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The Effect of Natural Disasters on Food Security in Sub-Saharan Africa

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Abstract

This study assesses the effects of natural disasters on food security in a sample of 40 sub-Saharan African countries. First, we assess the effects of natural disasters on the four dimensions of food security and secondly, we disaggregated natural disaster using the two dimensions that are most representative, namely hydrological and biological disasters. The regressions are based on the generalised method of moments on a dataset covering the period 2005-2020. Natural disasters are measured by the total number of people affected and food security by its characteristics: access, availability, use and sustainability. The results show that natural disasters increase the prevalence of undernourishment but reduce dependence on cereal imports. An increase in natural disasters by 1% increases the prevalence of undernourishment by the same proportion. As for import dependency, a 1% increase in natural disasters reduces dependency by 2.2%. The disaggregated effects show that hydrological disasters are more significant than biological disasters in impacting food security. Floods reduce the average energy supply adequacy but also dependence on cereal imports. Policy implications are discussed. The study complements the extant literature by assessing the effects of natural disasters on food security in a region where food insecurity is one of the worst in the world.

Keywords: Food security; Natural disasters; Sustainable development; Sub-Saharan Africa

1. Introduction

A recurrent global challenge as regards economic development is the increasing number of natural disasters and rapid climate change (Klomp et al., 2018). As a result of climate change, natural disasters have become increasingly frequent over the last few decades, especially in arid regions. In these regions, the agricultural sector is particularly linked to environmental degradation due to its direct dependence with and vulnerability to climatic hazards, which determine the frequency and intensity of natural disasters (Coronese et al., 2019; Baas et al., 2015; FAO, 2021). Thus, the possibility of food waste or water shortages, food security and crop losses are among the effects of climate change and natural catastrophes on socioeconomic systems (IPCC, 2014).

In this study, we empirically assess the effect of natural disasters on food security in a sample of 40 sub-Saharan African countries, using data from 2005 to 2020. Overall, natural disasters disrupt the entire economy especially, the industrial and construction sectors, households and businesses (De Haen et al., 2007). However, the agricultural sector remains the most vulnerable (Shah et al., 2022; Klomp et al., 2018; Baas et al., 2015). Natural disasters can affect food security through various channels. Reduced food production can make it harder for low-income households to maintain a healthy calorie intake and variety of diets, which could have a negative impact on nutition quality (Reddy et al., 2019). Drought episodes in the Sahel in the 1970s and 1980s had a direct impact on agricultural yields, water losses and livestock health, leading to a decline in food production and availability at country level (Klomp et al., 2018). By reducing the availability of water for irrigation, droughts can make land unsuitable for agricultural production and lead to shortages in drinking water supplies (De Haen et al., 2007).

The nexus between natural disasters and several facets of the economic system has been thoroughly investigated in the past (Skidmore and Toya, 2002; Felbermayr and Gröschl, 2014; Mu and Chen, 2016). Disasters also affect food security through future growth (Loayza et al., 2012; Skidmore and Toya, 2002). While natural disasters can have negative effects on growth, other authors have shown that the effect can be positive. For example, Hallegatte and Dumas (2009) have shown that certain disasters allow the introduction of new productive technologies to replace existing capital. This phenomenon generates positive results and economic gains referred to as 'productivity growth'. Loayza et al. (2012) have shown a positive impact of natural disasters on agricultural and industrial growth in developing countries when moderate natural disasters, including storms and floods, occur.

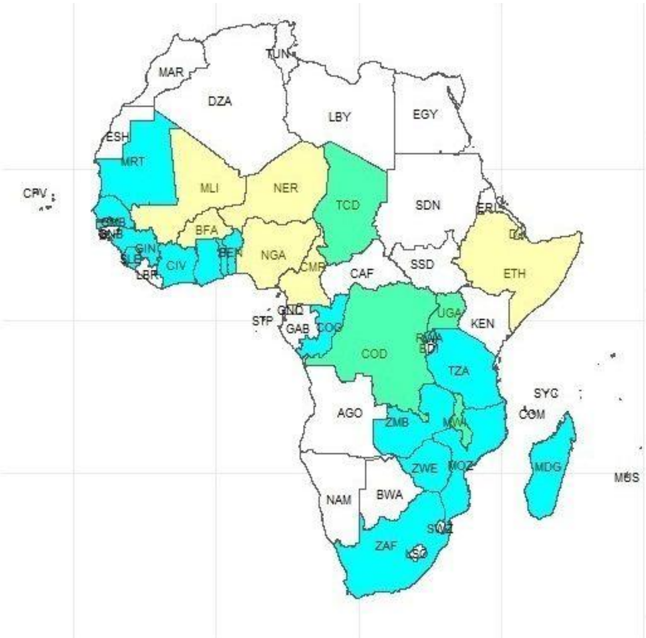
However, the impact of natural catastrophes on food security has only been examined by few studies. For example, drought as a recurrent natural hazard, can have an impact on water resources, including water quality, water supply, surface and groundwater availability and water resource management (Amin et al., 2016; FAO, 2021; Scanlon et al., 2022; van Loon et al., 2014). It has been established that extreme weather occurrences can compromise food security. In vulnerable areas, extreme weather events may negatively affect the availability and security of food (Silva et al., 2018). Furthermore, the output of crops, livestock and fisheries may be adversely affected by climate change (Wollenberg et al., 2016). According to Rosegrant and Cline (2003), there will likely be concerns about food security throughout the world in the 21st century because crop yields are insufficient in many areas because of a lack of infrastructure and research, as well as growing water scarcity. In this context, two research questions will be studied. First, what is the impact of natural disasters on the four dimensions of food security? Secondly, what is the impact of hydrological and biological disasters on the: adequacy of average dietary energy intake; prevalence of undernourishment; cereal import dependency rate and percentage of stunted children under 5 years? In the first research question, we focus on the impact of natural disasters in general on the indicators of the four dimensions of food security and in the second research question we disaggregated natural disasters into hydrological and biological disasters and even their impacts on the four dimensions of food security.

In analysing the effects of natural disasters brought by climate change on food security (which encompasses availability, access, stability and utilization) and thus, considering all four characteristics of food security that are essential for the success of any social protection policy, this study is distinct from previous works that have exclusively emphasized on one aspect of food security (Hameed et al, 2020; Fusco et al., 2020). Another contribution of our study is that, to our knowledge, there are no studies examining the link between natural disasters and food security for sub-Saharan African countries. The only existing study is Connolly-Boutin et al., (2018), which is limited to a descriptive and conceptual analysis only. The other studies focus on a single African country (Dembedza et al., 2023).

We explore the relationship between food security and natural disasters using the total population affected by disasters as a transmission channel. We also estimate the model by specifying natural disasters according to whether they are hydrological or biological. The Generalised Method of Moments (GMM) technique is adopted to deal with the endogeneity problems present in the model. Using several macroeconomic variables as controls, we empirically study the impact of natural disasters on food security in 40 sub-Saharan African countries between 2005 and 2020.

We focus on sub-Saharan African countries because they are often characterised by arid lands where the agricultural sector is particularly linked to environmental degradation and vulnerable to natural hazards and disasters (Sambo et al., 2024; Baas et al., 2015; FAO, 2021; see figure 1). In the case of drought, for example, sub-Saharan Africa has been hard hit in recent decades (Glantz, 1987; Benson and Clay, 1998). Over the period 2008-2018, more than 82% of all damage and losses caused by natural disasters such as droughts and floods were absorbed by agriculture (FAO, 2021). Meanwhile, according to the Emergency Events Database (EM-DAT), droughts affected 88.9 million people in ten African countries (Mali, Congo, Ethiopia, Chad, Nigeria, Niger, Cameroon, Burkina Faso, Uganda and Malawi) in 2022. After European heatwaves in 2022, the famine brought on by the drought in Uganda claimed 2,465 lives, making it the second most fatal disaster (Below et al., 2007). The work of Sambo et al. (2024) has shown that approximately 800 million people were chronically undernourished and 161 million children under 5 years of age were malnourished.

Figure 1: Flood and Drought in Sub-Saharan Africa (2022)



Flood	Drought

Code : Country name			
BEN	Benin	BFA	Burkina Faso
CAF	Central African Republic	CIV	Côte d'Ivoire
CMR	Cameroon	COG	Congo
COD	Democratic Republic of the Congo	CPV	Cape Verde
DJI	Djibouti	ETH	Ethiopia
GHA	Ghana	GIN	Guinea
GMB	Gambia	MDG	Madagascar
MLI	Mali	MOZ	Mozambique
MRT	Mauritania	MWI	Malawi
NER	Niger	NGA	Nigeria
RWA	Rwanda	SEN	Senegal
SLE	Sierra Leone	SML	Somalia
TCD	Chad	TGO	Togo
TZA	Tanzania	UGA	Uganda
ZAF	South Africa	ZMB	Zambia
ZWE	Zimbabwe		

Source: Authors

The rest of the study is organized in the following way. The corresponding literature is reviewed in Section 2 while Section 3 discusses the data and methodology. The empirical results are provided in Section 4. Section 5 concludes with implications

2. Literature review

The Emergency Events Database (EM-DAT 2022), defines a disaster as the accumulation of extensive losses linked to a natural hazard in many economic sectors that surpass the ability of the impacted population to recover. According to Israel et al. (2012), a natural disaster is defined as an occurrence that seriously impairs assets, production factors, output, employment, or consumption and interferes with the smooth operation of the economic system. Other authors extend the definition by advocating the need for a request for external assistance at national or international levels (CRED, 2017). At the same time, the definition of the concept of food security has evolved over time. The concept first appeared in the 1970s, against a backdrop of soaring cereal prices, according to the Committee on World Food Security (CFS). Another definition was adopted in 1974 at the World Food Conference, which emphasised availability. Subsequently, many studies have challenged the idea of food availability, following the example of Sen (1983), who focuses on malnutrition, and Burlingame et al. (2012) who are concerned with environmental sustainability. Around the year 2000, the Food and Agricultural Organisation (FAO) gave a comprehensive definition of food security, focusing on its four components: availability, access to food, supply stability and utilization. According to FAO (2006), food security is the ability of all people to always have physical, social, and economic access to adequate amounts of food that satisfy the dietary needs and preferences while also being safe and nutritious.

The literature on the link between natural disasters and food security characteristics is inconclusive. However, many authors agree that natural catastrophes and climate change stand as the main causes of hunger and therefore affect food security (Chitondo et al., 2024; Reddy 2019; Habiba et al., 2016). The recent experience of the 2021 global food crisis due to the intensification of major economic shocks and weather extremes ascertain that inhabitants in emerging countries that are already deficient in food are likely to be the most severely affected in the world (GRFC, 2022), due to their vulnerability. The work of De Haen (2008) has shown that most developing countries located in low-latitude regions are far more exposed to natural disasters than those in the northern hemisphere. Disasters occur when societies are vulnerable to this risk. The scale of a disaster is influenced by the severity of the hazardous incidence, a series of conditions resulting from processes of economic underdevelopment and the degree of vulnerability of the society affected (Palliyaguru et al., 2014; De Haen et al., 2007). These levels of vulnerability differ from one country to another, which explains why natural disasters of identical nature and intensity may have very different effects on different societies (Eshghi et al., 2008).

Since the agricultural sector is closely linked to the problem of food security, many authors have looked into the influence of these disasters on agriculture in order to analyse how natural disasters affect food security (Klomp et al., 2018; Israel et al., 2012; De Haen et al., 2007). Accordingly, water scarcity, land degradation and the loss of biodiversity, due to natural factors can limit the capacity for agriculture and severely impact food production (Chitondo et al., 2024). In low-income countries, floods and droughts are among the natural disasters that cause considerable damage by negatively impacting crops, storage, nutrition and food quality (Abass 2018; Loladze, 2014). Recent works have shown that yields of crops such as maize, wheat, sorghum and fruits have declined in Africa due to natural disasters leading to malnutrition and hunger (Sambo et al., 2024). In this vein, other authors stipulate that drought-related crop failures and increasing demand, which are the main causes of production losses and food price volatility, can on the one hand, significantly skew economic and physical access to food (which depends on resources and opportunities and sometimes state interventions) (Von Braun et al., 2012; Haile et al., 2017). On the other hand, reduced food production can affect the quality and quantity of nutrients absorbed (Delbiso et al., 2017). At the same time, these production losses, estimated in calories, hamper access to food and compromise food security (Reddy et al., 2019).

Concerning empirical works on the impacts of natural disasters on food security, some authors have focused on econometric and statistical methods to study the link between natural disasters and food security. Shah et al. (2022) use an ordered logit regression model to understand the determinants of household food security in the face of natural disasters in Bangladesh. According to the empirical findings, there is a higher likelihood of food insecurity among households who have experienced natural disaster shocks. In addition, Guo et al. (2019) explored the spatio-temporal variation of five main types of natural disasters (drought, flood, low temperature, storm and hail) using statistical tools such as social network analysis (SNA), Mann-Kendall (MK) and geographic information system (GIS) techniques. The results show that during the past four decades, drought and floods have been China's most severe natural disasters, accounting for over half of all grain production losses affecting the country's food security policy. Lastly, using a Bayesian linear regression model that can forecast food security in the Middle East, Hameed et al., (2020) investigate a casual association between drought and food security in the region. Their findings highlight the substantial effects that drought, livestock, population expansion, and agricultural goods have on Middle Eastern food security.

Other authors have focused on partial equilibrium techniques or computable general equilibrium models to simulate the effects of borne by catastrophes on food security. For instance, Israel et al., (2012) use a partial equilibrium model of 18 production sectors covering the agriculture, livestock and fisheries sub-sectors in the Philippines. Their results showed that floods do not have a significant impact on rice production losses, but typhoons do have a negative impact on rice production, thus affecting food security at the provincial level. Bandara et al., (2014) investigate how variations in crop productivity brought on by climate-related disasters affect food prices and food security in South Asia using a global dynamic computable general equilibrium model. Their findings show that changes in agricultural productivity brought on by natural catastrophes are likely to have a major detrimental effect on food production and prices in all of South Asia. The findings also sustain that food security issues are likely to arise in these countries.

3. Data and methodology

3.1. Data

We use a sample of 40 sub-Saharan African countries over the period 2005-2020 (see Table A1 for the list of countries). The frequency and number of countries included are determined by data availability constraints at the time of study. We draw our data mainly from three sources. Firstly, we consider the FAO data on food security. We take into account the four characteristics that cover food security, namely: availability, access, stability and use. In terms of availability, we use the indicator named "adequacy of average dietary energy intake (%) (average over 3 years)". The dietary energy intake is expressed as a proportion of the average dietary energy requirement by this indicator. In terms of access, we considered the indicator titled "prevalence of undernourishment (%) (average over 3 years)", which shows that the probability that an individual chosen at random from the population will not consume enough calories to cover his or her energy requirements for an active and healthy life.

The third characteristic is taken into account by the indicator named "cereal import dependency rate (%) (average over 3 years)", which indicates the proportion of the country's own production and imported share of the available national food supply in terms of cereals. Finally, we include the indicator titled "percentage of stunted children under 5 (modelled estimate) (%)", which is the percentage of stunted growth (the height for ages below -2 standard deviations away from the median of the Wealth Health Organization (WHO) child growth criteria) among children 0-59 months of age. For the measurement of natural disasters, we employed the emergency events database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED). CRED considers five types of natural disasters: hydrological, meteorological, geophysical, biological and climatological. The criteria of natural disaster are defined as an occurrence that satisfies one or more of the following four requirements: (i) a minimum of 10 fatalities; (ii) a minimum of 100 injuries, displacements, or other impacts; (iii) the declaration of a state of emergency; and (iv) the request for international assistance. For each country and each year, we add-up the disasters to obtain the sum total of affected people. This choice is justified, even though many natural disaster occurrences meet several criteria. Adopting the sum total of affected people eliminates a small proportion of natural catastrophes registered in the EM-DAT (2022). For the estimates, we used climatological, hydrological, and biological disasters because they are the most representative of the database for the countries under consideration. The use of these natural disaster data is consistent with previous and recent literature (Loayza et al., 2012; Rosselló, 2020).

In order to limit omission bias, we included control variables based on recent studies (Shah et al., 2022; Hameed et al., 2020) but also on data availability. We controlled for population growth because the high levels of undernourishment prevalence observed in Africa are attributable to increased food demand resulting from population growth (Hall et al., 2017). Molotoks et al. (2021) show that countries forecasting a reduction in population size enjoy lower food insecurity, while those predicting a swift rise in population size most often than not, tend to encounter worse effects on food security. To capture the effects on food security of economic factors, we control for the growth rate of GDP per capita in each country. A higher GDP per capita growth rate is expected to increase food security. In a study of East African countries, it is established by Ntiamoah et al. (2023) that in the long run, economic growth has a positive impact on food security. We include education to take account of the effect of human capital. Education is important for improving standard of living (Shen and Williamson, 1997). According to the endogenous growth theory, levels of human capital improve with increasing individual income (Barro and Lee, 2013). This will have a positive effect on food security in the country. Data on gross domestic product (GDP) per capita growth rate, population growth, education and access to sanitation come from World Bank open data.

The summary statistics for the variables are presented in Table A1 in the Appendix. The average economic growth rate of GDP per capita is 4.12%. However, the variability of the growth rate is high from one country to another. An even greater variability is observed for education, with an average of 103.9% and a standard deviation of 19.442%. The definition and sources of variables, summary statistics and correlation matrix are provided in Table A2, Table A3, Table A4, respectively. In other words, the list of sampled countries is disclosed in the Appendix Table A1 while Table A2 show the corresponding list of variables. The summary statistics is provided in Table A3 while the correlation matrix is disclosed in Table A4. It is important to clarify that no ethics approval and consent to participate is applicable to the study because the study relies on secondary data and hence, human and animals do not directly participate in the study.

3.2. Methodology

3.2.1. GMM specification

For the estimates, we used the generalised method of moments (GMM). The use of dynamic panel estimators following the Arellano-Bond (Arellano and Bond, 1991) and Arellano Bover/Blundell-Bond (Arellano and Bover, 1995; Blundell and Bond, 1998) strand of studies is becoming increasingly widespread in the empirical literature, as Roodman (2009) has pointed-out. The GMM specification requires compliance with a certain number of criteria, which our specification cannot escape. Firstly, it requires a large number of individuals (countries, in our study) and a few periods (years, in our study), which is the case since our study covers 40 countries over a 15-year period, from 2005 to 2020. Secondly, the dependent variable, or left-hand side variable, must be dynamic (i.e., it must depend on its own past observations). The literature shows that food security is persistent, and our regressions have estimated coefficients above 0.800, which exceeds the empirical threshold (Tchamyou et al., 2019). Third, the GMM regression method considers a data structure where the independent variables are not strictly exogenous (i.e., they are correlated with past realisations and possibly with the error term). GMM estimation corrects for endogeneity bias especially as it pertains to the simultaneity concern of endogeneity which is addressed with the use of time-invariant variables or years that are considered as strictly exogenous because they cannot be endogenous upon a first-difference (Boateng et al., 2018). Fourth, GMM estimation is designed for fixed individual effects. The extensions proposed by Roodman (2009) of Arellano and Bover (1995) are adopted to solve the instrument proliferation problem or limit overidentification. Finally, we take cross-sectional dependence into account in the sampling to solve the problem of instrument proliferation or to limit over-identification (Baltagi et al., 2007).

The regression design for the standard system GMM derives the equations below in level (1) and first difference (2):

$$FS_{it} = \emptyset_0 + \emptyset_1 FS_{it-\tau} + \emptyset_2 ND_{it} + \sum_{k=1}^{5} \delta_k W_{hit-\tau} + \varphi_i + \omega_t + \varepsilon_{it} \quad (1)$$

$$FS_{it} - FS_{it-\tau} = \emptyset_1 (FS_{it-\tau} - FS_{it-2\tau}) + \emptyset_2 (ND_{it} - ND_{it-\tau}) + \sum_{k=1}^{5} \delta_k (W_{hit-\tau} - W_{hit-2\tau}) + (\omega_t - \omega_{t-\tau}) + (\varepsilon_{it} - \varepsilon_{it-\tau}) \quad (2)$$

FS represents food security (i.e., average dietary energy supply adequacy, prevalence of undernourishment, cereal import dependency and children stunted); θ_0 represents the constant; ND denotes natural disasters (namely, hydrological, total affected, and biological); Wrepresents the vector of variables of control; τ reflects the unit coefficient of autoregression given that a lagged year is sufficient to display former information; ω_t denotes the time-specific effect; φ_i represents the country-specific impact constant while ε_{it} denotes the error term.

3.2.2 Identification and exclusion restrictions

The identification and restriction properties are of fundamental importance in the GMM specification. In this context, the control and variables of interest are generally recognised as not being strictly exogenous, while the "years" are assumed to be strictly exogenous, in line with the argument put forward by Tchamyou et al. (2019). This identification strategy is in line with the argument of Roodman (2009), who demonstrates that "years" can be considered as ideally strictly exogenous variables. Indeed, after an initial differentiation, "years" are unlikely to become endogenous.

With regard to the exogeneity of the instruments, given the above identification, the exclusion restriction hypothesis is assessed using the Difference in Hansen Test (DHT). The alternative hypothesis of this test suggests that the strictly exogenous variables identified do not exhibit strict exogeneity, as they do not exclusively influence the outcome indicators (i.e., food security) via the predetermined variables (i.e., control variables and variables of interest). Thus, for the identification and exclusion restriction strategies to be valid, it is essential that the null hypothesis of DHT is not rejected. The instrumental variables technique is consistent with these hypotheses, while respecting the corresponding criteria for assessing their validity. For the instruments identified to potentially affect the outcome variable only via the exogenous components of the independent variables, instrumental variable estimation requires rejecting the alternative hypothesis of the Sargan/Hansen test (Asongu and Nwachukwu, 2016; Beck, Demirgüç-Kunt and Levine, 2003). In the context described above, the DHT plays a crucial role in assessing the effectiveness of exogenous instruments. In order to guarantee the strict exogeneity of these instruments, it is imperative not to reject the null hypothesis. In line with the work of Roodman (2009), the DHT test is an essential indicator for assessing the exogeneity of instruments. As demonstrated by Roodman (2009), the variable considered to be strictly exogenous in this study is the time element, namely "years". To ensure the validity of the estimates, this research is mainly based on four information criteria taken from the literature. Firstly, with regard to Arellano and Bond's second-order autocorrelation test [AR (2)], it is important to note that the null hypothesis, which states that the residuals are not autocorrelated, should not be rejected. Secondly, with regard to the Sargan and Hansen tests, the results should indicate that the over-identifying restrictions (OIR) are not significant. In other words, the null hypotheses associated with these tests validate the relevance of the instruments or demonstrate their lack of correlation with the error terms. It should be noted, however, that Sargan's OIR test is not robust, although it was not weakened by the instruments. The Hansen OIR test which is robust, is weakened by the proliferation of instruments. To restrict the identification or limit the proliferation of instruments, it is important to point out that the number of instruments used should be less than the number of cross-sections for all specifications. In addition, DHT, which confirms the exogeneity of the instruments, is also included to validate the results of the Hansen OIR test. Finally, a Fisher test is applied to validate the estimated coefficients, thus completing the process of assessing the validity of the results.

4. Empirical results

In Table 1, we have estimated the effect of global natural disasters on food security. The results show the persistence of the food security variable. The level of food security in the current period is significantly explained by the level of security in the past period. The estimated coefficients on lagged food security are significantly positive in all models. We observe that natural disasters make it difficult to access the food captured by the prevalence of undernourishment variable. One more country affected by natural disasters leads to a 1% increase in the prevalence of undernourishment. This result is in line with the work of Belesova et al. (2019), which shows that extreme climatic events have a negative impact on long-term nutritional status. In terms of stability, there is a negative effect of natural disasters. Natural disasters significantly reduce dependence on cereal imports. A 1% increase in natural disasters reduces cereal import dependency by 2.2%. In countries faced with natural disasters, food donations from various national, international and non-governmental organisations can act as a lever to reduce the overall quantity of imports relative to exports. However, in the literature, the effect of natural disasters on imports is mixed. In a study of Pacific Island countries, Lee and Zhang (2023) showed that "severe" disasters worsen the balance of trade and therefore increase imports. In terms of availability and use, the effects are negative and positive respectively, but not significantly so. Natural disasters not only reduce dietary energy intake, they also stunt children's growth. However, the effects are not significant.

Table 1: Natural disasters and food security

	Dependent variable Dietery energy supply adequacy	**Prevalence of undernourishment**	**Cereal import dependency**	**Children stunted**
	(1)	**(2)**	**(3)**	**(4)**
ADESA (-1)	**1.144***** **(0.101)**	**-**	**-**	**-**
PUND (-1)	**-**	**1.254***** **(0.075)**	**-**	**-**
PRI (-1)	**-**	**-**	**0.989***** **(0.041)**	**-**
CUST (-1)	**-**	**-**	**-**	**1.116***** **(0.010)**
NATDI	-0.001 (0.001)	**0.010***** **(0.004)**	**-0.022***** **(0.006)**	0.00005 (0.001)
Popg	**0.060***** **(0.024)**	**-0.479***** **(0.105)**	**0.220**** **(0.108)**	**-0.045**** **(0.023)**
GDPper	-0.001 (0.003)	0.010 (0.017)	0.040* (0.024)	-0.006 (0.004)
School	-0.013 (0.046)	0.233 (0.272)	0.190 (0.269)	**-0.072**** **(0.0301**)
Sanitation	0.012 (0.011)	-0.046 (0.057)	**0.111*** **(0.060)**	**0.033***** **(0.011)**
Constant	-0.691 (0.459)	-1.378 (1.419)	-1.247 (1.293)	-0.360** (0.161)
Time effects	Yes	Yes	Yes	Yes
AR (1)	**(0.451)**	(0.091)	(0.046)	(0.312)
AR (2)	**(0.764)**	**(0.384)**	**(0.243)**	**(0.432)**
Sargan (OIR)	(0.000)	(0.035)	**(0.276)**	**(0.010)**
Hansen (OIR)	**(0.474)**	**(0.718)**	**(0.741)**	**(0.351)**
DHT for instruments				
(a) Instruments in levels				
H excluding group	**(0.346)**	**(0.813)**	**(0.335)**	**(0.479)**
Dif (null, H = exogenous)	**(0.463)**	**(0.643)**	**(0.747)**	**(0.310)**
(b) IV (years, eq(diff))				
H excluding group	**(0.805)**	**(0.901)**	**(0.467)**	**0.341)**
Dif (null, H = exogenous)	**(0.299)**	**(0.510)**	**(0.740)**	**0.358)**
Fisher	**232246.47**	**1599.77**	**49911.02**	**186758.19**
Instrument	**32**	32	32	32

Countries	38	38	38	38
Observations	310	310	290	310

Note: *, **, ***: significance levels of 10%, 5% and 1%, respectively. ADESA: Average dietary energy supply adequacy (percent) (3-year average). PUND: Prevalence of undernourishment (percent) (3-year average). CIDP: Cereal import dependency ratio (percent) (3-year average). CUST: Percentage of children under 5 years of age who are stunted. Sanitation: People using at least basic sanitation services (% of population). Popg: Population growth (annual %). School: Pupil-teacher ratio, primary. GDP: Gross Domestic Product per capita growth (annual %). Source: Authors.

For the control variables, population growth has a significant negative impact on the prevalence of malnutrition and stunting in children in sub-Saharan Africa. These results are in line with the work of Molotoks et al. (2021). On the other hand, the impact is positive on the other two characteristics of food security, namely: availability and stability. These results are supported by the work of Hall et al. (2017), who recommend that a reduction in population growth improves food security. Regarding the growth rate of GDP per capita, it has a significant and positive impact on cereal import dependency for these studied countries. This result is in line with our expectations and with the work of Ntiamoah et al. (2023).

In Table 2, specific emphasis is placed on the effects of hydrological and biological disasters on food security. Hydrological disasters include floods, which can impact food security in several ways. Floods can directly cause crop losses or damage, or indirectly impact food security by mitigating household's income (Akukwe et al., 2020; Ahmad and Afzal, 2021). Access to the market for food supplies can be made difficult by floods, which can damage infrastructure like bridges, roads and storage facilities (Codjoe and Owusu, 2011; Ramakrishna, 2014). Nutritional status can also be affected by public health problems that can arise from flooding (Rieckmann et al., 2018; Abass, 2022; Loladze, 2014). The findings demonstrate that droughts and floods have a significant negative impact on food availability by reducing average energy intake. They also have a negative impact on dependence on cereal imports. In Column 6, we find that floods have a significantly positive effect on stunted growth in children. Hydrological disasters have a negative impact on all food security indicators except stunting. However, these effects are not significant. Biological disasters such as crop diseases, insect pests and weeds are challenges for sustainable intensification of agricultural land (Song et al., 2020). These disasters have negative effects on the various food security indicators, with the exception of dependence on cereal imports. It should be noted that these impacts are not significant.

Table 2: hydrological, biological disasters and food security

	Dependent variable							
	Dietery energy supply adequacy		**Prevalence of undernourishment**		**Cereal import dependency**		**Children stunted**	
	Hydrological	**Biological**	**Hydrological**	**Biological**	**Hydrological**	**Biological**	**Hydrological**	**Biological**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
ADESA (-1)	**0.975*** (0.054)**	**1.061*** (0.058)**	-	-	-	-	-	-
PUND (-1)	-	-	**1.069*** (0.056)**	**1.090*** (0.042)**	-	-	-	-
PRI (-1)	-	-	-	-	**1.064*** (0.035)**	**0.804*** (0.098)**	-	-
CUST (-1)	-	-	-	-	-	-	**1.117*** (0.010)**	**1.100*** (0.009)**
HYDRO	**-0.0012** (0.0005)**	-	0.0003 (0.004)	-	**-0.030*** (0.007)**	-	**0.002* (0.001)**	-
BIOL	-	-0.0006 (0.0008)	-	-0.010 (0.009)	-	**0.022 (0.013)**	-	-0.0003 (0.001)
Popg	0.006 (0.016)	**0.070*** (0.025)**	**-0.188** (0.094)**	**0.305** (0.154)**	**-0.169* (0.088)**	**-0.535 (0.397)**	**-0.057*** (0.012)**	0.006 (0.026)
GDP	-0.0014 (0.003)	0.003 (0.002)	0.007 (0.016)	-0.035 (0.154)	**0.066*** (0.023)**	**-0.033 (0.034)**	-0.003 (0.004)	-0.006 (0.003)
School	-0.016 (0.035)	-0.045 (0.026)	0.284 (0.177)	0.150 (0.344)	-0.265 (0.200)	0.587* (0.317)	**-0.074*** (0.028)**	-0.018 (0.026)
Sanitation	0.0006 (0.009)	-0.0004 (0.009)	-0.110 (0.074)	-0.080 (0.064)	-0.06 (0.071)	0.103 (0.093)	**0.027*** (0.010)**	**0.022** (0.010)**
Constant	0.198 (0.332)	-0.1401 (.294)	-1.029 (0.991)	-0.847 (1.564)	**1.586*** (0.835)**	**-1.958 (1.796)**	**-0.362 (0.148)**	**-0.536*** (0.153)**
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR (1)	**(0.585)**	(0.551)	(0.095)	0.521)	(0.044)	(0.241)	0.056	(0.176)
AR (2)	**(0.710)**	**(0.403)**	**(0.219)**	**(0.373)**	**(0.537)**	**(0.437)**	**0.353**	**(0.468)**
Sargan (OIR)	(0.000)	(0.018)	(0.000)	0.338)	(0.299)	(0.003)	0.504	(0.077)
Hansen (OIR)	**(0.186)**	**(0.145)**	**(0.376)**	**(0.131)**	**(0.306)**	**(0.514)**	**0.717**	**(0.544)**
DHT for instruments								
(a) Instruments in levels								
H excluding group	**(0.967)**	**(0.476)**	**(0.283)**	**(0.069)**	**(0.551)**	**(0.230)**	**0.539**	**(0.201)**
Dif (null, H = exogenous)	**(0.137)**	**(0.112)**	**(0.383)**	**(0.268)**	**(0.258)**	**(0.600)**	**0.672**	**(0.660)**
(b) IV (years, eq(diff))								
H excluding group	**(0.027)**	**(0.156)**	**(0.182)**	**(0.164)**	**(0.151)**	**0.301**	**0.600**	**(0.704)**
Dif (null, H = exogenous)	**(0.644)**	**(0.231)**	**(0.530)**	**(0.201)**	**(0.473)**	**0.606**	**0.641**	**(0.381)**
Fisher	**3.12e+06*** **	**1.30e+07*** **	**8236.61*** **	**2.62e+06*** **	**33908.97*** **	**81023.96*** **	**381778.75*** **	**2.01e+06*** **
Instrument	28		32	33	32	32	32	32
Countries	42		37	32	37	33	37	33
Observations	525	133	232	122	216	122	232	133

Note: *, **, ***: significance levels of 10%, 5% and 1% respectively. ADESA: Average dietary energy supply adequacy (percent) (3-year average). PUND: Prevalence of undernourishment (percent) (3-year average). CIDP: Cereal import dependency ratio (percent) (3-year average). CUST: Percentage of children under 5 years of age who are stunted. Sanitation: People using at least basic sanitation services (% of population). Popg: Population growth (annual %). School: Pupil-teacher ratio, primary. GDP: Gross Domestic Product per capita growth (annual %). Source: Authors.

We carried out robustness checks by adding a control variable, namely conflict. Conflicts can lead to disturbance of agricultural-related activities, communities' displacement and infrastructural damage, and hence to food insecurity (Muriuki et al., 2023). Tables A5 and A6 show the results of the estimates. The results of the basic model remain robust with the addition of the control variable. Accordingly, in Appendix Table A5 provides the robustness of the effect of natural disasters on food security with the addition of control variables while Appendix Table A6 shows robustness tests of the effect of hydrological and biological disasters on food security with the addition of control variables.

5.Conclusion, implications and future research directions

5.1Conclusion

Natural disasters, which are a consequence of climate change phenomena, pose significant risks to countries' ability to ensure food security for their populations. In this article, we look at how natural disasters affect food security. We consider natural disasters as a whole, including hydrological, meteorological, geophysical, biological and climatological disasters. We examine the role of hydrological and biological disasters, which are the most representative in the area studied. We use the four characteristics of security from the FAO, namely: availability, access, stability and use. Using a panel dataset comprising 40 sub-Saharan African countries over the period 2005 to 2020 we investigate the causal effects of natural disasters on food security by employing the generalized method of moments (GMM).

The results show that natural disasters have a positive impact on the prevalence of undernourishment and a negative impact on cereal dependency (i.e., the higher the sum total of affected people by natural catastrophes, the higher the prevalence of undernourishment and the lower the dependency on cereal imports). However, there is considerable heterogeneity in the impact of different types of natural disasters. Hydrological disasters have negative effects on dietary energy supply adequacy and dependence on cereal imports. On the other hand, biological disasters do not have a significant impact on food security.

5.2Policy implications

Given the high levels of carbon emissions in the world, the losses caused by natural disasters are likely to increase, especially in an environment marked by population growth and economic activity. Our results call for the adoption of measures and programs to address the effects of natural catastrophes on food security in sub-Saharan Africa. Food insecurity fosters poverty and unemployment and hampers economic growth, which is detrimental to the countries that suffer from the consequences of natural disasters.

Given the adverse impact of natural disasters on food security, economic assistance and international post-disaster aid programs should develop measures to ensure food security for affected populations. Post-disaster aid programs must avoid focusing on the strategic interests of donors and instead respond to humanitarian needs. In addition, the objective of food security should fully be included in disaster preparedness and adaptation schemes. It has been observed that in countries hit by natural disasters, the emphasis is much more on infrastructure, but people also need to be helped to achieve food security. Moreover, aid programs should focus on access to food for populations in countries that are often affected by droughts, such as Mali, Niger, Chad and Ethiopia and propose support measures to these populations in order to reduce the prevalence of undernourishment.

Furthermore, consistent with the United Nations (2021), a disaster-resilient future to food insecurity is feasible, especially as it pertains to, *inter alia*: (i) investments in catastrophe risk reduction and resilience, particularly in the form of data collection and analysis for evidence-based decision-making, are critical to ensuring agriculture's critical role in realizing a sustainable future. (ii) In the catastrophe response process, multidisciplinary cooperation and holistic approaches are essential. To anticipate, prevent, plan for, and respond to catastrophe risk in agriculture, countries must implement a multi-hazard and multi-sectoral systemic risk management approach. In addition to environmental hazards, strategies must take into account man-made and biological threats, such the COVID-19 pandemic, and be grounded in an awareness of the interdependencies and systemic nature of risks. (iii) In the effort to lower the risks of agricultural disasters, innovations like machine learning, drones, remote sensing, geospatial information gathering, and disaster robotics are effective new instruments for data collection and assessment. (iv) Promoting public-private partnerships is essential in addition to effective governance in order to address the pressing need for investment in lowering the vulnerability of agriculture to natural catastrophes and climate change.

5.3 Limitations and future research directions

The main limitation of this paper is that it does not exhaustively addresses the spatial dimensions of the effects of natural catastrophes on food security. Due to the lack of data, we have not been able to look at localised disasters and determine their impact at local level. We have only examined the relationship between natural disasters and food security from a global perspective. Future studies should focus more on local level analyses in order to evaluate the nexus between natural catastrophes and food security. The underlying future research recommendation essentially builds on the shortcoming that country-specific effects are not practically involved in the GMM estimation exercise in an effort to avoid the concerns of endogeneity that arise from the correlation between the lagged dependent variable and country-specific effects.

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Appendices

Table A1: Countries included in the study

Angola	Congo. Rep.	Lesotho	Nigeria
Benin	Ivory Coast	Liberia	Rwanda
Botswana	Eswatini	Madagascar	Senegal
Burkina Faso	Ethiopia	Malawi	Sierra Leone
Cabo Verde	Gabon	Mali	South Africa
Cameroon	Gambia	Mauritania	Tanzania
Central African Republic	Ghana	Mauritius	Togo
Chad	Guinea	Mozambique	Uganda
Comoros	Guinea-Bissau	Namibia	Zambia
Congo. Dem. Rep.	Kenya	Niger	Zimbabwe

Source: Authors' compilation

Table A2: List of variables

Acronyms	Variable definition	Source
ADESA	Average dietary energy supply adequacy (percent) (3-year average)	FAO
PUND	Prevalence of undernourishment (percent) (annual value)	FAO
CIMD	Cereal import dependency ratio (percent) (3-year average)	FAO
CUST	Percentage of children under 5 years of age who are stunted (modelled estimates) (percent)	FAO
HYDRO	Number of persons affected by hydrological disasters	EM-DAT
BIOL	Number of persons affected by biological disasters	EM-DAT
NATDI	Total persons affected by natural disasters	EM-DAT
Popg	Population growth (annual %)	WDI
GDP	GDP per capita growth (annual %)	WDI
School	Pupil-teacher ratio, primary	WDI
Sanitation	People using at least basic sanitation services (% of population)	WDI

Source: Authors' compilation

Note: WDI: World Development Indicators; FAO: Food and Agriculture Organization of the United Nations; EM-DAT: Emergency Events Database.

Table A3: Summary statistics

Variable	Mean	Std. Dev.	Min	Max	Obs
ADESA	108.807	11.685	82	134	640
PUND	20.719	11.187	3.4	55.4	640
CIMD	38.283	29.665	-23.9	100	594
CUST	4.868	.782	0	5.749	640
HYDRO	121600.5	443900.3	14	7000867	327
BIOL	24143.83	167462.8	1	2300000	201
NATDI	363702.8	1128946	0	1.02e+07	640
Sanitation	32.452	19.787	4.316	95.478	636
School	103.968	19.442	48.356	149.315	522
Popgr	2.47280	.868	-.401	5.6274	640

Source : Authors' compilation

Table A4: Correlation matrix

ADESA	PUND	CIMD	NADTI	HYDRO	BIOL	Popgr	GDP	School	Sanitation	
1.000	-0.904	-0.137	-0.122	0.032	0.053	-0.051	-0.215	-0.187	0.235	ASESA
	1.000	0.035	0.092	-0.084	-0.080	0.208	0.227	0.092	-0.379	PUND
		1.000	-0.305	-0.165	-0.071	-0.277	-0.130	0.294	0.367	CIMD
			1.000	0.597	0.225	0.275	0.038	-0.142	-0.142	NADTI
				1.000	0.070	0.156	0.033	-0.104	-0.040	HYDRO
					1.000	0.101	-0.028	-0.109	0.080	BIOL
						1.000	0.155	-0.286	-0.372	Popgr
							1.000	0.039	-0.392	GDP
								1.000	0.322	School
									1.000	Sanitation

Source: Authors' compilation

Table A5: Robustness tests of the effect of natural disasters on food security with the addition of control variables

	Dependent variable			
	Dietary energy supply adequacy	**Prevalence of undernourishment**	**Cereal import dependency**	**Children stunted**
	(1)	**(2)**	**(3)**	**(4)**
ADESA (-1)	**1.197*** **	**-**	**-**	**-**
	(0.085)			
PUND (-1)	**-**	**1.259*** **	**-**	**-**
		(0.078)		
CIMD (-1)	**-**	**-**	**0.947*** **	**-**
			(0.048)	
CUST (-1)	**-**	**-**	**-**	**1.112*** **
				(0.012)
NATDI	-0.001	**0.008** **	**-0.014* **	0.001
	(0.0008)	**(0.003)**	**(0.008)**	(0.001)
Popg	**0.062*** **	**-0.494*** **	**0.130**	**-0.049* **
	(0.019)	**(0.102)**	**(0.114)**	**(.026)**
GDPper	-0.003	0.018	0.010	-0.006
	(0.002)	(0.015)	(0.032)	(0.004)
School	-0.004	0.024	0.827***	**-0.061**
	(0.030)	(0.216)	(0.336)	(**0.039**)
Sanitation	0.016	-0.046	**0.123* **	**0.021**
	(0.010)	(0.057)	**(0.104)**	**(0.013)**
Conflicts	-0.021	0.124	**-0.239**	**-0.021**
	(0.017)	(.134)	**(0.255)**	**(0.022)**
Constant	-0.974	-0.547	-3.832	-0.360**
	(0.362)	(0.971)	(1.545)	(0.161)
Time effects	Yes	Yes	Yes	Yes
AR (1)	**(0.306)**	(0.092)	(0.054)	(0.381)
AR (2)	**(0.786)**	**(0.378)**	**(0.344)**	**(0.255)**
Sargan (OIR)	(0.000)	(0.010)	**(0.800)**	**(0.053)**
Hansen (OIR)	**(0.208)**	**(0.417)**	**(0.940)**	**(.397)**
DHT for instruments				
(a) Instruments in levels				
H excluding group	**(0.178)**	**(0.194)**	**(0.689)**	**(0.590)**
Dif (null, H = exogenous)	**(0.295)**	**(0.570)**	**(0.910)**	**(0.297)**
(b) IV (years, eq(diff))				
H excluding group	**-**	**-**	**-**	**-**
Dif (null, H = exogenous)	**-**	**-**	**-**	**-**
Fisher	**895367.38**	**15324.28**	**3813.71**	**1.55e+06**
Instrument	33	33	33	33
Countries	38	38	38	38
Observations	310	310	290	310

Note: *, **, ***: significance levels of 10%, 5% and 1% respectively. ADESA: Average dietary energy supply adequacy (percent) (3-year average); PUND: Prevalence of undernourishment (percent) (3-year average); CIDP: Cereal import dependency ratio (percent) (3-year average); CUST: Percentage of children under 5 years of age who are stunted; Sanitation: People using at least basic sanitation services (% of population); Popg: Population growth (annual %); School: Pupil-teacher ratio, primary; GDP: Gross Domestic Product per capita growth (annual %). Source: Authors.

Table A6: Robustness tests of the effect of hydrological and biological disasters on food security with the addition of control variables

	Dependent variable							
	Dietery energy supply adequacy		Prevalence of undernourishment		Cereal import dependency		Children stunted	
	Hydrological	Biological	Hydrological	Biological	Hydrological	Biological	Hydrological	Biological
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ADESA (-1)	0.952***	1.092***	-	-	-	-	-	-
	(0.060)	(0.063)						
PUND (-1)	-	-	1.047***	0.996***	-	-	-	-
			(0.052)	(0.040)				
CIMD (-1)	-	-	-	-	1.010***	1.109***	-	-
					(0.032)	(0.036)		
CUST (-1)	-	-	-	-	-	-	1.118***	1.100***
							(0.009)	(.009)
HYDRO	-0.001*	-	0.001	-	-0.023**	-	0.002	-
	(0.0005)		(0.003)		(0.010)		(0.001)	
BIOL	-	-0.0003	-	0.002	-	-0.004	-	-0.0007
		(0.0007)		(0.004)		(0.012)		(0.001)
Popg	0.008	0.101***	-0.195**	-0.505***	-0.191*	-0.049	-0.055 ***	0.006
	(0.015)	(0.032)	(0.094)	(0.130)	(0.108)	(0.297)	(0.011)	(0.025)
GDP	-0.0001	0.002	0.006	-0.0149	0.062***	-0.033	-0.006	-0.004
	(0.003)	(0.001)	(0.016)	(0.007)	(0.021)	(0.0222)	(0.0048)	(0.004)
School	-0.026	0.009	0.220	-0.094	0.571**	0.240*	-0.049*	-0.050
	(0.024)	(0.027)	(0.147)	(0.179)	(0.264)	(0.400)	(0.027)	(0.036)
Sanitation	0.004	0.010	-0.114*	0.004	-0.114	-0.113	0.017	0.021**
	(0.009)	(0.011)	(0.064)	(0.043)	(0.087)	(0.095)	(0.012)	(0.010)
Conflicts	0.008	-0.043	-0.0230	0.066	-0.297***	0.227	-0.019	0.010
	(0.013)	(0.011)	(0.066)	(0.079)	(0.108)	(0.201)	(0.015)	(0.012)
Constant	0.328	-0.552	-1.029	0.834	-1.729*	-1.083	-0.430***	-0.402***
	(0.311)	(0.348)	(0.991)	(0.909)	(1.039)	(1.970)	(0.131)	(0.1757)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR (1)	(0.788)	(0.798)	(0.072)	(0.466)	(0.044)	(0.376)	0.102	(0.167)
AR (2)	(0.701)	(0.476)	(0.169)	(0.462)	(0.537)	(0.414)	0.103	(0.414)
Sargan (OIR)	(0.000)	(0.093)	(0.000)	(0.000)	(0.299)	(0.321)	0.379	(0.128)
Hansen (OIR)	(0.179)	(0.509)	(0.351)	(0.275)	(0.306)	(0.438)	0.660	(0.534)
DHT for instruments								
(a) Instruments in levels								
H excluding group	(0.967)	(0.410)	(0.118)	(0.260)	(0.551)	(0.210)	0.617	(0.643)
Dif (null, H = exogenous)	(0.137)	(0.508)	(0.598)	(0.330)	(0.258)	(0.610)	0.564	(0.400)
(b) IV (years, eq(diff))								
H excluding group	-	-	-	-	-	-	-	-
Dif (null, H = exogenous)	-	-	-	-	-	-	-	-
Fisher	2.34e+06***	3.22e+07 ***	27243.57***	2.42e+07***	58390.97***	7.80e+06***	381778.75***	2.25e+06***
Instrument	32	33	32	33	33	33	32	32

Countries	37	33	37	33	37	33	37	33
Observations	232	133	232	133	216	122	232	133

Note: *, **, ***: significance levels of 10%, 5% and 1% respectively. ADESA: Average dietary energy supply adequacy (percent) (3-year average); PUND: Prevalence of undernourishment (percent) (3-year average); CIDP: Cereal import dependency ratio (percent) (3-year average); CUST: Percentage of children under 5 years of age who are stunted; Sanitation: People using at least basic sanitation services (% of population);Popg : Population growth (annual %); School: Pupil-teacher ratio, primary; GDP: Gross Domestic Product per capita growth (annual %). Source: Authors.