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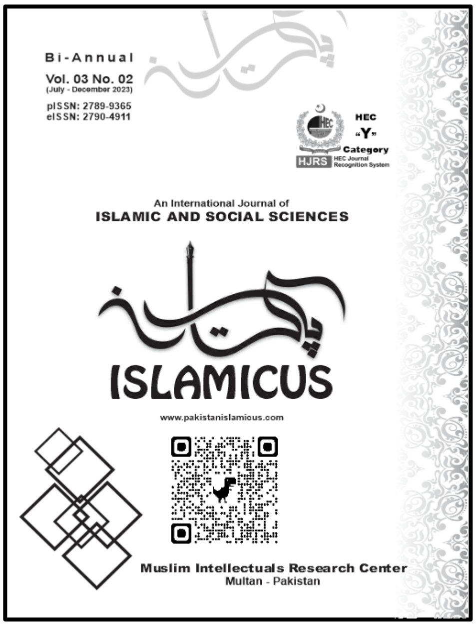

TOPIC

CLIMATE CHANGE AND FOOD SECURITY: EVIDENCE, IMPLICATIONS, AND CONVERGENCE FOR AFRICAN COUNTRIES

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CLIMATE CHANGE AND FOOD SECURITY: EVIDENCE, IMPLICATIONS, AND CONVERGENCE FOR AFRICAN COUNTRIES

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Abstract

The strong and complex multifaceted climate change impacts in African countries are evident from long-prevailing hunger and food insecurity, hence widespread undernourishment. The present study is designed to investigate the continuously evolving climate change impacts affecting the food security status of agrarian food-insecure African countries to envisage factual research-based policy implications for development practitioners and stakeholders. For this purpose, the data of key variables have been taken from 1990-2019, the Driscoll Kraay second-generation regression analysis has been employed for overall analysis. For in-depth analysis, the error correction method (ECM) with Pooled Mean Group Specification has been used to capture climate change's long-run and short-run impacts on food security coupled with other key control variables such as population density, democratic institutions, arable land and cereal production. The study found that a warmer climate and intensive rainfall adversely affect food security or worsen the condition of the prevalence of undernutrition. The long-run results of Discroll Kraay's methodology clarify that temperature is statistically significant and adversely associated with the prevalence of undernourishment. At the same time, temperature square, rainfall, and rainfall square are statistically significant and positively related to undernourishment prevalence. As far as the concern about the short run using Driscoll Kraay coefficient of error correction term is found to be negative and statistically significant, showing that there is convergence towards its long-run equilibrium. The estimated model also suggests that the adaptation of climate-smart technologies is helpful in the escalation of food security.

Keywords: Panel Data Model, Agriculture, Africa, Climate, African Countries
Jel Codes: C33, O13, O55, Q55

Introduction

Climate changes take place over an elongated period of stint and grow into a threat to almost all the regions of rondure. Agrarian economies are relatively more susceptible to climate change; amid these countries, African countries are additionally prone, and its devastating effects are increasing on agricultural production and livelihoods in a complex relation over time. Various major crops, for example, wheat, maize, mangoes, and sorghum, have reduced across the African region due to the changes and variability in climate (Fahmida, 2023). In this stance, Eze (2017) contributed that employment of 300 million Africans is associated with Cassava production and that it is highly vulnerable to frequent floods, rising temperatures, and deviations in relative humidity. In addition, sub-Saharan African countries are expected to face a decline in the production of sweet potato, sorghum, wheat, and millet by 2050 under the climate change scenario. The African 70%-80% rural population's livelihood is based on rain-fed agriculture, therefore, climate change exacerbates the vulnerability. Droughts and desertification have been in full swing due to arid, semi-arid, dry land and human activities in the continent since drought occurred due to the multifarious interplay of escalating temperature and deficit in precipitations coupled with the moisture of the soil. Eventually, droughts have been changing the landscape by cascading effects on food production. The complexity and strength of multifaceted relationships to climate change in Africa are emerging in the form of hunger, food insecurity, and the highest prevalence of undernourishment.

The prevalence of undernourishment, an indicator castoff to quantity global hunger, has amplified in Africa from 19.4% to 19.7% (11 million people) from 2021 to 2012, specifically in Southern and Northern Africa (FAO, 2023). The prevalence of undernourishment rose from 6.9% to 7.5% (2 million) and 22.2% to 22.5% (9 million) in Northern Africa and sub-Saharan Africa one-to-one. The situation is a little better in Middle Western, and Eastern Africa, accounting for 0.6% and 0.1% increase in the prevalence of undernourishment. Various stems, such as mounting domestic and international inflation, and a high rate of unemployment, added fuel to rising hunger in Southern Africa. At the same time, subsistence agricultural production further declines with extreme climatic events such as droughts and floods. Contrarily, Middle Africa has faced food inflation, heavy food import bills, revenue fluctuations in oil export, and climate-related events during 2022.

Climate change and variability have undermined food production, for example, rice, wheat, and maize in tropical, arid, semi-arid, and drylands of Africa due to low adaptability and less resilience. Moreover, long and short-term variations in climate potentially hurt food security and undernutrition. The incidence of moderate and severe food insecurity in Africa (60.9 %), Eastern Africa (2.4%), Middle Africa (3.0%), and Southern Africa (1.2%) was reported within one year (2021-2022) (FAO, 2023). However, 24% of the African population experienced severe food insecurity during 2022, while 0.3% (Western Africa), 0.8% (Northern Africa), 1.3% (Middle Africa), and 1.5% (Southern Africa) were in the pain of severe food insecurity in 2022.

To adequately retort to the challenges of climate change and variability with food and nutrition security, there is a dire need to understand the unswerving and ancillary factors. For instance, climate change-sharp rise in temperature directly emasculates agricultural production and crop yield and reduces food availability. Contrarily, food access decreases with crop failure, increase in food prices, and reduction in agricultural income. Similarly, extensive rainfalls in the form of floods damage the safe water resources and sanitation facilities and hence reduce food utilization and nutritional levels indirectly and increase various outbreaks of diseases like diarrhoea. All these direct and indirect factors have increased the food insecurity and prevalence of undernutrition collectively.

Although climate change is not the only factor of global hunger, food insecurity, malnutrition, and undernutrition, however, climate change acts as a catalyst like with other protuberant factors like poverty, conflicts, and slowdowns in many countries (FAO, 2017). Therefore, it is perilous to scrutinize in more depth how climate change and variability emasculate the status of food security and nutrition.

In the existing study, after the introduction, section 2 consists of a detailed discussion of previous literature, section 3 provides methodology, section 4 explains empirical results and discussions and section 5, provides the conclusion and policy suggestions.

Research Question

The study underpins the succeeding question of how climate change affects the path and levels of food security in food-insecure African countries.

Objective of the Study

The present study is designed to investigate the continuously evolving climate change impacts on the food security status of food-insecure African countries to envisage the factual and research-based evidence-based policy implications for national and international development practitioners and other stakeholders.

Review of Literature

Climate Change and Food Security: A Latent Analysis

Daily and Ehrlich (1990) applied a computer-based model- Stochastic Perturbations to quantify the simulated footprints of changing climate, hunger-related deaths, size of population, consumption, grain storage, and production on global food security. It is found that hunger-related deaths are likely to surge due to climatic changes. Likewise, the outcomes of the model specify that a diminution in agricultural production and a modest expansion in the growth of population growth (0.3%) will have a larger impact on global food security and hunger. Important implications can be drawn from the study regarding soil erosion, salinization and waterlogging of irrigated land, reduction in soil fertility, and shortages of fresh water in various regions of the World. The rising cost of pesticides and less use of chemical fertilizers are responsible for limited growth of grain production. The study also suggested that socioeconomic changes, food waste, improvements in agriculture sectors of developing countries, the impartiality of food distribution, and persistent decline in greenhouse gases are expected to ensure long-run food security.

Rosenzweig and Parry (1994) applied different scenarios to explain the linkages between climate change and food security Worldwide. In doing so, the impact of climate change scenarios (Global Circulation Model), simulated doubled carbon dioxide, and farm-level adaptations (changes in existing agricultural system and substantial changes in agriculture system) on world food production. The simulated crop production is projected to be adversely affected by carbon dioxide and climate change. The upshots of the study publicized that changes in the agricultural system and farm-level adaptation have adverse effects on cereal production and the nutritional qualities of agrarian production.

The risk of hunger (ROH) is expected to increase due to climate change, as pointed out by Butt et al. (2005). They employed the widely applied Canadian Coupled Model (CCM) and Hadley Coupled Model (HADCM) for Mali. For in-depth analysis, they also applied biophysical, economic, and policy adaptations to cease the impacts of climate change. The Hadley Coupled Model (HADCM) and Canadian Coupled Model (CCM) have forecasted that the mean temperature is expected to increase 1^0C to 2.75^0C by 2030. The temperature rise adversely affects cereal production and, consequently, food security. The results of the study projected that the cumulative effect of less rainfall and rise in food prices will expand ROH by 64% and 72%, respectively by 2030 in Mali. It is also expected that land degradation will also play its role in rising ROH by 34% to 44%. This pivotal study suggested that to mitigate the simulated antagonistic spatial climate change impacts in the agri sector, it is imperative to adopt crop mix migration, heat-resistance varieties, and trade adjustments that will help to reduce the risk of hunger in Mali.

Parry et al. (2005) advocated that the Risk of Hunger (ROH) is likely to soar in agrarian South Asian and African countries due to the rapid climate changes. As a result, truncated income and food inflation are liable for the exacerbation of susceptibility of people in these climatically vulnerable countries. Outcomes of the research study elucidate that substantial polarization and ROH are probable to escalate built-on crop production configurations amongst advanced and low-income countries.

Fischer et al. (2005) employed Agrieconomic Zone-Baseline Simulations (AEZ-BLS) to analyze the combined effects of different social, and economic progress paths and inter-related climate change on agricultural yields worldwide. Two different scenarios were analyzed in the study, one is with climate change and the other is, without climate change (absolute and relative importance). The researchers claimed that climate change is an unevenly pressing problem around the globe, specifically in developing countries, and there is a grim essential to tackle this matter on an urgent basis. Climate change is a multidimensional issue and involves various complex relationships between environmental, climatic, demographic, economic, political, social, health, technological, and institutional processes. Therefore, this multidimensionality of climate change affects the environment and socioeconomic systems and alters the paths and levels of water and food security systems, consequently. It is concluded that climate change adversely affects tropical countries in the long run rigorously. Extreme weather events also change local food production by damaging water resources and arable land in some regions of the world. Implications drawn from this study showed that agricultural production will decline by 5-10% in underdeveloped countries. The results of this pivotal study also indicate that in all scenarios, hunger will be reduced but very slightly, until 2030. However, this is possible for Sub-Saharan African countries until 2040. However, the study did not consider extreme precipitation events, such as droughts and floods, since due to the occurrence of extreme precipitation events in tropical and subtropical economies alters and diminishes the capacity for mitigation of climate change.

Ziervogel et al. (2006) examined household food security for various regions of the world due to climate change and climate variability. The study focused on drought-prone areas such as Mexico, Nigeria, South Africa, and Sudan. The selected case studies provide commonalities and differences in rural livelihoods. The household data consisted of interviews and ethnographic methodology. They argued that food security is not only related to the climate but also has a complex link with other economic, political, and social factors. They found that in most places, food security is considered as the availability of food only. Therefore, all the agriculture policies developed around the availability of food. To realize food security, the study, suggested that emphasis should be placed on enhancing productive farming, development of irrigation services in drought-prone areas, elimination of possible obstacles in ownership of land, and food provisioning programs during droughts. The implications can be drawn from this study that food security is not an issue of food production but also depends on livelihood security under the umbrella of economic, social and political systems.

Braun (2008) made the crucial point that climate change affects directly (soil fertility, crop production, and crop diseases) and indirectly (agricultural demand, economic growth) food security around the world, specifically in low-income countries. The research makes it further clear that rapid variations in weather conditions affect agriculture production adversely and become the root cause of the shortages of food supplies and increases in the prices of food. The key implication drawn from the research is that climate change affects the livelihood related to the agriculture sector, adversely. Since the majority of the population earns their income (directly and indirectly) from the agriculture sector and typically, they spend almost 60% of their income on food. However, net-exporting countries are enjoying high profits due to the rapid rise in food prices and by improving their terms of trade.

Ringler et al. (2010) applied the Comprehensive Climate Change (CCC) situation to capture the historical and futuristic climate change impacts on food production in Sub-Saharan African countries. The applied model captures the climate change impacts on variables cultivated area, changes in yield growth, food imports, low-calorie intake, and malnutrition in children. Malnutrition in children is found to be more affected even without changes in climate and economic prosperity in these deprived countries. The results of the climate change scenario predicted that the cultivated areas are expected to increase by 2.1 per cent while the reduction in the growth of cereal production and yield growth by 3.2 per cent and 4.6 per cent. Therefore, food inflation, import dependency, and child malnutrition are expected to rise. It was also predicted that 585,000 children will be undernourished by 2050. However, this study would be useful in explaining food security more rigorously if the demand side had been included too. The demand side is an imperative determinant in explaining food security because the increasing trends of the population in the face of changing climate will deteriorate the situation of present and future food security.

Demeke et al. (2011) investigated the association between food security and rainfall variations in rural Ethiopia. To accomplish this task, they developed a Food Insecurity Index (FSI) and Rainfall Satisfaction Index (RSI). These two indices are based on longitudinal panel data for

1994 to 2004 by applying Principal Component Analysis (PCA). They applied a fixed-effect instrumental regression and multinomial logistic regression. The results of the study highlighted the significant role of rainfall inconsistency in the status of households' food security. Moreover, the study concluded that various factors such as the size of the households, ownership of livestock, and membership of local saving groups have positive as well as significant impacts on the food security of a rural household.

Another study by Abafita and Kim (2014) took into account the numerous climatic and non-climatic aspects of food security status in rural Ethiopia. The study was conducted through two different measures multidimensional index of food security and self-reported food security status. It was found that the food security of rural households is determined by rainfall adequacy, availability of food stock, land area, ownership of livestock, number of crops cultivated, utilization of sanitary services, education, age of household head, per capita consumption expenditure, livestock possession, soil conversation practices, and off-farm income. The outcomes of the study publicized that remittances and access to credit negatively affect the status of food security. In general, rainfall has a significant and positive effect, while temperature negatively affects food security. Moreover, the study suggested that education, training, extension services, and income diversification can help to improve the status of food security in rural areas of Ethiopia. However, contemporary agricultural techniques, such as better arrangements of irrigation are required to alleviate the impact of climate change.

Badolo and Kinda (2014) underlined the various impacts of climatic variations on food security for a sample of 71 developing countries. Three approaches Production-Based Approach, Market-Based Approach, and Institutional Failure were followed by the researchers to capture the impact of climatic variability on food security. They applied panel data fixed and random effect modelling techniques on two alternative measures i.e., food supply and share of undernourished. The model is based on various climatic and non-climatic factors such as rainfall variability, population growth, income per capita, food price vulnerability, democratic institutions, and conflicts. The results of the model revealed that food supply is positively related to the income per capita, while, population size hurts food supply. Food supply and availability are found to be adversely affected by rainfall variability. The study highlighted that rainfall variability further reduces food security in the existence of civil skirmishes and food price shocks. The study found severe adverse effects for rain-fed agricultural economies, specifically for Sub-Saharan African Countries. The study also suggested that investment in agricultural research and infrastructure, provision of extension services, effective implementation of climate risk reduction strategies, and climatic aid can help to reduce the vulnerability to food insecurity in underdeveloped countries.

Obwocha (2015) assessed the impacts of climate change and variability on food security in West Pokot for the period 1980-2012. A Geographic Information System (GIS) was applied to assess the household's perceptions about the changing climate and the status of food security in West Pokot. Empirical results of the study have shown that climate change adversely affects crop productivity. The study indicates that only 32% of the households found food secure. On the other hand, the study also observes that climate variability also affects the wetland, forestland, grassland, and cropland of West Pokot.

Tirado, Hunnes, Cohen and Lartey (2015) declared that Africa is facing serious challenges of climate change and climate variability. The study explains that multiple stressors such as conflicts, endemic poverty, weak institutions, multifaceted emergencies, sensitive economies, frequent droughts, and low resilience scale make it vulnerable to climate change and extreme weather events. All these reasons are enough to keep the population undernourished and food insecure in the region. In this dismal scenario, poverty deteriorates the efforts to increase the economic growth and resilience of vulnerable communities. Moreover, this study also emphasizes further research in the fields of food security, nutrition, mitigation, and adaptation strategies.

Bocchiola et al. (2019) explored how climate change has affected agriculture productivity and food security in Dudh Koshi. The authors examined cropping patterns of maize, rice and wheat in present scenarios and future scenarios. Initially, they mapped the cropping area with remote sensing, then applied agronomic model Poly-crop and poly-crop with downscaling output from the Global Climate Model (GCM). An index-Nutritional Households Index (NHI) was developed to measure the household food security rank of Dudh Kashi, Nepal. The results of GCM projected that the nutritional index (food security) would decrease by 49% by 2050. A large expansion in the production of maize is expected by 2050. The study concluded that the status of households' food security is projected to be more unstable in Nepal. Moreover, the study suggested that the adaptation strategies for climate change are likely to have a positive effect on the food security situation in Nepal.

Affoh et al. (2022) studied the links between changing climate and three dimensions of food security for a panel of 25 Sub-Saharan African countries for the period 1985-2018. The study explained the impact of climate change on food availability, food access, and food utilization separately. The study employed a fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and pool mean group autoregressive distributed lag

(PMGARDL) model. The study encompassed several variables like cereal yield, land under cereal production, gross domestic product, carbon dioxide, population growth, inflation, cereal production, cereal dietary energy supply, yearly temperature, and rainfall. The results of the pool mean group autoregressive distributed lag model reveal that rainfall has positive and significant effects on the three dimensions of food security in the long run. At the same time, food availability and accessibility were found to be adversely affected by temperature, and no significant effects were found for the utilization of food. The Granger Causality test confirmed the causative association between food availability and carbon dioxide emissions in the short run. A casual relationship between accessibility and temperature was found, similarly, utilization of food is found to be strongly linked with temperature. Moreover, carbon dioxide and rainfall were connected with rainfall. Likewise, a two-way causal link was found between temperature and rainfall.

Anyika (2022) underpinned the widespread footprints of climate change in Sub-Saharan African countries. Due to rain-fed agriculture and less inclination towards climate-smart adaptation strategies, the region is found most vulnerable. Extreme meteorological conditions such as intensive rainfall and droughts are the two main reasons for agricultural loss, farm income, food insecurity, high rates of undernutrition, crop production, availability of water, fisheries, livestock, pest diseases and unstable food systems. Widespread food and nutrition insecurity is found to be the outcome of frequent droughts.

Methodology

Variables and Data Sources

The empirical investigation of the present study is based on annual secondary data spanning 1990-2019. Following, Table 1 provides symbols, operational definitions and data sources of dependent and independent variables. In which the prevalence of undernourishment (UP) is taken as dependent variable, temperature (TMP) and rainfall (RAI) are as independent variables, while democratic institutions (DEMO), population density (PD), arable land (AR) and cereal production (CP) help in the analysis as control variables.

Table 1: Symbols, Operational Definition and Data Sources

Symbols	Operational definitions	Sources
UP	Undernourishment prevalence is in %age. It is the chance of choosing a person with stumpy consumption of inadequate calories mandatory for an active and healthy life.	FAO
DEMO	Democracy Index. It is constructed on political involvement competitiveness, restraints on the paramount executive and	Polity V

	decision-making conscription competitiveness and openness. The value of this index lies from 0 to 1.	
PD	Population density. No people living a 1 km per square of land area	WDI
LNAR	Area of land which is capable growing of crops and measured in hectares	WDI
LNCP	Cereal production in the form of natural logarithm measured in metric ton	WDI
TMP	Annual average temperature	CKP
LNRAI	Annual average rainfall in natural logarithm	CKP
FAO = Food and Agriculture Organization, CKP = Climate Knowledge Portal, WDI = World Development Indicator		

The countries are selected based on the Global Hunger Index (GHI) 2019, and the list is available in the Appendix.

Estimation Equation and Method

Since the data is changing across time and cross-sections and has more than 19 years per cross-section, this study assumes that the data are non-stationary, in nature (Arshed et al., 2018). Further, since the set of countries are located close to each other, this may lead to the presence of cross-sectional dependence. Therefore, the study has used Pesaran (2015, 2021), Juodis & Resse (2021) and Fan et al. (2015) power enhancement and Pesaran & Xie (2021) with 4 PC(s) to check for cross-sectional dependency. The 2nd generation panel unit root (Pesaran, 2007) and panel cointegration (Westerlund, 2007) test are conducted to confirm the existence of long-run relation.

Hence, in edict to control for expected problems like cross-sectional heteroskedasticity, time series autocorrelation, and cross-sectional dependence, this study has availed the Driscoll and Kraay (1998) regression method with fixed effects and used the two-step ECM specification (Arshed et al., 2022; Ul-Durar et al., 2023; Iqbal et al., 2023). Equation 1 provides the first step in estimating long-run relations as long as $\mu_{it}$are stationary, and equation 2 provides the short run where μ_{it-1} is the convergence coefficient. In this two-step ECM, the long-run estimates are homogenous across cross-sections. The short-run estimates are heterogeneous across cross sections, resembling the pooled mean group (PMG) specification of Panel ARDL models (Blackburne III & Frank, 2007). Thus, this model becomes a second-generation dynamic panel data regression.

$$UP_{it} = \beta_0 + \beta_1 PD_{it} + \beta_2 LNAR_{it} + \beta_3 LNCP_{it} + \beta_4 TMP_{it} + \beta_5 TMP_{it}^2 + \beta_6 LNRAI_{it} + \beta_7 LNRAI_{it}^2 + \mu_{it} - -(1)$$

$$\Delta UP_{it} = \alpha_0 + \alpha_1 \Delta PD_{it} + \alpha_2 \Delta LNAR_{it} + \alpha_3 \Delta LNCP_{it} + \alpha_4 \Delta TMP_{it} + \alpha_5 \Delta TMP_{it}^2 + \alpha_6 \Delta LNRAI_{it} + \alpha_7 \Delta LNRAI_{it}^2 + \delta_8 \mu_{it-1} + \varepsilon_{it} - -(2)$$

Empirical Results and Debates

Table 2 is a brief picture of the sampled data used in the analysis of climate change and food security connotations with other explanatory variables for the African food-insecure countries. Here the average of the prevalence of undernourishment (UP), arable land (LNAR), cereal production (LNCP), temperature (TMP) and rainfall (LNRAI) are greater than their respective standard deviation, which is a clue that these variables are not dispersed, contrarily, the standard deviation of democratic institutions (DEMO) and population density (PD) is larger than their respective mean values and reveal the fact that these variables are highly dispersed under the range of data. While the up, DEMO and PD are positively skewed LNAR, LNCP, TMP, and LNRAI are negatively skewed for the given set of data. The Shapiro-Wilk test has been applied to check the normality of data, according to the above table, the data is not statistically normal, as the probability values of all the variables are statistically significant. This study avails the central limit theorem to assume that data is asymptotically normal amid the sample size being above 30 observations (Lind et al., 2022).

Table 2: Descriptive Statistics with Shapiro-Wilk Test for Normality

	UP	DEMO	PD	LNAR	LNCP	TMP	LNRAI
Mean	30.66	0.285	75.56	2.192	14.159	24.487	6.748
Median	29.7	0	41.48	2.31	14.32	24.88	6.92
SD	14.59	0.45	95.42	1.11	1.36	3.49	0.73
Skewness	0.39	0.95	2.27	-0.67	-0.12	-1.42	-1.46
Kurtosis	2.69	1.90	8.08	3.38	2.58	5.96	4.92
S-Wilk Test	5.516	1.582	12.163	7.931	5.800	10.088	10.434
Prob.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No. of Obs.	750	750	750	750	750	750	750

Table 3 explains the correlation matrix of all the variables studied in the present investigation. According to the estimates, democratic institutions, cereal production and temperature are negatively correlated with the prevalence of undernourishment, which means that undernourishment decreases with the increase in these variables. At the same time, population density, arable land and rainfall are positively correlated with the prevalence of undernourishment; it tells us that with the increase in population density, arable land and rainfall, the prevalence of undernourishment also increases.

Table 3: Correlation Matrix

	UP	DEMO	PD	LNAR	LNCP	TMP	LNRAI
UP	1.00						
DEMO	-0.213	1.00					
PD	0.190	-0.125	1.00				
LNAR	0.006	0.056	0.676	1.00			
LNCP	-0.214	0.075	-0.054	0.265	1.00		
TMP	-0.235	-0.032	-0.217	-0.133	0.253	1.00	
LNRAI	0.316	0.053	0.323	0.463	0.009	-0.247	1.00

Panel data tends to observe cross-section dependency and the panel data selected for this study is also related to all the food-insecure African countries, hence cross-section dependence is suspected. Therefore, it has a cross-sectional dependence.

Pesaran (2015, 2021); Juodis & Resse (2021) and Fan et al. (2015) power enhancement and Pesaran & Xie (2021) with 4 PC(s) have been used to confirm the cross-section dependence. Table 4 depicts that cross-section dependence exists in the data.

Table 4: Pesaran, Juodis, Resse, Fan et al. and Pesaran & Xie Cross-sectional Dependency Tests

	CD	CDw	CDw+	CD*
UP	36.51 (0.00)	5.19 (0.00)	945.45 (0.00)	-0.53 (0.59)
DEMO	2.04 (0.00)	-0.94 (0.35)	210.94 (0.00)	-0.48 (0.63)
PD	93.48 (0.00)	3.83 (0.00)	1622.97 (0.00)	-0.62 (0.53)
LNAR	46.76 (0.00)	-1.00 (0.32)	1106.91 (0.00)	0.28 (0.78)
LNCP	51.27 (0.00)	5.65 (0.00)	1064.30 (0.00)	1.54 (0.12)
TMP	53.20 (0.00)	2.55 (0.01)	926.08 (0.00)	2.71 (0.00)
LNRAI	17.78 (0.00)	0.13 (0.89)	349.71 (0.00)	0.21 (0.83)

The panel unit root test with the null hypothesis of data being non-stationary at level results is displayed in Table 5. The variables DEMO, and PD are non-stationary at level while others are stationary. This mixed order of integration between variables requires the use of the panel ARDL model.

Table 5: Panel 2nd Generation Unit Root Test

	CIPS*	10% CV	5% CV	1% CV
UP	-2.618	-2.07	-2.15	-2.3
DEMO	0.298	-2.07	-2.15	-2.3
PD	-1.977	-2.07	-2.15	-2.3
LNAR	-2.452	-2.07	-2.15	-2.3
LNCP	-3.323	-2.07	-2.15	-2.3
TMP	-4.081	-2.07	-2.15	-2.3
LNRAI	-5.188	-2.07	-2.15	-2.3

Table 6: Panel Cointegration Test

	Statistic	Prob
Variance Ratio Test	3.478	0.00

The Westerlund test for cointegration (in Table 5) is found significant and shows that there is cointegration exists among the selected variables. It also indicates a long-run relationship among the panels.

Table 7: Panel ARDL Estimates Using Driscoll and Kraay Regression

Variables	Coef (Prob)	Variables	Coef (Prob)
Long Run Estimates		**Short Run Estimates**	
DEMO	1.087 (0.11)	ΔDEMO	0.272 (0.10)
PD	-0.059 (0.00)	ΔPD	-0.006 (0.82)
LNAR	-8.717 (0.00)	ΔLNAR	-3.675 (0.05)

LNCP	-7.895 (0.00)	ΔLNCP	-0.812 (0.00)
TMP	-66.363 (0.04)	ΔTMP	-10.732 (0.04)
TMP^2	0.769 (0.05)	ΔTMP^2	0.126 (0.05)
LNRAI	-0.344 (0.79)	ΔLNRAI	0.429 (0.03)
LNRAI^2	1228.868 (0.05)	ΔLNRAI^2	206.788 (0.04)
		ECM$_{t-1}$	-0.06 (0.00)
Cons	-634.63 (0.19)	Cons	-0.331 (0.05)
Regression Statistics			
Obs	750	Obs	725
Groups	25	Groups	25
F test	272.65 (0.00)	F test	41.92 (0.00)
R squared	0.741	R squared	0.085
Residuals Stationary	Yes		

The long-run and short-run impacts of climate change are captured by using Driscoll Kraay, a second-generation regression technique, for in-depth analysis, the error correction method (ECM) with pooled mean group specification has been used. The long-run estimates are illustrated in Table 7, with their respective standard errors and p-values in the first column. The data from 750 observations are used from 25 countries, leading to a significant F statistic confirming long-run estimates being an overall fit.

Here, the coefficient of democratic institutions (DEMO) is found to be positive but statistically insignificant, which reveals that current democratic institutions do not play an important role in the selected African countries in determining paths and scales of food security. The results are consistent with the ground realities of fragile African democratic institutions and their interplay with other key socio-economic sectors, as reported by the Economist, Oct 5, 2023[1]. The coefficient of population density (PD) is adversely and significantly related to food security (UP), and a 1% increase in density of population decreases the 0.06% of food security. Various factors are responsible for high population density in urbanization is one of them and the urbanization rate in Africa will be almost 41% in 2021. Therefore, population density affects food security by changing land use such as fertile agricultural land converted into industrial or residential colonies and food production shifts into less fertile lands for example, every year almost 2600 hectares of fertile agricultural land in Accra (Ghana) is converted into residential areas (Maxwell et al., 2000). Consequently, low food production puts pressure on food prices, particularly on the vast majority of the urban population as they are mostly net

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[1] https://www.economist.com/leaders/2023/10/05/why-africans-are-losing-faith-in-democracy?utm_medium=cpc.adword.pd&utm_source=google&utm_campaign=a.io_apac_content&utm_content=conversion.content.anonymous.apac_au_en_content-boosting_na_content_google_subs_dsa_other_content-boosting_na&gclid=EAIaIQobChMI-qfYp-CbggMVXYtoCR0pkwfFEAAYASAAEgIv6fD_BwE

buyers and dependent upon urban employment opportunities and cash income (Matuschke, 2009). Therefore, they choose high-calorie but less nutritious food.

The estimate of arable land (LNAR) shows negative and significant effects on food security (UP) in selected countries. A 1% reduction in arable land increases the prevalence of undernourishment by 8.7% since a large portion of the population is heavily dependent on existing arable land in the country. The countries are experiencing subsistence farming with a limited amount of cultivated land and a high rate of urbanization and industrialization, which in turn leads to lower per capita food production.

The coefficient of the next independent variable, cereal production (LNCP), is adversely but significantly related to the prevalence of undernourishment (UP). The estimate shows that a 1% decrease in cereal production increases the prevalence of undernourishment by 7.8%. It implies that a cereal chain with an increase in cereal production such as maize, wheat, barley and rice raises the quantity of cereals, mitigates the shortages of food, increases accessibility to nutritious food, brings food stability and eventually reduces undernourishment since the population of selected countries is largely dependent on cereals. In addition, an increase in cereal production also escalates the farmer's income and boosts backwards and forward linkage industries, resulting, in raising the purchasing power of people and enabling them to afford and buy a variety of nutritious food.

The coefficient of temperature (TMP) shows a significant positive relationship to the outcome variable i.e. the prevalence of undernourishment (UP). A 1^0c upsurge in annual average temperature decreases 66% of the prevalence of undernourishment (UP) in African countries. Contrarily, a rise in temperature square hurts food security, and A 1^0c rise in square of temperature (TMP^2) increases 0.7% of the prevalence of undernourishment (UP) since a sharp temperature rise will have negative effects on different phases of crops such as destruction of plant cells, flowering stages, grain filling stages (Fahmida, 2023) reduce cereal production and consequently food supply (Tariq et al., 2014; Affoh et al., 2022; Zahid et al., 2022) and nutritious food. Hoffman et al. (2018) pointed out that sub-Saharan African countries are experiencing rising temperatures with reduced yields of groundnuts, maize and sorghum and a greater number of undernourished people.

The coefficient of rainfall (LNRAI) is significantly and negatively connected with the prevalence of undernourishment, which indicates that rainfall helps to reduce undernourishment by increasing cereal production, agricultural income and livelihood in these sampled countries. It indicates a 1mm increase in rainfall reduces the 0.34% undernourishment. At the same time, the coefficient of rainfall square ($LNRAI^2$) is positively and significantly related to the prevalence of undernourishment by implying that 1mm intensification in rainfall raises the 1228% undernourishment prevalence in African food-insecure countries. Extreme climate events or climate variability have an adverse footprint on food security by deteriorating agricultural productivity, and physical availability of food and causing a high rate of undernourishment (Muttarak, 2019). However, the effects of a temperature rise were found to be more devastating for food security than the rainfall's positive effects. Further, extreme weather is responsible for changing patterns of local production of food by verging water resources and destroying arable land capacity in many regions of the globe (Fahmida, 2023). Various studies such as Abiona et al. (2016), Ifeanyi-obi et al. (2016) and Onyeneke (2018) made the point that climate change destructively sways arable land, and livelihoods and consequently, Nigeria is in the poverty trap. Further, Lewis (2017) reported that Ethiopia has undergone acute local food and nutritional insecurity due to the droughts even with the growth in cereal production in the current epochs.

Quadratic Effects of Climate Change on Food Security

The real-time quadratic effects of climatic changes on food security can be comprehended in the following Figures 1 and 2. Figure 1 shows a U-shape connection between temperature and the prevalence of undernourishment and provides evidence that undernourishment reduces as temperature decreases until a specific level and after that, it tends to increase as temperature rises by deteriorating soil quality, cereal production, agricultural gross domestic product and hence food security and consequently undernourishment upsurge with other various channels. In addition, the observed effects of rainfall on food security are presented in the following Figure 2, which spectacles a U-shape linkage between the prevalence of undernourishment and rainfall. This piece of evidence highlights the fact that the undernourishment upsurges as rainfall intensity increases after a particular level since rainfall of nearly 120 days is required for the growth of crops and cereals in rain-fed areas (Fahmida, 2023).

Figure 2: Temperature and Prevlenace of Undernourishment

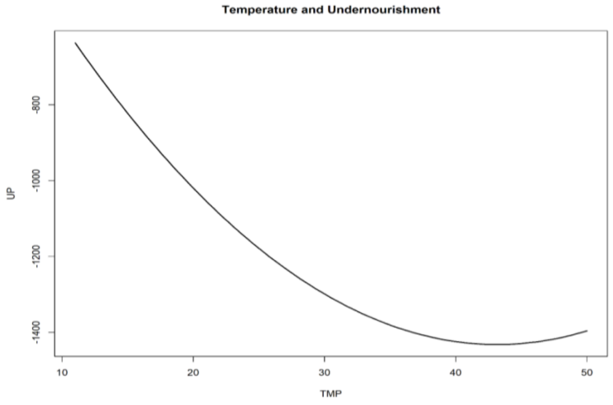
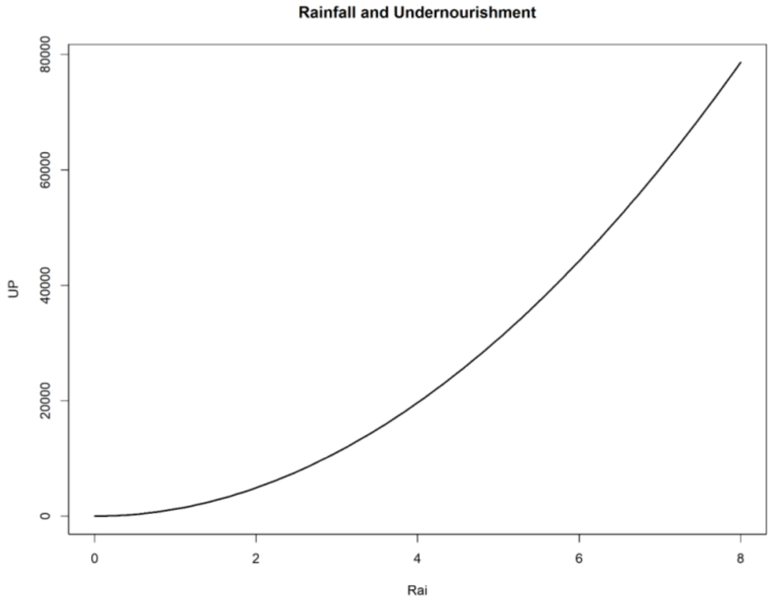


Figure 3: Rainfall and Prevlenace of Undernourishment



The residuals of the long-run estimated equations were calculated and found to be stationary at levels. Therefore, it can be interpreted that long-run is not spurious, and short-run estimates may hold.

The short-run estimates are enclosed in Table 7 with their one-to-one standard errors and p-values in the 3rd and 4th columns. Based on 725 observations adjusted to the first differences of variables, the overall short-run model is fit amid the significant F test. The estimated coefficient of democratic institutions (DEMO) is positive but statistically insignificant in the long run, which makes the appearance that democratic institutions do not play a fundamental role in the selected African countries.

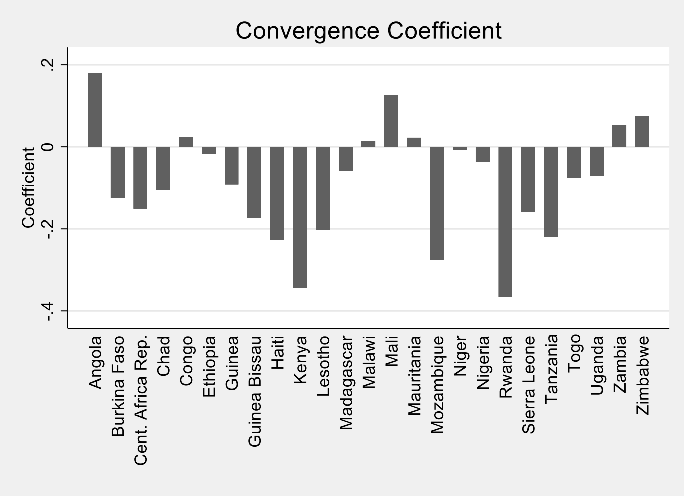
The next coefficient is related to the population density (PD), which is adversely and statistically insignificant associated with food security (UP), and a 0.001% increase in population density decreases the 0.1% of food security in the short run.

Here, the estimate of arable land (LNAR) shows negative and significant effects on food security (UP) in selected countries. A 1% decline in arable land increases the undernourishment prevalence by 3.67%; the results are similar to long-run estimates.

The result of the subsequent independent variable, cereal production (LNCP), is negatively and significantly linked to the prevalence of undernourishment (UP); moreover, it is similar in the long run. The estimate shows that a 1% lessen in cereal production upsurges the prevalence of undernourishment by 0.81%, which can be deduced that the population of these countries is heavily dependent on cereal production to fulfill their dietary needs. The estimated coefficient of temperature (TMP) shows a significant negative relationship to the outcome variable i.e. the prevalence of undernourishment (UP). A 1^0c increase in annual average temperature decreases 10.7% of the prevalence of undernourishment (UP) in African countries. Perversely, an upswing in temperature square has a positive effect on the prevalence of undernourishment (UP), and a 1^0c rise in the square of temperature (TMP^2) increases 0.13% of the prevalence of undernourishment (UP) even in the short run, since a sharp temperature rise will reduce cereal production, food supply and consequently availability and accessibility of nutritious food.

The short-run coefficient of rainfall (LNRAI) is significantly and positively allied with the prevalence of undernourishment, which specifies that rainfall exacerbates undernourishment by damaging cereal production, agricultural income, and livelihood in these sampled countries. It indicates a 1mm increase in rainfall increases the 43% undernourishment. At the same time, the coefficient of rainfall square ($LNRAI^2$) is positively and significantly related to the prevalence of undernourishment by implying that 1mm intensification in rainfall raises the 206.78% undernourishment prevalence in African food insecure countries. Extreme climate events or climate variability have an adverse impression on food security by increasing undernourishment even in the short run. As far as concern about the short run using Driscoll Kraay coefficient of error correction term, ECM is found to be negative and statistically significant, showing that there is convergence exists in the model. The speed of adjustment or convergence rate is 0.06%, which means this model will converge towards its long-run equilibrium.

Figure 3: Convergence Coefficients from Countrywide Short-Run Estimates



As Figure 3 clarifies only a few countries (Angola, Congo, Mali, Zambia and Zimbabwe) have positive ECM where the long-run relationship does not hold. At the same time, rest of the other countries such as Burkina Faso -0.12%, Central Africa -0.15%, Chad -0.10%, Ethiopia -0.1%, Guinea -0.1%, Guinea Bissau -0.17%, Haiti -0.22%, Kenya -0.34%, Lesotho -0.20%, Madagascar -0.5%, Mozambique -0.27%, Niger-0.01%, Nigeria -0.3%, Rwanda -0.37%, Sierra Leone -0.15%, Tanzania -0.22%, Togo -0.7% and Uganda -0.7% will likely to converge towards its long-run equilibrium.

Conclusion and Policy Implications

The bottom line deduction drawn from the present study is that climate change is affirmative and harmful, affecting food security with other control variables such as population density, democratic institutions, arable land and cereal production in African food-insecure countries. Moreover, a warmer climate and intensive rainfall adversely affect food security or worsen the condition of the prevalence of undernutrition. The long-run results of Discroll Kraay methodology clarify that population density (PD), arable land (LNAR) and cereal production (LNCP) are adversely and significantly related to food security (UP). At the same time, temperature and rainfall have a U-shaped effect on food insecurity.

Based on the above-estimated results, evidence policy suggestions can be devised for selected countries as there is a dire need to promote drought-sturdy crop varieties with crop rotation techniques in the agriculture sector such as in many parts of Africa, drought-sturdy maize varieties have been introduced and adopted. Reforestation and afforestation can help alleviate the adverse impacts of changing climate reduce soil erosion, and help to maintain the fertility of arable land. Although, in this study, the role of democratic institutions is found insignificant, it indirectly reveals that democratic institutions are deficient and not playing their due role in achieving the goal of food security in African countries under the challenge of climate change. Therefore, food and climate change governance could be strengthened by strengthening democratic institutions, hence governance. The population density rate is very high revealing that demand for residential land competes with land for growing food, therefore, it is imperative to devise sustainable urbanization strategies to ensure food security during times of high rate of urbanization coupled with climate change challenges.

Appendix

Sample Countries

Sr. No	Country	GHI	Sr. No	Country	GHI
1	Angola	45.9	14	Madagascar	28.9
2	Rwanda	44.2	15	Haiti	28.8
3	Ethiopia	41.5	16	Tanzania	28.6
4	Sierra Leone	38.1	17	Guinea-Bissau	28.5
5	Zambia	34.9	18	Nigeria	27.9
6	Niger	34.5	19	Togo	26.7

7	Chad	34.4	20	Zimbabwe	25.8
8	Central African Republic	33.8	21	Uganda	25.8
9	Mozambique	32.8	22	Congo, Rep.	24.9
10	Burkina Faso	30.4	23	Kenya	24.9
11	Malawi	30.3	24	Mauritania	23.2
12	Mali	30.2	25	Lesotho	22.8
13	Guinea	29.8			

Declarations

Ethical Approval: No human or animal experiments are used which require ethical approval.

Author Contributions: All authors have equally contributed to the study.

Funding: No funding or grant sources are utilized for this study.

Conflict of Interest: Authors declare no competing interest.

Data Availability: Data sources are mentioned in Table 1.

References

Abafita, J., & Kim, K. R. (2014). Determinants of household food security in rural Ethiopia: An empirical analysis. Journal of Rural Development/Nongchon-Gyeongje, 37(1071-2016-86950), 129-157.

Abiona, B. G., Fakoya, E. O. and Esun, J. (2016). The impacts of climate change on the livelihood of arable crop farmers in Southwest, Nigeria. In Innovation in Climate Change Adaptation, 289-296. Springer, Cham.

Affoh, R., Zheng, H., Dangui, K. & Dissani, B. M. (2022). The impact of climate variability and change on food Security in Sub-Saharan Africa: Perspective from Panel Data Analysis. Sustainability, 14(2), 759.

Anyika, V. O. (2023). Climate change and food security in sub-Saharan Africa: evolving African-based adaptability strategies. Journal of African Studies and Sustainable Development.

Arshed, N., Anwar, A., Kousar, N., & Bukhari, S. (2018). Education enrollment level and income inequality: A case of SAARC economies. Social Indicators Research, 140, 1211-1224.

Arshed, N., Nasir, S., & Saeed, M. I. (2022). Impact of the external debt on standard of living: a case of Asian countries. Social Indicators Research, 163(1), 321-340.

Badolo, F., & Kinda, S. (2014). Climatic variability and food security in developing countries. Etudes et Documents, (05).

Blackburne III, E. F., & Frank, M. W. (2007). Estimation of nonstationary heterogeneous panels. The Stata Journal, 7(2), 197-208.

Bocchiola, D., Brunetti, L., Soncini, A., Polinelli, F. & Gianinetto, M. (2019). Impact of climate change on agricultural productivity and food security in the Himalayas: A case study in Nepal. Agricultural systems, 171, 113-125.

Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T. & Stuth, J.W. (2005). The economic and food security implications of climate change in Mali. Climatic Change, 68(3), 355-378.

Daily, G. C., & Ehrlich, P. R. (1990). An exploratory model of the impact of rapid climate change on the world food situation. Proceedings of the Royal Society of London. Series B: Biological Sciences, 241(1302), 232-244.

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.

Dimitrova, A., Levy, M., Schwarz, L., Gershunov, A., Villanueva, M., & Benmarhnia, T. (2022, September). How agricultural droughts are contributing to child undernutrition in sub-Saharan Africa. In ISEE Conference Abstracts (Vol. 2022, No. 1).

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. Review of Economics and Statistics, 80(4), 549-560.

Eze, S. O. (2017). Constraints to climate change adaptation among cassava women farmers: Implications for agricultural transformation and food security in Ebonyi state, Nigeria. International Journal of Ecosystem and Ecology Science, 7(2), 219-228.

Fahmida. (2023). Climate Change and Food Security: An Empirical Investigation in Worldwide Perspective. National College of Business Administration & Economics. (unpublished PhD Thesis).

FAO, IFAD, UNICEF, WFP & WHO. (2017). The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

FAO, IFAD, UNICEF, WFP & WHO. (2018). The State of Food Security and Nutrition in the World 2017. Building climate resilience for food security and Nutrition. Rome, FAO.

FAO, IFAD, UNICEF, WFP & WHO. (2023). The State of Food Security and Nutrition in the World. Urbanization, Agrifood Systems, Transformation and Healthy Diets across the Rural-Urban Continuum. Rome, FAO.

Fischer, G., Shah, M. N., Tubiello, F. & Van Velhuizen, H. (2005). Socioeconomic and climate change impacts on agriculture: an integrated assessment, 1990–2080. Philosophical Transactions of the Royal Society B: Biological Sciences, 360 (1463), 2067-2083.

Hoffman, A. L., Kemanian, A. R., & Forest, C. E. (2018). Analysis of climate signals in the crop yield record of sub-Saharan Africa. Global Change Biology, 24(1), 143-157.

Ifeanyi-obi, C. C., Togun, A. O. & Lamboll, R. (2016). Influence of climate change on cocoyam production in Aba agricultural zone of Abia State, Nigeria. In Innovation in Climate Change Adaptation, 261-273. Springer, Cham.

Iqbal, M., Ul-Durar, S., Arshed, N., Shahzad, K., & Ayub, U. (2023). Connecting higher education and renewable energy to attain sustainability for BRICS countries: A climate Kuznets curve perspective. International Journal of Emerging Markets.

Juodis, A., & Reese, S. (2022). The incidental parameters problem in testing for remaining cross-section correlation. Journal of Business & Economic Statistics, 40(3), 1191-1203.

Lewis, K. (2017). Understanding climate as a driver of food insecurity in Ethiopia. Climatic Change, 144, 317-328.

Lind, D. A., Marchal, W. G., & Wathen, S. A. (2022). Basic statistics for business & economics. McGraw-Hill.

Matuschke, I. (2009). Rapid urbanization and food security: Using food density maps to identify future food security hotspots (No. 1005-2016-79128).

Maxwell, D. (Ed.). (2000). Urban livelihoods and food and nutrition security in Greater Accra, Ghana (Vol. 112). Intl Food Policy Res Inst.

Muttarak, R. (2019). Too few nutrients and too many calories: climate change and the double burden of malnutrition in Asia. Asian Population Studies, 15(1), 1-7.

Onyeneke, R. U., Igberi, C. O., Uwadoka, C. O. & Aligbe, J. O. (2018). Status of climate-smart agriculture in southeast Nigeria. Geo Journal, 83(2), 333-346.

Obwocha, E. B. (2015). Assessment of impacts of climate change and variability on food security in west Pokot County, Kenya. Unpublished Master’s Thesis, Kenyatta University, Kenya.

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G. & Livermore, M. (1999). Climate change and world food security: a new assessment. Global Environmental Change, 9, S51-S67.

Pesaran, M. H., & Xie, Y. (2021). A Bias-Corrected CD Test for Error Cross-Sectional Dependence in Panel Data Models with Latent Factors. arXiv preprint arXiv:2109.00408.

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. Econometric reviews, 34(6-10), 1089-1117.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics, 22(2), 265-312.

Ringler, C., Zhu, T., Cai, X., Koo, J. & Wang, D. (2010). Climate Change Impacts on Food Security in Sub-Saharan Africa. IFPRI Discussion Paper 01042 December 2010.

Rosenzweig, C. & Parry, M. L. (1994). Potential impact of climate change on world food supply. Nature, 367(6459), 133-138.

Tariq, A., Tabasam, N., Baksh, K., Ashfaq, M. & Hassan, S. (2014). Food security in the context of climate change in Pakistan. Pakistan Journal of Commerce and Social Sciences, 8(2), 540- 550.

Tirado, M. C., Hunnes, D., Cohen, M. J., & Lartey, A. (2015). Climate change and nutrition in Africa. Journal of Hunger & Environmental Nutrition, 10(1), 22-46.

Ul-Durar, S., Arshed, N., Anwar, A., Sharif, A., & Liu, W. (2023). How does economic complexity affect natural resource extraction in resource-rich countries? Resources Policy, 86, 104, 214.

Von Braun, J. (2008). Food and financial crises: Implications for agriculture and the poor (Vol. 20). Intl Food Policy Res Inst.

Westerlund, J. (2007). Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics, 69(6), 709-748.

Zahid, F., Hanif, U., & Javed, F. (2022). Climate change and food security: are Asian economies tracking sustainable development goals? IRASD Journal of Economics, 4(4), 561-582.

Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortés, S., & Downing, T. (2006). Climate variability and change: Implications for household food security. Assessment of Impacts and Adaptations to Climate Change (AIACC): Washington, DC, USA.