REA | ITALIAN REVIEW OF AGRICULTURAL ECONOMICS

Firenze University Press
www.fupress.com/rea

Citation: Chiara Perelli, Giacomo Branca (2023). Food security beyond global warming: economic and policy perspectives from Uganda. *Italian Review of Agricultural Economics* 78(1): 17-32. DOI: 10.36253/rea-13583

Received: April 12, 2022

Revised: February 16, 2023

Accepted: February 23, 2023

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Corresponding Editor: Catia Zumpano

Research article

Food security beyond global warming: economic and policy perspectives from Uganda

Chiara Perelli*, Giacomo Branca

Department of Economics, Engineering, Society and Business Organization (DEIM), Tuscia University, Italy

*Corresponding author. E-mail: chiara.perelli@unitus.it

Abstract. Climate change has severe and pervasive impacts on natural systems and affects many aspects of human life. Increasing temperatures and alterations in the regimes of precipitations are adding pressure to global agricultural systems, which are already struggling to respond to expanding global demand for food. This directly translates into additional risks for poor people living in developing countries who already face precarious food security conditions. Focusing on the case of Uganda and using household data from the National Panel Survey merged with climatic data from the US National Oceanic and Atmospheric Administration, this paper explores the link between climate change and households' food insecurity. By applying a generalized ordered logit model, this work provides quantitative evidence about the impact of climate variability on food and nutrition security of clustered food consumption groups of smallholder farmers. Among the different socio-economic and environmental variables affecting the households' food security conditions, time and cross-sectional variations in the regime of precipitations play a crucial role. The results highlight that adaptation programmes aimed to reduce climate-induced food insecurity and improve coping abilities of rural communities should be site-specific and involve local communities with the aim of considering the specific risk exposure of the different agro-ecological areas.

Keywords: climate change, food and nutrition security, smallholder farming, generalized ordered regression, East Africa.

JEL codes: O13, P48, Q18.

HIGHLIGHTS:

- Climate-induced effects on food production risk exacerbating the already precarious livelihood and food security conditions of people living in Uganda.
- Socio-demographic characteristics as well as agricultural activities based on crop diversification and mixed crop-livestock systems have an important influence on household food security.
- Time and cross-sectional variations in precipitation regime play a crucial role.
- Policy interventions should be site-specific and based on the involvement of local communities.

1. INTRODUCTION

Climate change is widely recognized as the most important global environmental problem, the scientific evidence of which is unequivocal (Pachauri *et al.*, 2014). More than other major economic sectors, agriculture is particularly affected by weather alterations because it is climate-sensitive and highly dependent on natural equilibriums. Increases in temperatures, rainfall variations and growing frequency of extreme weather events are adding pressure to agricultural systems, which are already struggling to respond to increasing food demand due to global population growth (FAO, 2015). These risks are unevenly distributed and are usually greater for people living in developing countries because of their socio-economic vulnerability, poor agricultural production systems, and diffuse food insecurity (Collier *et al.*, 2008). This is particularly true in Sub-Saharan Africa, a region mostly exposed to climatic drivers whose alteration risks exacerbating the incidence and severity of extreme weather events (Collier *et al.*, 2008) with unavoidable consequences in terms of food and nutrition insecurity (Campbell *et al.*, 2016). In such vulnerable contexts, severe climate variations might affect food systems in several ways, ranging from direct effects on crop production, livestock and fisheries, to changes in markets, food prices and supply chain infrastructures (Gavagnin, Zolin, 2016). With reference to crop production, climate change simulations combining all Sub-Saharan regions suggest consistent negative effects on major cereal crops, with yield losses ranging from 2% for sorghum to 35% for wheat by 2050 (Ebi *et al.*, 2014). Climate shocks can also exacerbate livestock activities and grazing systems with the following negative impacts (Ebi *et al.*, 2014; Hopkins, Del Prado, 2007; Solomon *et al.*, 2007; Smucker, Wisner, 2008; Galvin, 2009; Thornton *et al.*, 2009; Dougill *et al.*, 2010; Ifejika Speranza, 2010): (i) rangeland degradation; (ii) increased variability in access to water; (iii) changes in land tenure; (iv) fragmentation of grazing areas; (iv) lack of opportunities to diversify livestock; (v) immigration of non-pastoralists into grazing areas; and (vi) changes in herbage quality and pasture composition. The negative impacts of climate change not only affect the food production, but also influence the farmers' income, food accessibility, food supply, and food security (Murniati, 2020).

Such climate-induced effects are projected to be particularly severe in East Africa due to the interactions of multiple factors such as a fast-growing population, extreme poverty, violent conflicts, poor infrastructure, overdependence on rainfed agriculture, and a severe food insecurity situation. Most rural households living in these regions face precarious livelihood conditions due to political and social instability, economic constraints and poor access to resources and infrastructures. Declining soil fertility, low crop yields and livestock losses caused by climatic variability risk exacerbating the already precarious livelihood and food security conditions of local people (Kristjanson *et al.*, 2012; Jayne *et al.*, 2006; Rufino *et al.*, 2013; Wichern *et al.*, 2017). In Eastern Africa, since 2005 the number of undernourished people has increased, reaching a peak of 133.1 million people in 2018, while the prevalence of severe and moderate food insecurity resulted respectively equal to 25.9% and 62.7% of the total population. (FAO, IFAD, UNICEF, WFP and WHO, 2019).

Focusing on the case of Uganda and using household data from the National Panel Survey merged with climatic data from the US National Oceanic and Atmospheric Administration, this paper explores the link existing between climate change and households' food insecurity. Specifically, it aims to answer the following research questions: (i) what are the main socio-economic and environmental factors affecting households' food security? (ii) to what extent can climate change affect food security?

Much research has been conducted with reference to the link existing between climate change and agricultural productivity (Chipanshi *et al.*, 2003; Knox *et al.*, 2012; Tingem *et al.*, 2008; Ayinde *et al.*, 2011; Nastis *et al.*, 2012; Calzadilla *et al.*, 2014; Bandara, Cai, 2014), but only a few of them analyse the direct and indirect impacts that climate change has on food security dimensions (Esham *et al.*, 2017), especially at household level. Furthermore, the majority of studies analyse climate change effects on food security considering just the perception of farmers towards weather alterations as an indicator of the on-going climate change (Mekonnen *et al.*, 2021). However, this approach appears limited since it is strongly connected to personal opinions which do not always reflect the actual weather modifications. Hence, the main goal of this study is to provide a more objective perspective by empirically assessing the role played by temperature and precipitation changes on food security. For that purpose, indicators of climate variability were introduced into a rigorous econometric model applied using national household's data from different agro-ecological zones. The robust results obtained could contribute to the existing literature and can be used to define and adjust policies aimed at reducing food insecurity and vulnerability in developing contexts.

The paper is structured as follows. Section 2 provides a description of climate change dynamics in the study area. Section 3 illustrates the data used in the analysis. Section 4 presents the conceptual framework and methodologies applied. Results are described and discussed in Section 5. Conclusions and policy implications are provided in Section 6.

2. DESCRIPTION OF CLIMATE CHANGE DYNAMICS AND IMPACTS IN UGANDA

The study analyses the case study of Uganda, a landlocked country located in the Eastern part of the African continent. It is characterized by diverse climate patterns due to the country's unique biophysical features. Rainfall varies throughout the country, with patterns ranging from "bimodal" (with a first rainy season occurring from March to June and a second from September to December) to "unimodal" (with a unique rainy season occurring from March to October). This last climatic condition characterizes the northern region, which forms one quarter of the country and lies outside the tropical belt (World Bank, 2021). Such patterns are also influenced by the action of El Niño Southern Oscillation phenomena, which are principal driving forces of intra-annual to inter-annual rainfall variability. These natural equilibriums are however altered by the on-going global warming. Time series analyses show that average temperatures in Uganda have increased by 1.3 °C since the 1960s, with hot days increasing by an average of 8-6 days per month (World Bank, 2021). Uganda has also experienced statistically significant changes in annual precipitations. Since the 1960s, seasonal rainfall has been characterized by decreases of 6.0 mm per month, per decade (McSweeney, Lizcane, 2010). However, the incidence of such changes in precipitation patterns varies within the country. Specifically, over the past 20 years, western, northern and north-eastern regions have experienced an increase in the frequency and magnitude of long-lasting extreme events like drought periods and flooding (World Bank, 2021).

Considering the high-emission scenario, monthly temperature in Uganda is expected to increase by 1.8 °C for the 2050s and by 3.7 °C by the 2090s. At the same time, the percentage of rainfall occurring from heavy precipitation events is anticipated to increase, which would also escalate the risk of disasters such as floods and landslides (USAID, 2012).

All these projected changes risk further compromising the productivity of the agricultural sector, which plays a crucial role in Uganda's food security and economic prosperity. Projected heat stresses, reduced water availability and watershed re-charge and increased frequency and intensity of extreme weather events are likely to contribute to reductions in the national production of food crops such as cassava, maize and groundnuts. More in depth, water stresses lead to shortening of the crop reproduction stage, reduction in leaf area and closure of stomata to minimize water loss, reducing crop yields (Adhikari *et al.*, 2015). Increased heat and water scarcity can also alter the occurrence and distribution of pests, and stress livestock and fishery activities, resulting in disrupted livelihoods and significant economic losses (Walter *et al.*, 2010; Kimaro, 2013; Bett, 2017; Rahimi, 2021).

Such unstable agricultural and food production may have negative implications not only in terms of food availability and access, but also with regard to food utilization, by reducing the variety and number of foods used as micronutrients' sources, influencing decisions to grow crops of different nutritional value, and/or altering the nutritional content of specific foods (Burke, Lobell, 2010). Moreover, climate change may increase the incidence of infectious diseases thereby increasing the caloric requirements of affected populations, reducing the body's absorption and utilization of essential nutrients, and then increasing the overall nutrition needs (World Food Programme, 2012).

All the aforementioned climate-induced consequences risk exacerbating the already precarious food security conditions of people living in Uganda. Indeed, despite the majority of the population in this country having an acceptable food consumption score, 17.6 million people are undernourished, while about 12% continue to be chronically food insecure, don't have an adequate energy intake and can't afford a diversified diet (FAO, IFAD, UNICEF, WFP and WHO, 2019).

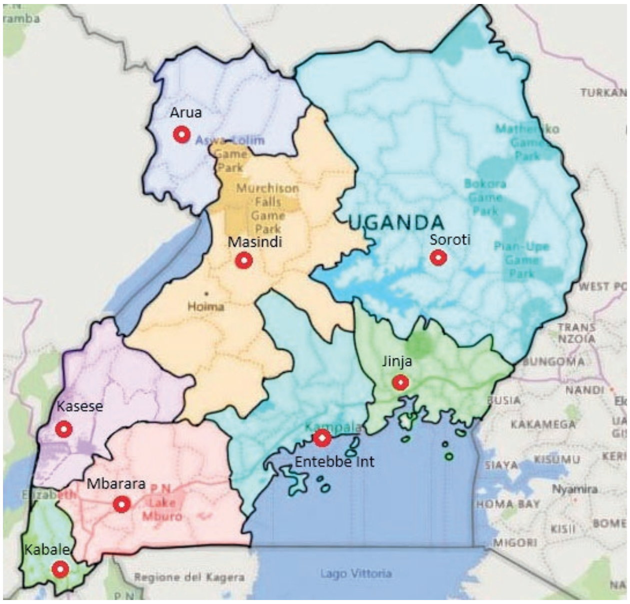
3. DATA AND STUDY AREA

For the purpose of this study, we used a combination of household and climatic data obtained from two different sources. Household data were extracted from the Uganda National Panel Survey (UNPS), referred to the 2013/2014 cropping seasons[1]. They were collected from a sample of 3,123 households equally distributed in 101 districts and covering all the country regions: Central, Eastern, Western and Northern (Uganda Bureau of Statistics, 2014).

Using the UNPS data, we selected demographic and socio-economic information including: household

[1] The UNPS data were collected in Uganda from September 2013 to August 2014, as part of an household survey commenced in 2009/2010 and supported financially and technically by the Government of Netherlands and the World Bank Living Standard Measurement Study – Integrated Surveys on Agriculture (LSMS – ISA) project (UBOS, 2014).

Figure 1. Geographical distribution of districts and weather stations in Uganda.



members' demographics (i.e. age, gender, marital status, level of education or formal schooling, health); life conditions (i.e. household incomes, welfare conditions and food security); and agricultural activities (i.e. region, crop land area, crop and livestock inputs). With the aim of computing and introducing climatic variables in the analysis (i.e. median absolute deviation of temperature and precipitation), historical data of rainfall and temperature made available from the US National Oceanic and Atmospheric Administration (NOAA) were also used. The following weather stations have been considered: (i) Arua; (ii) Entebbe International; (iii) Jinja; (iv) Kabale; (v) Kasese; (vi) Masindi; (vii) Mbarara; and (viii) Soroti.

The geographical distribution of sampled districts and weather stations is shown in Figure 1.

4. CONCEPTUAL FRAMEWORK AND METHODOLOGY

4.1. Conceptual framework

The academic and political debate surrounding food security measurement is ongoing, due to its multidimensional aspects (Cafiero *et al.*, 2014; Bertelli, 2019). Several indexes are defined to capture part of this multidimensionality through food supply quantification at country level, as well as food consumption characterization and nutritional outcome measurement at household or individual level. Cafiero *et al.* (2014) proposed a framework to classify food security indicators in the following two categories: (i) indicators based on the concept of food consumption adequacy (e.g. Prevalence of undernourishment, Household Dietary Diversity Score and Food Consumption Score); and (ii) indicators based on experience-based food security scales (e.g. Household Food Security Survey Module, Household Food Insecurity Access Scale, Latin American and Caribbean Food Security Scale, and the Food Insecurity Experience Scale).

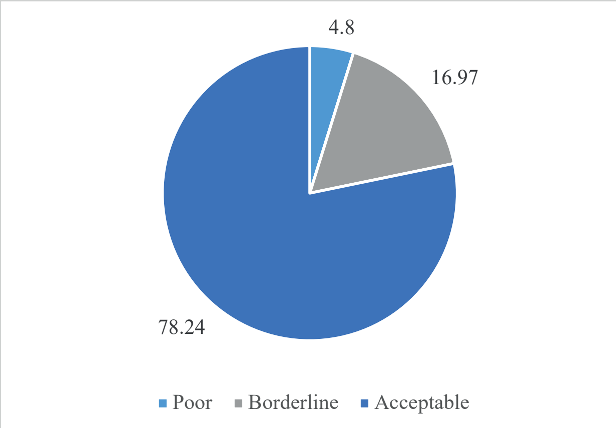
For the purpose of this study, we decided to adopt an approach based on food consumption adequacy. Specifically, we selected the Food Consumption Score (FCS) as a proxy for the households' food security level because it allowed us to capture both quality (dietary diversity) and quantity (number of foods consumed) perspectives of nutrition security. FCS is defined as «the frequency-weighted diet diversity score calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey» (World Food Programme, 2008). It aims to capture aspects such as dietary diversity, frequency of food group consumption, and nutritional value of food (Leroy *et al.*, 2015). Such an indicator allows food security to be summarized by summarizing the three aspects reflected in the food frequency data: (i) dietary diversity; (ii) frequency of food group consumption; and (iii) nutrition value of food (Cafiero *et al.*, 2014).

We computed the FCS following the Food Consumption Analysis guidelines published by the World Food Programme (2008): (i) we considered a list of 62 foods that were indicated by farmers as being consumed in the previous 7 days; (ii) we classified food items in 9 groups; (iii) we computed the score by multiplying each food group frequency by related food-group weights (reflecting the caloric density and macronutrient content of foods) and then summing these scores into one composite score; (iv) we categorized the selected households as having a poor (0-28), borderline (28.5-42), or acceptable (< 42) food consumption profile[2].

Following this procedure, we obtained the food consumption groups shown in Figure 2. Despite most households (about 78%) showing an acceptable food consumption level, about 17 and 5% were characterized as borderline and poor respectively. This estimate confirms the results obtained by the FAO (2016), which identified

[2] The thresholds adopted to classify sampled households in these food consumption clusters were set according to assumptions of dietary patterns. In particular, since the households in the sample were found to have a high frequency of sugar and oil consumption (mean consumption of which was equal to more than 7 times per week), it was necessary to use the alternative cut-offs of 28 and 42.

Figure 2. Food consumption profile of respondent households (% of households).



24.8% of the total population as being unable to meet their minimum dietary energy requirements. Such food group clustering was used in the study to build a three-category dependent variable.

4.2. Econometric model

An ordered logit model was initially considered to identify factors affecting the household level of dietary diversity, food frequency and relative nutrition value. This econometric model is widely used in the literature to perform analyses where the dependent variable is represented by the food consumption score (Lokosang *et al.*, 2011; Aweke *et al.*, 2020; Hilemelekot *et al.*, 2021). It is commonly presented as a latent variable model where *y* is defined as the observed ordinal variable and y* as a continuous unmeasured latent variable ranging from -∞ to ∞ and having various thresholds points.

In this study, the continuous latent variable y* is equal to:

$$y^*_i = x'_i\beta + \varepsilon_i \quad (1)$$

where *i* is the household observed, *x* is the set of socio-demographic, economic and climate – related independent variables (see Table 1), β is the kx1 vector of unknown parameters and ε is the random error. The observed dependent representing the food consumption score y is determined by the following model:

$y_i = 1$ if $y^*_i \le \omega_1$ *Poor food consumption profile*
$y_i = 2$ if $\omega_1 \le y^*_i \le \omega_2$ *Borderline food consumption profile*
$y_i = 3$ if $y^*_i \ge \omega_2$ *Acceptable food consumption profile*

where ω_k, or cut-points, are unknown parameters to be assessed. Estimates are obtained by maximizing the log likelihood function for each category of y. In our case as the dependent variable takes on the value 1,2 and 3, there are two cut-points ω_1 and ω_2.

The sign of the parameters **β** can be immediately interpreted as determining whether the latent variable (y*) increases or decreases with the regressors. If β_i is positive, an increase in x_i (or, in the case of dummy variable, the presence of the specific characteristic x_i) increases the probability of being in the highest category (acceptable food consumption profile) and decreases the probability of being in the lowest categories (poor and borderline food consumption profiles) (Cameron and Trivedi, 2010).

In the ordered regression model, both coefficients and cut-points are usually estimated using maximum likelihood (Williams, 2006). After this estimation it is possible to identify the underlying probability that y will take on a specific value (Scott Long & Frees, 2014):

$$\Pr(y_i = k) = \Pr(\omega_k \le y^* \le \omega_{k+1}) \quad (2)$$

where

$$P(y_i^* > \omega_k) = \frac{\exp(aX_i' - k_j)}{1+\exp(aX_i' - k_j)} \qquad k = 1,2 \quad (3)$$

Based on the parallel line assumption, in the ordered logit model, the relationship between any pairs outcome category is assumed to be equal. Specifically, the thresholds have to be fixed for all explanatory variables. However, this assumption resulted violated in the ordered logit model implemented for the purpose of this study (the Brant test of parallel regression assumption resulted statistically significant). To address this problem and avoid biased estimates, a generalized ordered logit/partial proportional odds model was used.

By applying this econometric model, the probability of having y* larger than a specific threshold can be specified as (Williams, 2006):

$$P(y_i^* > \omega_k) = \frac{\exp(X_{1i}' b_1 + X_{2i}' b_{2j} - k_j)}{1+\exp(X_{1i}' b_1 + X_{2i}' b_{2j} - k_j)} \qquad k=1,2 \quad (4)$$

where b_1 is a vector of parameters of variables that follow the parallel line assumption (X_{1i}) and b_{2j} is a vector of parameters of variables that vary across different food consumption profiles (X_{2i}).

In order to indicate how different factors affect the response variable on the underlying scale, marginal effects were estimated as follows:

$$\frac{\partial \Pr(y_i=j)}{\partial x_w} = \{F'(\alpha_{j-1} - x'_i\beta) - (\alpha_j - x'_i\beta)\} - \beta_i \quad (5)$$

This provides information on the impact that changes may have on the average probability of having some food consumption profile.

5. RESULTS AND DISCUSSIONS

5.1. Description of variables

The independent variables used in the econometric model are described in Table 1. Households' demographics provide information about family members as well as gender, age, marital status, and education level of the household head. Descriptive statistics indicate that sampled smallholder farmers are mostly middle-aged, male, monogamous and with (at least) a primary education level.

A second variables group includes physical and economic assets such as: (i) income; (ii) size of cropland used; (iii) livestock ownership (measured using tropical livestock units[3]); (iv) use of organic and chemical agricultural inputs; (v) use of improved varieties; and (vi) crop diversification. The introduction of this last variable is based on the assumption that an increasing number of cash and food crops can have both direct and indirect impacts on the food security status of the household. Indeed, while an increase in the production of cash crops can determine an increase in the agricultural income of the household (economic food access), a greater variety of food crops can directly affect the diversification of the diet adopted by family members. In the construction of the variable, we tried to represent the wide range of agricultural products produced in Uganda such as coffee, tea, sugar, cotton, tobacco, plantains, corn, beans, cassava, sweet potatoes, millet, sorghum and groundnuts.

A third variables group considers environmental and climatic factors such as household geographical location and climate. Since in developing countries like Uganda meteorological stations are sparse and climate data at micro-level are scarce (Demeke *et al.*, 2011), the study uses both subjective and objective measures of climate variability. Specifically, the subjective indicator considers households' perception of extremes such as drought periods and flooding events occurred in the preceding agricultural season. Furthermore, we included in the analysis the observed rainfall data from nearby weather stations illustrated in Section 3. Finally, considering long-term climate variability, the Median Absolute Deviation[4] (MAD) of both temperature and precipitations was computed and included in the analysis with the aim of detecting the riskiness of temperature and rainfall variations. This indicator represents a measure of statistical dispersion based on the absolute deviations from the median of the distribution (Howell, 2014).

5.2. Interaction effects and regional comparisons

With the aim of conducting more in-depth analyses on the effects climate variations have on household's food security, we defined interaction terms[5] combining the regional location of households with time and cross-sectional climatic variations. Given the strong variability existing among the different geographical regions in terms of timing and regularity of rainfall patterns, and taking into consideration the crucial role water availability has for rural farms, we decided to build interaction terms by involving climatic variables connected with precipitations. Using analysis of variance (ANOVA) to detect the existence and significance of the interactions, we defined the interaction terms involving the regional location of the households with median absolute deviation of precipitation as well as the average precipitation level occurred in the last agricultural season.

5.3. Results

The results of the econometric analysis are shown in Table 2.

a) Households' demographics

With reference to the gender of households' head, results show that an acceptable food security profile is negatively connected with male headed households (the probability of having an acceptable food consumption profile decreases by 7.4%). This result seems not to be in line with part of the literature that considers female-headed households among the hardest hit by hunger (Jones *et al.*, 2017; Kassie *et al.*, 2014; Tibesigwa, Visser, 2016). In contrast, a growing body of evidence in international development found no significant differences in food security condition between male and female-headed households (Mallick, Rafi, 2010). In this regard, our results provide support to the literature that considers the

[3] Tropical Livestock Units (TLU) are computed converting to a common unit the number of livestock heads of different animal species. Conversion factors used are: cattle = 0.7; sheep= 0.1; pigs=0.2; chickens=0.01 (FAO, 2009).

[4] In the presence of distributions with heavier tails, MAD is a robust statistic and is more efficient than variance or standard deviation, being more resilient to outliers in the dataset.

[5] An interaction describes non-causal associations and occurs when an independent variable has a different effect on the outcome depending on the value of another independent variable (Cox, 1984).

Table 1. Independent variables: names, description and measurement units.

Variables name	Description	Mean	St.Dev.
Demographics			
Household head male	Dummy, =1 if the household head is male, 0 otherwise	0.690	0.463
Household head age	Age of household head in years	47.223	15.435
Household head marital status	Categorical variable illustrating the marital status of the household head,		
	=1 if household head is monogamous,	0.559	0.497
	=2 if household head is polygamous,	0.195	0.397
	=3 widows or not married	0.246	0.431
Household head educated	Dummy, =1 if the household head attended at least primary school, 0 otherwise	0.832	0.374
Family members	Number of household members	6.033	2.940
Physical and economic assets			
Cropland area	Size of land under cultivation in acres	3.130	3.964
Organic fertilizers	Dummy, =1 if the household uses organic fertilizers, 0 otherwise	0.117	0.322
Chemical fertilizers	Dummy, =1 if the household uses chemical fertilizers, 0 otherwise	0.061	0.239
Pesticides	Dummy, =1 if the household uses pesticides, 0 otherwise	0.142	0.349
Improved varieties	Dummy, =1 if the household uses improved varieties, 0 otherwise	0.224	0.417
Livestock	Tropical Livestock Units (TLU)	1.197	2.644
Crop diversification	Number of crops cultivated in the last agricultural season	4.970	2.644
Income	Amount of family income (USD)	22.992	216.045
Environmental and climatic context			
Geographical region	Categorical variable illustrating the geographical location of the household,		
	=1 if household is located in the Western region,	0.258	0.438
	=2 if household is located in the Central region,	0.219	0.414
	=3 if household is located in the Eastern region,	0.254	0.436
	=4 if household is located in the Northern region	0.268	0.443
Urban area	Dummy, =1 if household is in an urban area, 0 otherwise	0.136	0.343
Variability of precipitation	Mean Absolute Deviation of precipitation considering the long-term period 1995-2013 (mm)	26.65	24.659
Variability of temperature	Mean Absolute Deviation of temperatures considering the long-term period 1995-2013 (°C)	0.717	0.581
Mean rainfall	Average district rainfall occurred in 2013 and obtained from the nearby weather station (mm)	43.599	47.681
Perception of erratic rainfall	Dummy, =1 if farmers perceived drought events in the last 12 months, 0 otherwise	0.282	0.450

increasing importance of women at household and community levels as a significant determinant of better agricultural and development outcomes, including increases in farm productivity, progresses in family nutrition and improvements in the level of child undernourishment and child mortality (Farnwortha, Colversonb, 2015; Scanlan, 2004; Sraboni *et al.*, 2014; Zhou *et al.*, 2019).

With reference to the marital status, households whose head is monogamous or polygamous are more likely to be food secure than households managed by individuals who are widowed or not married. This is probably due to the precarious socio-economic conditions underlying this last status, which is more common among female-headed households (Verma, 2001).

We found that households managed by an educated head are characterized by a higher level of food security (the probability of having an acceptable food consumption profile increases by 8.8 percentage points). This result is in line with the literature and confirms that education plays an important role in ensuring food security and improving nutritional status (Keenan *et al.*, 2001; Smith *et al.*, 2017). Educated farmers utilize their knowledge to improve agricultural production and seek alternative livelihood opportunities with the aim of enhancing its resilience to climate change and improving food systems (Mwaura, 2017).

The increasing number of family members is positively associated with a high level of food security. Since family size is considered a proxy for labour availability, this result confirms that large families whose members work in the field could benefit from an increase in total agricultural and food production. On the other hand, a large number of family members could be linked to different sources of income that can support the household economic access to food.

b) Households' physical and economic assets

Size of plots available (expressed in acres) is found to be related to a high food security level. The avail-

Table 2. Results of generalized ordered logit regression model.

Food Consumption Score (Acceptable vs. Poor – Borderline)	Coeff. (Std. Err.)	Marginal Effects (Std. Err.)		
		Poor	Borderline	Acceptable
Household's demographics				
Household head male	-0.515***	0.018***	0.056***	-0.074***
	(0.174)	(0.006)	(0.019)	(0.025)
Household head age	0.005	0.000	-0.001	0.001
	(0.004)	(0.000)	(0.000)	(0.001)
Household head monogamous	0.509***	-0.018***	-0.056***	0.074***
	(0.189)	(0.007)	(0.021)	(0.027)
Household head polygamous	0.431**	-0.015**	-0.047**	0.062**
	(0.197)	(0.007)	(0.021)	(0.028)
Household head educated	0.610***	-0.022***	-0.067***	0.088***
	(0.157)	(0.006)	(0.017)	(0.022)
Family members	0.060***	-0.002**	-0.007***	0.009***
	(0.023)	(0.001)	(0.002)	(0.003)
Household's physical and economic assets				
Cropland area	0.056*	-0.002*	-0.006**	0.008**
	(0.029)	(0.001)	(0.003)	(0.004)
Organic fertilizers	0.246	-0.009	-0.027	0.035
	(0.240)	(0.009)	(0.026)	(0.035)
Chemical fertilizers	1.107***	-0.039***	-0,121***	0.160***
	(0.413)	(0.015)	(0.045)	(0.060)
Pesticides	0.005	0.000	-0.001	0.001
	(0.201)	(0.007)	(0.022)	(0.029)
Improved varieties	0.400**	-0.014**	-0.044**	0.058**
	(0.163)	(0.006)	(0.018)	(0.024)
Livestock	0.305***	-0.011***	-0.033***	0.044***
	(0.063)	(0.002)	(0.007)	(0.009)
Crop diversification	0.059**	-0.002**	-0,006**	0.008**
	(0.028)	(0.001)	(0.003)	(0.004)
Income	0.001	0.000	0.000	0.000
	(0.001)	(0.000)	(0.000)	(0.000)
Environmental and climatic context				
Eastern region	-1.333**	-0.065*	-0.066	0.131***
	(0.581)	(0.034)	(0.064)	(0.064)
Central region	-0.625	-0.063*	-0.048	0.112***
	(0.399)	(0.033)	(0.046)	(0.039)
Northern region	-1.413***	-0.039	0.017	0.022
	(0.461)	(0,035)	(0.047)	(0.045)
Urban area	0.171	-0.006	-0.019	0.025
	(0.177)	(0.006)	(0.019)	(0.026)
Variability of temperature	-0.110	0.004	0.012	-0.016
	(0.164)	(0.006)	(0.018)	(0.024)
Perception of erratic rainfall	-0.002	0.000	0.000	0.000
	(0.136)	(0.005)	(0.015)	(0.020)
Region # Variability of precipitation				
Western region # Variability of precipitation	-0.004	-	-	-
	(0.020)	-	-	-

Food Consumption Score (Acceptable vs. Poor – Borderline)	Coeff. (Std. Err.)	Marginal Effects (Std. Err.)		
		Poor	Borderline	Acceptable
Eastern region # Variability of precipitation	-0.065	-	-	-
	(0.094)	-	-	-
Central region # Variability of precipitation	0.001	-	-	-
	(0.021)	-	-	-
Northern region # Variability of precipitation	-0.032**	-	-	-
	(0.026)	-	-	-
Region # Mean rainfall		-	-	-
		-	-	-
Western region # Mean rainfall	-0.027**	-	-	-
	(0.012)	-	-	-
Eastern region # Mean rainfall	0.103	-	-	-
	(0.153)	-	-	-
Central region # Mean rainfall	0.000	-	-	-
	(0.011)	-	-	-
Northern region # Mean rainfall	0.035***	-	-	-
	(0.017)	-	-	-
Cut point 1	2.517			
	(0.425)			
Cut point 2	-0.525			
	(0.414)			
LR $chi^2(27)$	236.53			
Prob > chi^2	0,0000			
Pseudo R^2	0.0930			
AIC[1]	2,367.67			

* significant at 10%, ** significant at 5%, *** significant at 1%.

[1] The Akaike information criterion (AIC) is a measure of fit that can be used to assess models. This measure uses the log-likelihood, but adds a penalizing term associated with the number of variables. Such a measure tries to balance the GOF versus the inclusion of variables in the model. The AIC is computed as follows: AIC = -2 x LL + 2p (Lord *et al.*, 2021).

ability of large plots of land probably allows farmers to expand their agricultural activities and increase food production. At the same time, an increasing number of crops cultivated in the field positively influences the food security status of the household. This result confirms that, in subsistence-oriented agricultural systems, a diverse agricultural portfolio allows a more diversified and nutritious diet. At the same time, in market-oriented households, an increase in the number of cash crops can determine higher agricultural incomes and then improvements in the economic food access.

The use of chemical fertilizers is found to be statistically significant and positively related with a high level of food security (with an increase in the probability of having an acceptable food security profile equal to 16%). Increased inorganic fertilizer use can lead to immediate and important increases in yields, especially in contexts where the adoption of traditional soil-fertility-maintenance techniques and organic fertilizers are often ineffective (Emmanuel *et al.*, 2016). For yields increase and fertility maintenance, chemical fertilizer application is considered the least-cost solution because of the limited supply and low nutrient levels of organic inputs (e.g. manure) and the limited crop residues available for mulching (Abdoulaye and Sanders, 2005)

Not surprisingly, the adoption of improved varieties is positively associated with a high level of food security, confirming that such agricultural technology can significantly increase household crop production and income, enhancing the household's chances of escaping poverty and food insecurity (Kassie *et al.*, 2011).

Livestock ownership is found to be positively related with high food security levels (with an increase of one TLU, the probability of having an acceptable food consumption profile increases by 4.4%). This result could be linked with the role of livestock activities, which represents a direct source of food (meat and milk) for the household members and are also an important source of income.

Furthermore, it is demonstrated that farmers specialized in crop production are more vulnerable than those in mixed crop-livestock systems (Tibesigwa *et al.*, 2015).

c) Environmental and climatic context

With reference to the environmental and climatic aspects, results show that households' food security conditions vary greatly across the country. Specifically, it is clear that the smallholder farms located in the Northern and Eastern regions have a lower probability to be food secure with respect to those located in the Western areas. This result confirms the most precarious conditions affecting rural communities living in such regions, which are characterized by food deficits due to unfavourable socio-economic and agro-ecological conditions. (Wichern *et al.*, 2017). The precarious situation of the Northern region is particularly evident considering also the climatic variables. Indeed, the parameter estimate for rainfall variability measured by the long-run median absolute deviation is found to be statistically significant and negatively associated with acceptable levels of food security of local households. The Northern region in general, and the Karamoja area in particular, is characterized by changeable and unreliable precipitations during the rainy season. Despite dry periods being considered a natural occurrence in these territories, long-term climatic trends show that their frequency and intensity seem to be exacerbated by the on-going climate change (Jordaan, 2015). The pivotal role of precipitation in this region is also confirmed by the variable representing the average rainfall occurred during the last agricultural season (during 2013). This variable was found to be statistically significant and positively connected with higher levels of food security. This result confirms that, in those territories with a semi-arid climate and prolonged drought periods, an increasing occurrence of precipitations can have positive effects on food production and then on food security (Demeke *et al.*, 2011). On the other hand, in the Western region of Uganda, the incidence of increasing rainfall occurred in 2013 was found to be statistically significant and negatively connected with acceptable food security levels. This result could be due to the incidence of the exceptional flooding event that occurred in May 2013, which is considered the worst since 1966 (Boyce *et al.*, 2016). Specifically, between the 1st and 5th of May 2013, heavy rains caused flooding that submerged 9 sub counties of Kasese District. Houses and infrastructures were destroyed, causing enormous damage to the livelihood conditions of local populations. This result confirms that, although in some cases a moderate increase in rainfall can bring benefits in terms of agricultural production and food security to areas with a predominantly arid climate, in some other contexts extreme precipitations and flooding events can cause enormous damage and adversely affect livelihood, health and food safety.

Although not statistically significant, the long-run temperature variability and its negative coefficient provide important insights. Specifically, an increase in the median absolute deviation of temperatures determines a decrease in the probability of being food secure equal to 1.6%. This result could be due to the fact that higher temperatures increase suitable conditions for crop diseases and pest infestations such as blast and bacterial leaf blight in rice, aflatoxin in maize, fungal and viral disease in banana, and coffee rust in coffee trees (World Bank, 2021). Such temperature-induced effects on food production appear however not significant and/or determinant with reference to the case study illustrated here.

The role of the climate variables illustrated above is also confirmed by the results obtained by dividing the sample according to geographical areas and using parallel econometric models (Appendix).

Surprisingly, the variable illustrating the perception of erratic rainfall appears to be not statistically significant. This result demonstrates that the perception of farmers can often be biased by a subjective perspective, which is not always adherent to the real weather situation. Using the farmers' perception as unique proxy for climate change is therefore not always effective and may lead to conclusions that are not entirely objective and in line with the reality.

6. CONCLUSIONS

This study provided quantitative evidence and conceptual insights of factors determining smallholders' food and nutrition security in a context characterized by increasing weather variability and climate change. The food consumption score index was used to define the households' food security profile, while a set of climatic variables were introduced in the analysis to detect the incidence that climate variability has on food and nutrition security.

Results confirm that socio-demographic aspects like gender, education and marital status of the household head, as well as family size, can have a determinant role in the food security level of households. Furthermore, variables mainly connected to agricultural productivity, such as the existence of mixed crop-livestock systems, the use of improved seeds and chemical fertilizers, and the adoption of agricultural systems based on crop diversification have a pivotal role in the improvement of household food and nutrition security. Among the environmental and climatic variables, variations in the regime of precipitations (both in a long- and short-term perspective) seems to be particularly important in the definition of food security. However, the effect of erratic rainfall seems to be strongly connected with the geographical location of the smallholder farms. Such results suggest that policy actions and adaptation programmes should be site-specific and designed taking into consideration the specific risk exposure of the different agro-ecological areas. In order to generate ad-hoc policies based more on the different exposure of Uganda regions to climate change, it will also be necessary to involve local communities, which are currently excluded from strategic decisions and policies formulation (Ampaire *et al.*, 2017). Furthermore, the communication between national, district and community levels should be improved to allow for greater responsiveness to local needs, climate emergencies and food crises.

To address food insecurity caused by climate variability and improve smallholder farm's resilience, it is also important to adopt an approach based on absorptive, adaptive and transformative capacity measures. Indeed, while the absorptive and adaptive capacity measures are based on the ability to minimize the exposure to shocks and make informed choices about strategies to adopt, transformative capacity actions are focused on system level conditions that are necessary to create long-term resilience (Ansah *et al.*, 2019).

Results obtained in the study also suggest that, at farm level, adaptation strategies may be achieved by implementing various sustainable practices such as: (i) crop diversification; (ii) inter-planting (mixed cropping); and (iii) planting drought-resilient crops (Al Dirani *et al.*, 2021).

Even if the paper focuses on the case of Uganda, the methods used could be easily replicated in other countries. Results could be of interest for the international community because they may apply to many developing countries with a similar structure of smallholder agriculture and food and nutrition security problems, as well as climatic drivers and agriculture framework.

Limits to the validity of our results exist. Although the multidimensionality of the FCS allowed nutritional aspects of food security to be considered, it tends to overestimate the frequency of food secure units compared to some other food security indicators (Lovon, Mathiassen, 2014). This implies that the results could be biased by food insecurity incidence underestimation. Such an element is also confirmed by the low percentage representing households with a poor food consumption profile. Furthermore, dietary energy content is used in FCS to define food categories. However, the energy content of certain food combinations is not necessarily the best way to capture adequacy regarding nutritional value (Cafiero *et al.*, 2014). Further researches could therefore involve the use and comparison of different food security indicators in order to provide more evidence to support the thesis discussed in the present study.

REFERENCES

Abdoulaye T., Sanders J.H. (2005). Stages and determinants of fertilizer use in semiarid African agriculture: the Niger experience. *Agricultural economics*, 32(2): 167-179. DOI: https://doi.org/10.1111/j.0169-5150.2005.00011.x

Adger W.N., Huq S., Brown K., Conway D., Hulme M. (2003). Adaptation to climate change in the developing world. *Progress in development studies*, 3(3): 179-195. DOI: https://doi.org/10.1191/1464993403ps060oa

Adhikari U., Nejadhashemi A.P., Woznicki S.A. (2015). Climate change and eastern Africa: a review of impact on major crops. *Food and Energy Security*, 4(2): 110-132. DOI: https://doi.org/10.1002/fes3.61

Al Dirani A., Abebe G.K., Bahn R.A., Martiniello G., Bashour I. (2021). Exploring climate change adaptation practices and household food security in the Middle Eastern context: a case of small family farms in Central Bekaa, Lebanon. *Food Security*, 13(4): 1029-1047. DOI: 10.1007/s12571-021-01188-2

Ampaire E.L., Jassogne L., Providence H., Acosta M., Twyman J., Winowiecki L., Van Asten P. (2017). Institutional challenges to climate change adaptation: A case study on policy action gaps in Uganda. *Environmental Science & Policy*, 75: 81-90. DOI: https://doi.org/10.1016/j.envsci.2017.05.013

Ansah I.G.K., Gardebroek C., Ihle R. (2019). Resilience and household food security: a review of concepts, methodological approaches and empirical evidence. *Food Security*, 11(6): 1187-1203. DOI: https://doi.org/10.1007/s12571-019-00968-1

Aweke C.S., Lahiff E., Hassen J.Y. (2020). The contribution of agriculture to household dietary diversity: evidence from smallholders in East Hararghe, Ethiopia. *Food Security*, 12(3): 625-636. DOI: https://doi.org/10.1007/s12571-020-01027-w

Ayinde O.E., Muchie M., Olatunji G.B. (2011). Effect of climate change on agricultural productivity in Nigeria: a co-integration model approach. *Journal of Human Ecology*, 35(3): 189-194. DOI: https://doi.org/10.1080/09709274.2011.11906406

Bandara J.S., Cai Y. (2014). The impact of climate change on food crop productivity, food prices and food security in South Asia. *Economic Analysis and Policy*, 44(4): 451-465. DOI: https://doi.org/10.1016/j.eap.2014.09.005

Bertelli O. (2019). Food Security Measures in Sub-Saharan Africa. A Validation of the LSMS-ISA Scale. *Journal of African Economies,* 29(1): 90-120. DOI: https://doi.org/10.1093/jae/ejz011

Bett B., Kiunga P., Gachohi J., Sindato C., Mbotha D., Robinson T., Lindahl J., Grace D. (2017). Effects of climate change on the occurrence and distribution of livestock diseases. *Preventive veterinary medicine*, 137: 119-129. DOI: https://doi.org/10.1016/j.prevetmed.2016.11.019

Bita C.E., Gerats T. (2013). Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat stress-tolerant crops. *Frontiers in Plant Science*, 4: 273. DOI: https://doi.org/10.3389/fpls.2013.00273

Boyce R., Reyes R., Matte M., Ntaro M., Mulogo E., Metlay J.P., Band L., Siedner M.J. (2016). Severe flooding and malaria transmission in the western Ugandan Highlands: implications for disease control in an era of global climate change. *The Journal of infectious diseases*, 214(9): 1403-1410. DOI: 10.1093/infdis/jiw363

Branca G., Paolantonio A., Grewer U., Cavatassi R., Longwe A., Cattaneo A., Vetter S., Lipper L. (2016). Linking food security, climate change adaptation and mitigation: the case of sustainable land management in Malawi. *Italian Review of Agricultural Economics*, 71(1): 521-532. DOI: https://doi.org/10.13128/REA-18669

Burke M., Lobell D. (2010). Climate effects on food security: an overview. *Climate Change and Food Security,* 37: 13-30. DOI: https://doi.org/10.1007/978-90-481-2953-9_2

Cafiero C., Melgar-Quinonez H.R., Ballard T.J., Kepple A.W. (2014). Validity and reliability of food security measures. *Annals of the New York Academy of Sciences*, 1331(1): 230-248. DOI: 10.1111/nyas.12594

Calzadilla A., Zhu T., Rehdanz K., Tol R.S., Ringler C. (2014). Climate change and agriculture: Impacts and adaptation options in South Africa. *Water Resources and Economics*, 5: 24-48. DOI: https://doi.org/10.1016/j.wre.2014.03.001

Cameron A.C., Trivedi P.K. (2013). *Regression analysis of count data,* (Vol. 53). Cambridge university press.

Campbell B.M., Vermeulen S.J., Aggarwal P.K., Corner-Dolloff C., Girvetz E., Loboguerrero A.M., Ramirez-Villegas J., Rosenstock T., Sebastian L., Thornton P.K., Wollenberg E. (2016). Reducing risks to food security from climate change. *Global Food Security*, 11: 34-43. DOI: https://doi.org/10.1016/j.gfs.2016.06.002

Challinor A.J., Watson J., Lobell D.B., Howden S.M., Smith D.R., Chhetri N. (2014). A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 4(4): 287-291. DOI: https://doi.org/10.1038/nclimate2153

Chipanshi A.C., Chanda R., Totolo O. (2003). Vulnerability assessment of the maize and sorghum crops to climate change in Botswana. *Climatic change*, 61(3): 339-360. DOI: https://doi.org/10.1023/B:CLIM.0000004551.55871.eb

Collier P., Conway G., Venables T. (2008). Climate change and Africa. *Oxford Review of Economic Policy*, 24(2): 337-353. https://www.jstor.org/stable/23606648

Cook K.H., Vizy E.K. (2015). Detection and analysis of an amplified warming of the Sahara Desert. *Journal of Climate*, 28(16): 6560-6580. DOI: https://doi.org/10.1175/JCLI-D-14-00230.1

Cooper P.J.M., Dimes J., Rao K.P.C., Shapiro B., Shiferaw B., Twomlow S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment*, 126: 24-35. DOI: http://dx.doi.org/10.1016/j.agee.2008.01.007

Cox D.R. (1984). Interaction. *International Statistical Review/Revue Internationale de Statistique*, 52(1): 1-24. DOI: https://doi.org/10.2307/1403235

Demeke A.B., Keil A., Zeller M. (2011). Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia. *Climatic change*, 108(1): 185-206. DOI: https://doi.org/10.1007/s10584-010-9994-3

Dixon J., Gulliver A., Gibbon D. (2001). *Farming systems and poverty: improving farmers' livelihoods in a changing world.* Food Agriculture Organization of the United Nations and World Bank. Rome and Washington, D.C.

Lord D., Qin X., Geedipally S.R. (2021). *Highway Safety Analytics and Modeling*. Elsevier.

Dougill A.J., Fraser E.D.G., Reed M.S. (2010). Anticipating vulnerability to climate change in dryland pastoral systems: Using dynamic systems models for the Kalahari. *Ecology and Society*, 15(2): 17. https://www.jstor.org/stable/26268132

Ebi K.L., Ndebele-Murisa M.R., Newsham A.J., Schleyer (2014). Africa. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Emmanuel D., Owusu-Sekyere E., Owusu V., Jordaan H. (2016). Impact of agricultural extension service on adoption of chemical fertilizer: Implications for rice productivity and development in Ghana. *NJAS-Wageningen Journal of Life Sciences*, 79: 41-49. DOI: https://doi.org/10.1016/j.njas.2016.10.002

Esham M., Jacobs B., Rosairo H.S.R., Siddighi B.B. (2017). Climate change and food security: a Sri Lankan perspective. *Environment, Development and Sustainability*, 20: 1017-1036. DOI: https://doi.org/10.1007/s10668-017-9945-5

FAO (2015). *Climate change and food systems: global assessment and implications for food security and trade*. Food Agriculture Organization of the United Nations, Rome.

FAO (2016). *The FAO Hunger Map 2015*, World Food Program, Rome.

FAO (2018). *National gender profile of agriculture and rural livelihoods* – Uganda. Country Gender Assessment Series, Kampala.

FAO, IFAD, UNICEF, WFP, WHO (2019). *The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns*. Food Agriculture Organization of the United Nations, Rome.

Farnwortha C.R., Colversonb K.E. (2015). Building a gender-transformative extension and advisory facilitation system in Sub-Saharan Africa. *Journal of Gender. Agriculture and Food Security*, 1(1): 20-39. DOI: https://doi.org/10.22004/ag.econ.246040

Galvin K.A., (2009). Transitions: Pastoralists living with change. *Annual Review of Anthropology*, 38: 185-198. DOI: https://doi.org/10.1146/annurev-anthro-091908-164442

Gavagnin C., Zolin M.B. (2016). Weather events vs food security: an Asian perspective from the supply side. *Italian Review of Agricultural Economics*, 70(3): 247-269. DOI: https://doi.org/10.13128/REA-18164

Hepworth N., Goulden M. (2008). *Climate Change in Uganda: Understanding the implications and appraising the response*. LTS International, Edinburgh.

Hilemelekot F., Ayal D.Y., Ture K., Zeleke T.T. (2021). Climate change and variability adaptation strategies and their implications for household food Security: The case of Basona Worena District, North Shewa zone, Ethiopia. *Climate Services*, 24, 100269. DOI: https://doi.org/10.1016/j.cliser.2021.100269

Hopkins A., Del Prado A. (2007). Implications of climate change for grassland in Europe: impacts, adaptations and mitigation options: a review. *Grass and Forage Science*, 62(2): 118-126. DOI: https://doi.org/10.1111/j.1365-2494.2007.00575.x

Howell D.C. (2014). Median absolute deviation. *Wiley statsRef: statistics reference online*. DOI: https://doi.org/10.1002/9781118445112.stat06232

Ifejika Speranza C. (2010). Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni district, Kenya. *European Journal of Development Research*, 22(5): 623-642. DOI: https://doi.org/10.1057/ejdr.2010.39

Jayne T.S., Mather D., Mghenyi E. (2006). *Smallholder farming under increasingly difficult circumstances: Policy and public investment priorities for Africa*. MSU International Development Working Paper (Vol. 86). East Lansing: Michigan State University.

Jones N., Holmes R., Presler-Marshall E., Stavropoulou M. (2017). Transforming gender constraints in the agricultural sector: The potential of social protection programmes. *Global food security*, 12: 89-95. DOI: https://doi.org/10.1016/j.gfs.2016.09.004

Jordaan A.J. (2015). *Food security, drought and climate change: The case of Karamoja, Uganda*. Living Land. Ed. Griffiths, J. UNCCD and Tudor Rose. pp142-145.

Kassie M., Ndiritu S.W., Stage J. (2014). What determines gender inequality in household food security in Kenya? Application of exogenous switching treatment regression. *World Development*, 56: 153-171. DOI: https://doi.org/10.1016/j.worlddev.2013.10.025

Kassie M., Shiferaw B., Muricho G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, 39(10): 1784-1795. DOI: https://doi.org/10.1016/j.worlddev.2011.04.023

Keenan D.P., Olson C., Hersey J.C., Parmer S.M. (2001). Measures of food insecurity/security. *Journal of Nutrition Education*, 33: S49-S58. DOI: https://doi.org/10.1016/S1499-4046(06)60069-9

Kimaro E.G., Chibinga O.C. (2013). Potential impact of climate change on livestock production and health in East Africa: A review. *Livestock Research for Rural Development*, 25(7).

Knox J., Hess T., Daccache A., Wheeler T. (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environmental research letters*, 7(3), 034032. DOI: 10.1088/1748-9326/7/3/034032

Kristjanson P., Neufeldt H., Gassner A., Mango J., Kyazze F.B., Desta S., Sayula G., Thiede B., Förch W., Thornton P.K., Coe R. (2012). Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security*, 4(3): 381-397. DOI: https://doi.org/10.1007/s12571-012-0194-z.

Leroy J.L., Ruel M., Frongillo E.A., Harris J., Ballard T.J. (2015). Measuring the food access dimension of food security: a critical review and mapping of indicators. *Food and nutrition bulletin,* 36(2): 167-195. DOI: https://doi.org/10.1177/0379572115587274

Lokosang L.B., Ramroop S., Hendriks S.L. (2011). Establishing a robust technique for monitoring and early warning of food insecurity in post-conflict South Sudan using ordinal logistic regression. *Agrekon*, 50(4): 101-130. DOI: https://doi.org/10.1080/03031853.2011.617902

Lovon M., Mathiassen A. (2014). Are the World Food Programme's food consumption groups a good proxy for energy deficiency? *Food security,* 6(4): 461-470. DOI: https://doi.org/10.1007/s12571-014-0367-z

Mallick D., Rafi M. (2010). Are female-headed households more food insecure? Evidence from Bangladesh. *World Development,* 38(4): 593-605. DOI: https://doi.org/10.1016/j.worlddev.2009.11.004

McCarthy N., Lipper L., Mann W., Branca G., Capaldo J. (2012). Evaluating synergies and trade-offs among food security, development, and climate change. In: *Climate Change Mitigation and Agriculture*. Londra: Earthscan, ISBN: 978-0-203-14451-0

McSweeney C., New N., Lizcane G. (2010). *Uganda, UNDP Climate Change Country Profiles*. URL: https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Uganda/Uganda.hires.report.pdf

Mekonnen A., Tessema A., Ganewo Z., Haile A. (2021). Climate change impacts on household food security and farmers adaptation strategies. *Journal of Agriculture and Food Research*, 6, 100197. DOI: https://doi.org/10.1016/j.jafr.2021.100197

Murniati K. (2020). The impact of climate change on the household food security of upland rice farmers in Sidomulyo, Lampung Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, 21(8). DOI: https://doi.org/10.13057/biodiv/d210809

Mwaura G.M. (2017). Just Farming? Neoliberal Subjectivities and Agricultural Livelihoods among Educated Youth in Kenya. *Development and Change,* 48(6): 1310-1335. DOI: https://doi.org/10.1111/dech.12342.

Nastis S.A., Michailidis A., Chatzitheodoridis F. (2012). Climate change and agricultural productivity. *African journal of agricultural research*, 7(35): 4885-4893. DOI: 10.5897/AJAR11.2395

Okonya J.S., Syndikus K., Kroschel J. (2013). Farmers' perception of and coping strategies to climate change: Evidence from six Agro-Ecological zones of Uganda. *Journal of Agricultural Science*, 5(8): 252. DOI: http://dx.doi.org/10.5539/jas.v5n8p252

Pachauri R.K., Allen M.R., Barros V.R., Broome J., Cramer W., Christ R., Church J.A., Clarke L., Dahe Dahe Q., Dasqupta P., Dubash N.K., Edenhofer O., Elgizouli I., Field C.B., Forster P., Friedlingstein P., Fuglestvedt J., Gomez-Echeverri L., Hallegatte S., Hegerl G., Howden M., Jiang K., Jimenez Cisneros B., Kattsov V., Lee H., Mach K.J., Marotzke J., Mastrandrea M.D., Meyer L., Minx J., Mulugetta Y., O'Brien K., Oppenheimer M., Pereira J.J., Pichs-Madruga R., Plattner G.-K., Pörtner H.-O., Power S.B., Preston B., Ravindranath N.H., Reisinger A., Riahi K., Rusticucci M., Scholes R., Seyboth K., Sokona Y., Stavins R., Stocker T.F., Tschakert P., van Vuuren D., van Ypersele J.-P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change* (p. 151). IPCC.

Pender J., Jagger P., Nkonya E., Sserunkuuma D. (2004). Development pathways and land management in Uganda. *World Development*, 32(5): 767-792. DOI: https://doi.org/10.1016/j.worlddev.2003.11.003.

Pérez-Escamilla R., Gubert M.B., Rogers B., Hromi-Fiedler A. (2017). Food security measurement and governance: Assessment of the usefulness of diverse food insecurity indicators for policy makers. *Global Food Security,* 14: 96-104. DOI: https://doi.org/10.1016/j.gfs.2017.06.003

Pouw N.R. (2008). Food priorities and poverty: The case of smallholder farmers in rural Uganda. *Journal of African Economies*, 18(1): 113-152. DOI: https://doi.org/10.1093/jae/ejn010

Rahimi J., Mutua J.Y., Notenbaert A.M., Marshall K., Butterbach-Bahl K. (2021). Heat stress will detrimentally impact future livestock production in East Africa. *Nature Food*, 2(2): 88-96. DOI: https://doi.org/10.1038/s43016-021-00226-8

Roudier P., Sultan B., Quirion P., Berg A. (2011). The impact of future climate change on West African crop yields: what does the recent literature say? *Global environmental change*, 21(3): 1073-1083. DOI: https://doi.org/10.1016/j.gloenvcha.2011.04.007Get rights and content

Rufino M.C., Thornton P.K., Ng'ang'a S.K., Mutie I., Jones P.G., van Wijk M.T., Herrero M. (2013). Transitions in agro-pastoralist systems of East Africa: Impacts on food security and poverty. *Agriculture Ecosystems and Environment*, 179: 215-230. DOI: https://doi.org/10.1016/j.agee.2013.08.019.

Scanlan S.J. (2004). Women, food security, and development in less-industrialized societies: Contributions and challenges for the new century. *World Development*, 32(11): 1807-1829. DOI: https://doi.org/10.1016/j.worlddev.2004.05.009

Scott Long J., Freese J. (2014). *Regression models for categorical dependent variables using Stata.* Stata Press.

Smith M.D., Rabbitt M.P., Coleman-Jensen A. (2017). Who are the world's food insecure? New evidence from the Food and Agriculture Organization's Food Insecurity Experience Scale. *World Development*, 93: 402-412. DOI: https://doi.org/10.1016/j.worlddev.2017.01.006

Smucker T.A., Wisner B. (2008). Changing household responses to drought in Tharaka, Kenya: Vulnerability, persistence and challenge. Disasters, 32(2): 190-215. DOI: 10.1111/j.1467-7717.2007.01035.x

Solomon T.B., Snyman H.A., Smit G.N. (2007). Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management*, 82(4): 481-494. DOI: https://doi.org/10.1016/j.jenvman.2006.01.008

Spiegel M.R. (1973). *Statistica [Statistics].* Collana Schaum Teoria e Problemi, ETAS Libri.

Sraboni E., Malapit H.J., Quisumbing A.R., Ahmed A.U. (2014). Women's empowerment in agriculture: What role for food security in Bangladesh? *World Development,* 61: 11-52. DOI: https://doi.org/10.1016/j.worlddev.2014.03.025

Stone P. (2001). The effects of heat stress on cereal yield and quality. In: Basra A.S. (eds.) *Crop responses and adaptations to temperature stress,* 243-291. Food Products Press, Binghamton, NY.

Sultan B., Roudier P., Quirion P., Alhassane A., Muller B., Dingkuhn, M., Ciais P., Guimberteau M., Traore S., Baron C. (2013). Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa. *Environmental Research Letters*, 8(1), 014040. DOI: 10.1088/1748-9326/8/1/014040

Thornton P.K., van de Steeg J., Notenbaert A., Herrero M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems*, 101(3): 113-127. DOI: https://doi.org/10.1016/j.agsy.2009.05.002

Thornton P.K., Jones P.G., Ericksen P.J., Challinor A.J. (2011). Agriculture and food systems in sub-Saharan Africa in a 4°C+ world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369(1934): 117-136. DOI: https://doi.org/10.1098/rsta.2010.0246

Tibesigwa B., Visser M., Turpie J. (2015). The impact of climate change on net revenue and food adequacy of subsistence farming households in South Africa. *Environment and Development Economics*, 20(3): 327-353. DOI: https://doi.org/10.1017/S1355770X14000540

Tibesigwa B., Visser M. (2016). Assessing gender inequality in food security among small-holder farm households in urban and rural South Africa. *World Development,* 88: 33-49. DOI: https://doi.org/10.1016/j.worlddev.2016.07.008

Tingem M., Rivington M., Bellocchi G., Azam-Ali S., Colls J. (2008). Effects of climate change on crop production in Cameroon. Climate Research, 36(1): 65-77. DOI: https://doi.org/10.3354/cr00733

Uganda Bureau of Statistics (2014). *The Uganda National Panel Survey (UNPS) 2013/2014*. Basic Information Document. Kampala, Uganda.

Verma R. (2001). *Gender, land and livelihoods in East Africa: through farmers' eyes*. Idrc

Waithaka M., Nelson G.C., Thomas T.S., Kyotalimye M. (eds.) (2013). *East African agriculture and climate change: A comprehensive analysis*. Intl Food Policy Res Inst.

Wheeler T.R., Crauford P.Q., Ellis R.H., Porter J.R., Vara Prasad P.V (2000). Temperature variability and the yield of annual crops. *Agriculture, Ecosystems and Environment*, 82: 159-167. DOI: https://doi.org/10.1016/S0167-8809(00)00224-3

Wichern J., van Wijk M.T., Descheemaeker K., Frelat R., van Asten P.J., Giller K.E. (2017). Food availability and livelihood strategies among rural households across Uganda. *Food security*, 9(6): 1385-1403. DOI: https://doi.org/10.1007/s12571-017-0732-9

Williams R. (2006). Review of regression models for categorical dependent variables using Stata, by Long and Freese. *The Stata Journal*, 6(2): 273-278. DOI: https://doi.org/10.1177/1536867X0600600208

World Bank (2021). *Climate risk country profile: Uganda*. The World Bank Group. Washington, DC. US.

World Food Programme (2008). *Food consumption analysis: Calculation and use of the food consumption score in food security analysis*. United Nations Vulnerability Analysis and Mapping Branch. World Food Programme. Rome. Italy.

World Food Programme (2012). *Climate impacts on food security and nutrition*. A review of existing knowledge. World Food Programme. Rome. Italy.

World Food Programme (2016). *Food Security and Nutrition Assessment*. Karamoja, Uganda, July 2016. Analysis, Monitoring and Evaluation Unit. World Food Programme. Rome. Italy.

Wortmann C.S., Eledu C.A. (1999). *Uganda's agroecological zones: A guide for planners and policy makers.* In: C. I. d. A. T. (CIAT) (eds.), pp. 59. Kampala, Uganda.

Zhou D., Shah T., Ali S., Ahmad W., Din I.U., Ilyas A. (2019). Factors affecting household food security in rural northern hinterland of Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, 18(2): 201-210. DOI: https://doi.org/10.1016/j.jssas.2017.05.003

APPENDIX

Table A.1. Results of generalized ordered logit regression model, by region.

Food Consumption Score (Acceptable vs. Poor – Borderline)	Western		Eastern		Central		Northern	
Household's demographics								
Household head male	0.062		-0.282		-1.446	***	-0.675	***
Household head age	0.007		0.001		0.005		0.004	
Household head monogamous	0.368		0.321		0.717	*	0.655	**
+Household head polygamous	0.389		0.214		1.241	**	0.525	
Household head educated	0.315		0.212		0.954	**	1.041	***
Family members	-0.003		0.117	***	0.062		0.037	
Household's physical and economic assets								
Cropland area	0.097		0.162	**	0.119		-0.027	
Organic fertilizers	-0.174		0.384		0.321		13.087	
Chemical fertilizers	-0.126		2.296	**	1.233		12.919	
Pesticides	-0.304		0.397		-0.208		0.136	
Improved varieties	0.701		0.045		0.581		0.415	*
Livestock (TLU)	0.743	***	0.230	**	0.142		0.340	***
Crop diversification	0.032		-0.028		0.150	**	0.099	
Income	0.012		0.000		0.000		0.002	
Environmental and climatic context								
Urban area	0.415		0.414		-0.159		0.159	
Variability of precipitation	0.001		-0.640		-0.001		-0.027	*
Variability of temperature	0.030		-6.269		-0.046		-1.379	
Mean rainfall	-0.033	**	1.036		-0.001		0.010	***
Perception of erratic rainfall	0.276		-0.337		-0.354		0.213	
LR chi^2(27)	82.080		67.47		62.01		85.29	
Prob > chi^2	0.000		0.000		0.000		0.000	
Pseudo R^2	0.132		0.097		0.138		0.115	
AIC	583.39		670.61		429.06		700.31	

* significant at 10%, ** significant at 5%, *** significant at 1%.