 | -0.003*** | 27.834** | 0.184 | 896 | 472 |
| | | | (2.889) | (1.111) | (0.146) | (0.001) | (11.985) | | | |
| **(43)** | 0.328 | -0.592 | -5.226** | -1.849 | | | 30.119*** | 0.184 | 961 | 488 |
| | (0.283) | (0.400) | (2.467) | (1.060) | | | (10.328) | | | |
| **(44)** | 0.291 | -0.534 | -5.102** | -2.197** | -0.024 | -0.003*** | 30.892*** | 0.189 | 896 | 472 |
| | (0.3433) | (0.476) | (2.584) | (1.017) | (0.155) | (0.001) | (10.675) | | | |

Source: Author's calculations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

[a] The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications also include the number and size of the owned parcels of land. Weather variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations are in parentheses. *, **, *** indicates 10, 5 and 1% level of significance, respectively.

**Table 13** Fixed effect estimates: Effect of Weather Variability on Transfers [a]

| | Dependent variable: ln (monthly non-consumption expenditures) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rain (-1) | Days (-1) | Max t(-1) | Min t.(-1) | Ownland | Landsize | Const | Rsqr | N | NH |
| **(45)** | 0.985*** | | | | | | -11.028*** | 0.119 | 961 | 488 |
| | (0.353) | | | | | | (3.148) | | | |
| **(46)** | 1.041*** | | | | 1.335** | -0.002** | -13.269*** | 0.114 | 896 | 472 |
| | (0.346) | | | | (0.594) | (0.001) | (3.774) | | | |
| **(47)** | 1.675** | -1.153 | | | | | -11.532*** | 0.122 | 961 | 488 |
| | (0.689) | (0.952) | | | | | (3.482) | | | |
| **(48)** | 1.371 | -0.551 | | | 1.313** | -0.002* | -13.603*** | 0.115 | 896 | 472 |
| | (0.774) | (0.937) | | | (0.596) | (0.001) | (4.138) | | | |
| **(49)** | | | -8.322 | -16.077 | | | 67.787* | 0.131 | 961 | 488 |
| | | | (5.125) | (10.380) | | | (36.987) | | | |
| **(50)** | | | -11.593** | -17.692* | 1.517*** | -0.002** | 82.175** | 0.135 | 896 | 472 |
| | | | (5.532) | (10.259) | (0.541) | (0.001) | (31.992) | | | |
| **(51)** | 1.635** | -1.708 | -5.651 | -15.084 | | | 52.455 | 0.143 | 961 | 488 |
| | (0.732) | (1.032) | (4.890) | (9.323) | | | (37.829) | | | |
| **(52)** | 1.279 | -1.154 | -8.559 | -16.344 | 1.465*** | -0.002 | 64.628* | 0.143 | 896 | 472 |
| | (0.782) | (0.984) | (5.540) | (9.534) | (0.514) | (0.001) | (36.199) | | | |

Source: Author's elaborations based on LSMS 2005/06-2009/10 household panel and UDOM (2012) weather data.

[a] The control variables included in the odd numbered specifications are: sex, age (also squared) and education of the head of the household, size and demographic composition of the household, ownership of the house and number of rooms, year dummy. The even numbered specifications also include the number and size of the owned parcels of land. Weather variables are calculated as natural logarithm of the weather indicator (level) in the first season preceding the interview (-1) or in the second previous season (-2). Robust standard errors clustered by synoptic stations in parentheses. *, **, *** indicates 10, 5 and 1% level of significance, respectively.

**Table 44** Comparison of results across studies

| | | Simulated temperature changes | |
|---|---|---|---|
| Study | Dependent Variable | +1°C | +1.8°C |
| Lazzaroni & Bedi (2014)[a] (Uganda) | Food consumption –(rainfall at long-term mean) | -10.7% | -19.2% |
| Thornton et al. (2010) (Uganda) | Maize yields (projections for mixed rainfed humid-subhumid area in 2030) | | -4.6% |
| | Maize yields (projections for mixed rainfed humid-subhumid area in 2050) | | -12.9% |
| | Bean yields (projections for mixed rainfed humid-subhumid area in 2030) | | -3.7% |
| | Bean yields (projections for mixed rainfed humid-subhumid area in 2050) | | -20.8% |
| Lobell et al. (2011)[b] (Sub-Saharan Africa) | Maize yields (optimal rain-fed management) | -11.8% | |
| | Maize yields (drought management) | -20% | |

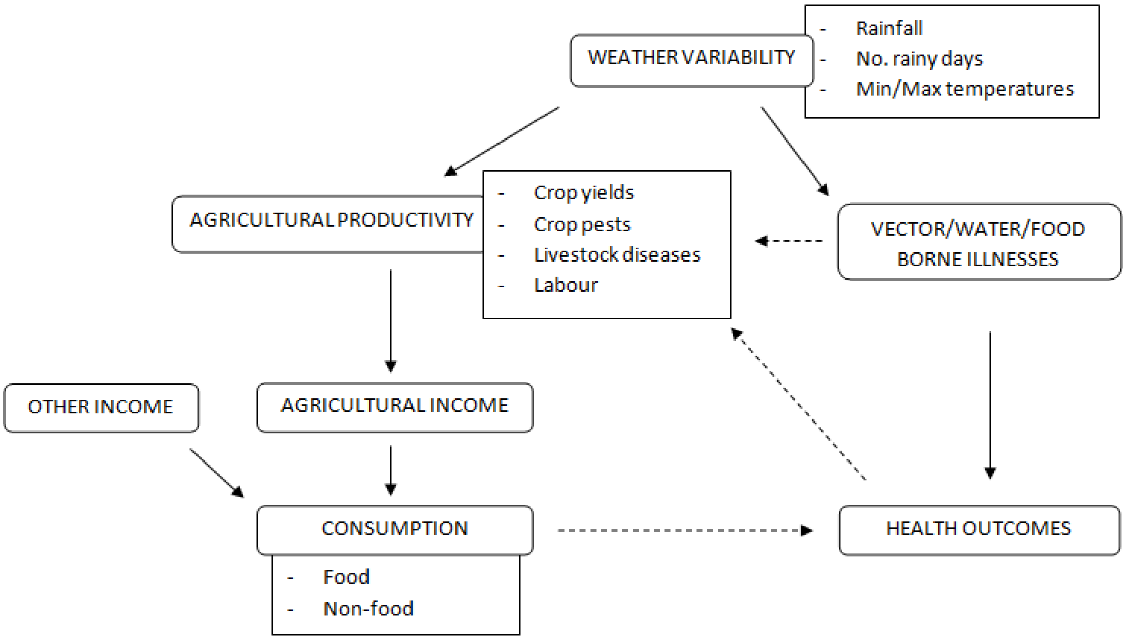
Source: Authors' elaborations

[a] Average maximum temperature for the full panel (both years) is 29.2°C, hence an increase of 1°C (1.8°C) corresponds to 3.42% (6.16%) increase in maximum temperatures. The calculation is based on Table 10, row 8.

[b] Conditional on the maximum temperature being 30°C+; Under drought (optimal) management a decline in yield is predicted for 75 (65) percent of maize-growing areas.

# FIGURES

**Figure 1** Weather variability and its impact on household welfare.




*Source:* Adapted from Skoufias *et al.* (2011).

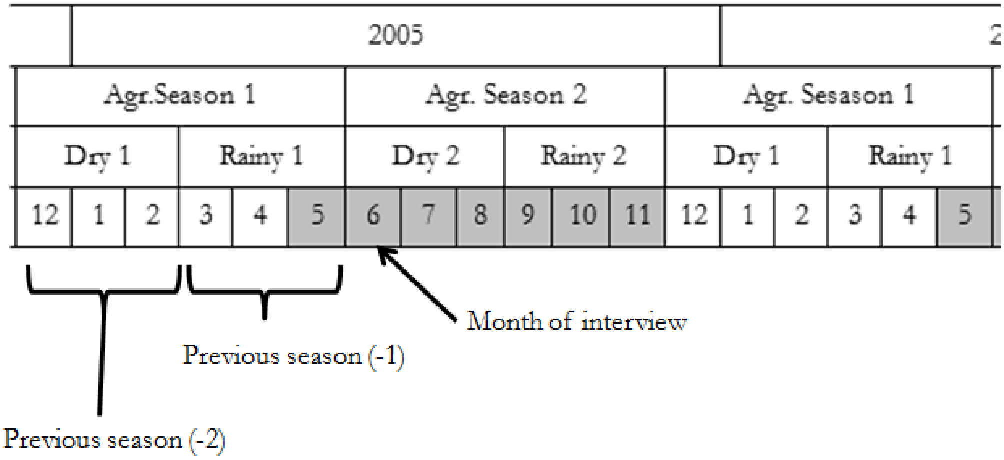
| **Year** | 2004 | | | | | | | 2005 | | | | | | | | | | | | 2006 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agr. Season** | Agr. Seas 2 | | | | | | Agr.Season 1 | | | | | | Agr. Season 2 | | | | | | Agr. Season 1 | | | | | | Agr. Season 2 | | | | | |
| **Season** | Dry 2 | | | Rainy 2 | | | Dry 1 | | | Rainy 1 | | | Dry 2 | | | Rainy 2 | | | Dry 1 | | | Rainy 1 | | | Dry 2 | | | Rainy 2 | | |
| **Month** | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |

| **Year** | | 2009 | | | | | | | | | | | | 2010 | | | | | | | | | | | | 2011 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agr. Season** | Agr. Season 1 | | | | | | Agr. Season 2 | | | | | | Agr. Season 1 | | | | | | Agr. Season 2 | | | | | | Agr. Season 1 | | | | | |
| **Season** | Dry 1 | | | Rainy 1 | | | Dry 2 | | | Rainy 2 | | | Dry 1 | | | Rainy 1 | | | Dry 2 | | | Rainy 2 | | | Dry 1 | | | Rainy 1 | | |
| **Month** | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 |

*Source:* Elaborated by the authors based on LSMS 2005/06-2009/10 household panel and Asiimwe and Mpuga (2007).

*Note:* The shaded boxes in light grey denote the month in which the interviews were conducted.

**Figure 3** Example of the assignment mechanism of weather deviations.




*Source:* Elaborated by the authors based on LSMS 2005/06-2009/10 household panel and Asiimwe and Mpuga (2007).

**Map 1** Map of Uganda (regions and districts) with the 13 synoptic stations.

Source: Adapted from http://commons.wikimedia.org/wiki/File:UgandaRegionsLegend.png, accessed 13 November 2012.

## SUPPLEMENTAL APPENDIX

**Table A.1** Descriptive statistics of weather indicators: long-term means and levels for the second season preceding the interview (-2) in 2005/06 and 2009/10. [a]

| Weather variable | Season | N | Long term means Mean | St.D. | 2005/06 Mean | St.D. | 2009/10 Mean | St.D. |
|---|---|---|---|---|---|---|---|---|
| Rainfall mm | Rainy 2 | 58 | 140.13 | 25.81 | 137.44 | 44.19 | 153.64 | 15.89 |
| | Dry 1 | 262 | 54.46 | 23.10 | 45.74 | 24.92 | 105.41 | 39.69 |
| | Rainy 1 | 168 | 140.18 | 37.26 | 138.79 | 46.86 | 119.38 | 46.44 |
| No. rainy days | Rainy 2 | 58 | 10.98 | 1.13 | 11.40 | 1.43 | 12.81 | 1.03 |
| | Dry 1 | 262 | 5.29 | 2.14 | 4.32 | 2.08 | 8.30 | 2.10 |
| | Rainy 1 | 168 | 11.33 | 1.96 | 11.73 | 2.79 | 10.93 | 1.55 |
| Max temp. (°C) | Rainy 2 | 58 | 28.48 | 1.94 | 28.67 | 2.14 | 28.38 | 1.91 |
| | Dry 1 | 262 | 29.91 | 2.31 | 31.25 | 2.49 | 29.66 | 2.59 |
| | Rainy 1 | 168 | 28.22 | 1.38 | 28.91 | 1.37 | 28.71 | 1.52 |
| Min temp. (°C) | Rainy 2 | 58 | 15.88 | 2.35 | 16.46 | 2.08 | 17.03 | 1.81 |
| | Dry 1 | 262 | 16.41 | 2.21 | 17.73 | 1.80 | 17.47 | 1.87 |
| | Rainy 1 | 168 | 17.29 | 1.31 | 18.15 | 1.14 | 17.77 | 1.11 |

Source: Author's elaborations from UDOM (2012) weather data.

[a] Long-term means are calculated as average weather indicator in the season considered in the period 1960-1990 for rainfall millimeters and number of rainy days and 1980-2010 for maximum and minimum temperatures.

**Table A.2** Weather indicators between 2005 and 2010: percentage deviations from long-term means. [a]

| Weather variable | Season | N | 2005/06 Mean | St.D. | 2009/10 Mean | St.D. | 2006/07-2009/10 Mean | St.D, |
|---|---|---|---|---|---|---|---|---|
| Rainfall mm | Rainy 2 | 58 | -2.00 | 27.06 | 159.65 | 92.21 | 5.63 | 5.76 |
| | Dry 1 | 262 | -15.84 | 29.20 | 2.98 | 15.64 | 28.34 | 19.07 |
| | Rainy 1 | 168 | -1.55 | 15.77 | -27.05 | 19.96 | -11.5 | 7.46 |
| No. Rainy days | Rainy 2 | 58 | 4.14 | 10.85 | 91.12 | 38.41 | 7.56 | 16.49 |
| | Dry 1 | 262 | -12.18 | 36.75 | 3.40 | 10.74 | 33.65 | 34.62 |
| | Rainy 1 | 168 | 3.83 | 19.07 | -19.28 | 10.73 | -2.35 | 11.86 |
| Max temp. | Rainy 2 | 58 | 0.62 | 1.79 | -1.05 | 3.75 | 0.07 | 1.64 |
| | Dry 1 | 262 | 4.53 | 2.65 | 1.39 | 2.29 | 0.33 | 1.56 |
| | Rainy 1 | 168 | 2.56 | 5.00 | 5.51 | 2.13 | 1.71 | 2.01 |
| Min temp. | Rainy 2 | 58 | 4.31 | 8.51 | 8.27 | 6.50 | 11.94 | 14.50 |
| | Dry 1 | 262 | 8.93 | 9.64 | 4.80 | 6.37 | 6.58 | 8.02 |
| | Rainy 1 | 168 | 5.29 | 6.61 | 6.26 | 6.71 | 2.09 | 5.91 |

Source: Author's elaborations based on UDOM (2012) weather data.

[a] Weather indicators assigned to households based on proximity to synoptic station. The reported data are rainfall millimeters, number of rainy days and maximum and minimum temperature in a particular period, relative to the long-term mean, expressed as percentage deviation. Yearly indicators are the percentage deviations in the season preceding the interview, reported in the second column. The four years indicators are the percentage deviations of the average indicator in the period, relative to the long term mean. The long term mean for every indicator, in the season considered is based on all available observations of the relevant synoptic station in the period 1960-1990 for rainfalls and number of rainy days and 1980-2010 for maximum and minimum temperatures.

**Table A.3** Test for differences in means for LSMS Uganda full panel and study sample. Year: 2005. [a]

| | Full dataset | | | 488 households sample | | | |
|---|---|---|---|---|---|---|---|
| | *N* | Mean | St.Dev. | *N* | Mean | St.Dev. | Difference |
| Sex Head HH[a] (Female=1) | 2248 | 0.2656 | 0.4417 | 488 | 0.2275 | 0.4196 | 0.0381** |
| Age Head HH | 2248 | 42.9057 | 15.6442 | 488 | 42.6783 | 15.2597 | 31.714 |
| Education head of the HH | | | | | | | |
| (1) Don't know | 2227 | 0.0004 | 0.0212 | 482 | 0.0000 | 0.0000 | 0.0004 |
| (2) Never attended school | 2227 | 0.2241 | 0.4171 | 482 | 0.1784 | 0.3833 | 0.0456** |
| (3) Some schooling but not completed primary | 2227 | 0.4432 | 0.4969 | 482 | 0.4502 | 0.4980 | -0.0070 |
| (4) Completed primary | 2227 | 0.1495 | 0.3567 | 482 | 0.1701 | 0.3761 | -0.0206 |
| (5) Completed post primary specialization | 2227 | 0.0296 | 0.1696 | 482 | 0.0353 | 0.1847 | -0.0056 |
| (6) Completed junior high | 2227 | 0.1172 | 0.3217 | 482 | 0.1286 | 0.3351 | -0.0114 |
| (7) Completed secondary | 2227 | 0.0063 | 0.0791 | 482 | 0.0062 | 0.0791 | 0.0001 |
| (8) Completed post secondary specialization | 2227 | 0.0265 | 0.1606 | 482 | 0.0290 | 0.1681 | -0.0026 |
| (9) Degree or above | 2227 | 0.0031 | 0.0560 | 482 | 0.0021 | 0.0455 | 0.0011 |
| Household size | 2248 | 5.5338 | 3.0451 | 488 | 5.8443 | 3.1349 | -0.3105** |
| Share of males 0-5 | 2248 | 0.1023 | 0.1347 | 488 | 0.1224 | 0.1439 | -0.0201*** |
| Share of males 6-11 | 2248 | 0.0798 | 0.1169 | 488 | 0.0823 | 0.1150 | -0.0025 |
| Share of males 12-17 | 2248 | 0.0683 | 0.1181 | 488 | 0.0728 | 0.1176 | -0.0045 |
| Share of males 18-64 | 2248 | 0.2236 | 0.2280 | 488 | 0.2125 | 0.2015 | 0.0110 |
| Share of males >65 | 2248 | 0.0245 | 0.1154 | 488 | 0.0231 | 0.1150 | 0.0014 |
| Share of females 0-5 | 2248 | 0.1041 | 0.1393 | 488 | 0.0982 | 0.1375 | 0.0059 |
| Share of females 6-11 | 2248 | 0.0794 | 0.1126 | 488 | 0.0745 | 0.1033 | 0.0049 |
| Share of females 12-17 | 2248 | 0.0663 | 0.1133 | 488 | 0.0598 | 0.1028 | 0.0065 |
| Share of females 18-64 | 2248 | 0.2235 | 0.1672 | 488 | 0.2303 | 0.1749 | -0.0069 |
| Share of females >65 | 2248 | 0.0283 | 0.1250 | 488 | 0.0240 | 0.1122 | 0.0043 |
| Own house (Yes=1) | 2247 | 0.8794 | 0.3257 | 488 | 0.8955 | 0.3062 | -0.0161 |
| No. Rooms | 2244 | 4.0321 | 2.3635 | 488 | 3.9918 | 2.3615 | 0.0403 |
| Own land (Yes=1) | 2010 | 3.5447 | 19.2189 | 446 | 5.7250 | 34.7912 | -2.1803* |
| Owned parcels size (Ha) | 2009 | 0.8417 | 0.3651 | 444 | 0.8581 | 0.3493 | -0.0164 |
| Ln monthly food consumption | 2242 | 11.0721 | 0.7202 | 488 | 11.1114 | 0.7128 | -0.0393 |
| Region 1 – Central | 2248 | 0.2464 | 0.4310 | 488 | 0.2725 | 0.4457 | -0.0261 |
| Region 2 – Eastern | 2248 | 0.2513 | 0.4339 | 488 | 0.2459 | 0.4311 | 0.0054 |
| Region 3 – Northern | 2248 | 0.2473 | 0.4326 | 488 | 0.2951 | 0.4565 | -0.0478** |
| Region 4 – Western | 2248 | 0.2549 | 0.4359 | 488 | 0.1865 | 0.3899 | 0.0684*** |

Source: Author's elaborations based on LSMS 2005/06-2009/10 households dataset.

[a] *, **, *** stand for level of significance at 10, 5 and 1% respectively.

**Table A.4** Distribution of synoptic stations across Uganda.

| Synoptic Station | Region | Longitude | Latitude | Altitude (meters) | Region Area (sq-Km) |
|---|---|---|---|---|---|
| Arua | Northern | 30.917 | 3.05 | 1280 | 85,391.7 |
| Gulu | | 32.283 | 2.783 | 1105 | |
| Kitgum | | 32.883 | 3.3 | 940 | |
| Lira | | 32.933 | 2.317 | 1110 | |
| Soroti | Eastern | 33.617 | 1.717 | 1132 | 39,478.8 |
| Tororo | | 34.167 | 0.683 | 1170 | |
| Jinja | | 33.183 | 0.45 | 1175 | |
| Kampala | Kampala | 32.633 | 0.25 | 1200 | 197.0 |
| Entebbe | Central w/o Kampala | 32.45 | 0.05 | 1155 | 61206.3 |
| Mbarara | Western | 30.683 | -0.6 | 1420 | 55,276.5 |
| Masindi | | 31.717 | 1.683 | 1147 | |
| Kasese | | 30.1 | 0.183 | 691 | |
| Kabale | | 29.983 | -1.25 | 1869 | |

Source: Author's calculations based on UDOM (2012) weather data.