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The Impact of Climate Change on Food Security in Selected African Countries

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ABSTRACT

The study investigated the impact of climate change on food security in SANE countries, using yearly time series data from 1990 to 2020. The study used descriptive analysis to summarize the behaviour of the variables, second generation panel unit root to test the stationarity of the variables, the panel co-integration test was carried out using the Westerlund test co-integration technique to test the long-run relationship among the variables and it was discovered that there is a long run relationship among the variables. As a result of this, an augmented mean group (AMG) was used to examine the long-run dynamics of variables. The results of the study revealed that climatic change, namely temperature, has a negative and significant impact on food security in SANE countries, indicating a vulnerability of agricultural production to changing climatic conditions. Thus, the study therefore recommended that countries in the SANE region should prioritize their policy towards adopting a climatic-resilient agricultural practice, and also encourage the use of diversification of agricultural systems such as integrating crops with varying temperature sensitivity and agroforestry practices.

INTRODUCTION

1.1 Background of the Study

Anthropogenic activities and the subsequent release of greenhouse gases are believed to be responsible for the long-term, gradual shift in average weather patterns and global temperatures, which has been referred to as climate change (Osuafor and Nnorom, 2014; Onyimonyi, 2012; Yadav, Hegde et al., 2019). Climate change is an extensively deliberated topic and widely accepted phenomenon, which has been a growing concern particularly in Africa where its impact on agricultural productivity and food security is on the rise (Masipa, 2017; Laborde, et al., 2020; Rafiat-Ogunpaimo et al., 2021). Such changes have resulted in various ecological and environmental challenges like severe landslide, erosion, flooding, drought, pests and diseases which in turn have devastating effect on agriculture.

Numerous studies have demonstrated that climate change is a significant determinant of agribusiness productivity, as it affects temperature, precipitation, and carbon dioxide concentrations (Yadav et al., 2019; Rafiat-Ogunpaimo et al., 2021). For instance, statistical data indicate a substantial increase in temperature in Sub-Saharan Africa, making the region vulnerable to unpredictable weather changes and rising temperatures (Collins, 2011; Field & Barros, 2014). The semi-arid and sub-humid zones in West Africa, for example, have experienced an average reduction of rainfall by 15-40% over the past 30 years compared to the period between 1931 and 1960 (Nicholson et al., 2013). The worrying trend of decreased rainfall is likely to lead to water stress for up to 370 million people in Africa by the year 2025 (Chalchisa, 2016), thus demonstrating the urgent need for mitigating measures to address climate change impacts on agricultural productivity.

Also, the problem of food security has become one of the trending topics that have attracted growing attention in recent times. Africa is particularly affected, with severe food insecurity rising from 210.7 million to 277 million between 2014 and 2018, impacting 21.5% of the population in 2018 (FAO et al., 2019). Almost every sub-region in Africa is experiencing an increase in food insecurity, with Southern Africa having the highest prevalence at 30.6%, followed by Eastern Africa (25.9%), Western Africa (17.6%), and Northern Africa (8%). (Pickson and Boating, 2021). As a result, all components of food security, such as food availability, food accessibility, and food stability, will be affected, ultimately leading to unacceptable levels of poverty in sub-Saharan Africa (Coulibaly et al., 2018).

In Africa, climate change is recognized as a major environmental challenge, capable of undermining food security by reducing crop yields and having an impact on food prices (Kotir, 2010). Empirical evidence suggests that climate change's impact on food security has worsened with the increasing frequency of extreme weather conditions (Mendelsohn and Wang, 2017; Sigh and Thadani, 2015). There has been an alarming increase in global hunger and undernourishment, which is projected to increase by 60 million people in the next five years (FAO et al., 2020). These escalating figures are a clear indication that achieving the UN's Sustainable Development Goal of eradicating hunger by 2030 may remain a far-fetched reality (United Nations, 2015).

Against this backdrop, this research focuses on SANE (South Africa, Algeria, Nigeria, and Egypt) countries. These countries, situated in climate change-prone regions, face heightened risks from more frequent and severe droughts, heat stress, and variable rainfall patterns, which adversely impact agriculture, causing decreased crop yields, food scarcity, higher food prices, and overall food security concerns (Elum and Momodu, 2017; Masipa. 2017). In South Africa, the risks associated with climate change, pose a significant threat to food security by impacting the availability, accessibility, utilization, and affordability of food (Masipa. 2017). In Nigeria there has been an increased desert encroachment and severe drought in the Northern part of the country (Medugu, Majid & Choji, 2008; Abaje Ati, Iguisi & Jidauna, 2013). Also, Coastal cities in the country (Lagos and Port Harcourt), are facing the threat of flooding due to rising sea levels, heavy rainfall, and the absence of a proper drainage system for flooded water (Masipa, 2017). Finally, Algeria and Egypt face threats to food security as a result of climate change and associated factors, increasing temperature a high drought risk (Schilling et al., 2020). Given the complex interplay between climate change and food security in these SANE countries, there is the need to further investigate the impact of climate change on food security in SANE countries. Hence, this study aims to evaluate the long-run relationship between climate change and food security and also determine the overall impact of CO2 emission on food security in these SANE countries.

This study adds to the ongoing discussions on climate change and food security by focusing on Africa. This study will contribute to existing literature by providing a more comprehensive analysis of the relationship between climate change and food security in SANE countries which, best to authors' knowledge is inconclusive in existing literature. This will be done by addressing the question whether a long-run relationship exist between climate change and food security in SANE countries and what is the overall impact of CO2 emission on food security in SANE countries. The study will recommend cogent strategies to coping with the current level of food insecurity across the SANE economies which have severe impact on the global economy.

This study is guided by the following research hypotheses:

HO: there is no significant relationship between climatic change and food security in SANE countries.

HO: there is no significant impact of CO_2 emission on food security in SANE countries.

The remainder of this study is organized as follows: chapter two shall focus on the literature review which will consider the review of empirical findings of the previous studies on the subject. Chapter three will present the methodology. Chapter four of this study will be concerned with data presentation and analysis, and discussion of the results. Chapter five will present study conclusion and recommendations.

LITERATURE REVIEW

2.1. Climate Change and Food Security

The Food and Agriculture Organization (FAO) defines food security as a "situation which exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life". This definition of the FAO involves four important dimensions of food supplies: availability, stability, access, and utilization (Schmidhuber and Tubiello, 2007). The "availability" refers to the availability of food of appropriate quality in sufficient quantities, supplied either through domestic production or imports.

The "stability" relates to the stable access to food as per the demand because to be food secure, a population, household or individuals must have access to adequate amounts of food at all times. The third dimension, "access", involves access by individuals to adequate resources in order to acquire appropriate foods in sufficient quantity for a nutritious diet. Finally, "utilization" encompasses all food safety and quality aspects of nutrition. In other words, utilization of food through adequate diet, clean water, sanitation, and health care to reach a state of nutritional well-being where all physiological needs are met.

Agriculture is not only a source of the food but also a source of income for the majority of the population. Therefore, the critical point for food security is not whether food is available in sufficient quantity but the monetary and non-monetary resources at the disposal of the population that are sufficient to allow everyone access to adequate quantities of quality food. Climate change will affect all four dimensions of food security such as food availability or food production, access to food, stability of food supplies, and food utilization (FAO, 2006). About 2 billion out of the global population of over 7 billion is food insecure because they fall short of one or several of FAOs dimensions of food security. However, the overall impact of climate change on food security differs from region to region and over time, and also on the overall socioeconomic conditions of the population (IPCC, 2001).

2.2 Review of Empirical Literature

Many studies have focused attention on factors influencing food security. For example, on the cross-country level of analysis, following Krishnamurthy et al. (2020) early warning drought signals for food security. Pickson and Boateng (2021) in their study titled "Climate change: a friend or foe to food security in Africa?" This study presented new evidence of the role of climate change in Africa's food security using Mann–Kendall test and Sen's slope estimator to analyse climate change trends. Also, the study employed the pooled mean group technique and the Dumitrescu–Hurlin panel causality test to investigate the effect of climate change on food security in 15 African countries between 1970 and 2016. The empirical findings revealed three things. First, rainfall plays a decisive role in Africa's food security when examined broadly. However, the significance of the effect of rainfall varied substantially across the 15 countries. Secondly, there was no robust impact of temperature on food security in the long run. However, the short-run results showed that extreme temperatures impede food security, with varying magnitudes across countries. Thirdly, except for rainfall, a bidirectional causality exists between food security and temperature in Africa. Given the risks associated with rain-fed agriculture, the authors argue that African countries need to limit their dependence on rain-fed agriculture to boost food production.

Similarly, Affoh et al. (2022) investigated the relationship between climate variables such as rainfall amount, temperature, and carbon dioxide (CO2) emission and the triple dimension of food security (availability, accessibility, and utilization) in a panel of 25 sub-Saharan African countries from 1985 to 2018. After testing for cross-sectional dependence, unit root and cointegration, the study estimated the pool mean group (PMG) panel autoregressive distributed lag (ARDL). The empirical outcome revealed that rainfall had a significantly positive effect on food availability, accessibility, and utilization in the long run. In contrast, temperature was harmful to food availability and accessibility and had no impact on food utilization. Lastly, CO2 emission positively impacted food availability and accessibility but did not affect food utilization. The Granger causality test was conducted to determine the causal link, if any, among the variables. There was evidence of a short-run causal relationship between food availability and CO2 emission. Food accessibility exhibited a causal association with temperature, whereas food utilization was strongly connected with temperature. CO2 emission was linked to rainfall. Lastly, a bidirectional causal link was found between rainfall and temperature.

Ortega and Tachirley (2017) investigated "Demand for food safety in emerging and developing countries: A research agenda for Asia and sub-Saharan Africa". They looked at the literature on food safety economics in Asia and Sub-Saharan Africa (SSA), focusing on research that looked at consumer demand and producer behavior in relation to food safety. A special focus was placed on regions that needed more research. The review was exploratory in nature, with pertinent studies on food safety economics selected via Google Scholar and Web of Science and thoroughly examined in accordance with the review's aims. The findings demonstrate that as urbanization and income levels rise, consumers in emerging nations will become more conscious of food safety concerns. Nonetheless, they found that the cost of ensuring food safety in modernizing food systems was relatively high, despite the fact that current incomes in developing SSA were far lower than in Asia. Furthermore, consumers in SSA were found to be less knowledgeable of food safety issues than those in Asia.

Battese et al. (2017) looked into the factors that influence wheat farmers' productivity and efficiency in Punjab, Pakistan, in order to learn about strategies that can help small-scale and marginal wheat farmers improve their productivity and efficiency so that their households can benefit from zinc-fortified varieties. The survey design was utilized to estimate a stochastic frontier production model, and the data collected was used to do so. The newer wheat varieties had significantly higher productivities than the older varieties, according to the findings. This was determined to be in accordance with theory.

Kumar et al. (2018) examined if contract farming increase profits and food safety, evidence from tomato growing in Nepal", to determine how the financial benefits of contract farming (CF) and the implementation of food safety measures (FSMs) at the farm level may be assessed. The factors that influence CF involvement were also investigated. The study was based on a survey of 600 Nepalese tomato farmers. The data was analyzed using regression analysis and propensity score matching. According to the findings, CF provides farmers with improved returns and increased adoption of FSMs at the farm level. Furthermore, contract farmers' net returns are around 38% greater than independent farmers', and contract farmers' adoption of food safety measures is approximately 38% higher than independent farmers'.

To see how customers' food safety concerns and income levels affect vegetable consumption patterns and expenditure, Amfo et al. (2019) investigated "the effects of income and food safety perception on vegetable expenditure in the Tamale Metropolis, Ghana." The design was based on a survey of 300 metropolitan consumers. The data was examined using quantile regression analyses. In comparison to protein-rich foods, vegetables and cereals account for more than half of household food spending, according to the research. Despite the fact that impoverished households spent less money on food, the proportion of their income spent on food was found to be higher than wealthy households. Furthermore, while Bennett's law was found to apply to a range of food categories in high-income houses, Engel's law was found to apply to both composite and specific food classes.

Policy improvement and cassava attractiveness were investigated by Inegbedion et al. (2020). The goal was to discover the best rewards utilizing three different sales tactics in order to encourage the nation's economy to diversify while also ensuring food security. Data was collected from 360 cassava farmers using a cross-sectional survey design. The Howard policy improvement technique was used to anticipate projected rewards to cassava farmers employing the three techniques in the three local government districts. The findings suggest that cassava farmers will reap substantial benefits in the long run. This will encourage more unemployed individuals to take up cassava growing, thereby improving food security.

Cole et al. (2018) investigated "framing the food security dilemma against global megatrends" in order to tie future global food demand to the role of agriculture and food science in the production and stabilization of foods to meet that demand. They draw attention to major limits to food and agricultural systems, such as climate change and global megatrends, which are influencing the future globe. They discuss measures to reduce food waste and loss. In the face of global and industry global trends, their research reveals that agricultural production, food safety, health, and nutrition, as well as processing and supply chain efficiency, are all critical to food security. They believe that science should be approached in a multidisciplinary and collaborative manner.

In Ikere-Ekiti, Ekiti State, Nigeria, Oluwaseyi (2018) explored the influence of rural road transportation challenges on food security. A cross-sectional survey of 150 randomly selected farmers in selected villages in the study area was used as the research design. The target communities were chosen using COVID-19lockdownpurposive sampling. To obtain the essential data from the respondents, structured and semi-structured questionnaires were used. In the data analysis, descriptive statistics and the weighted mean were used. The findings revealed that the area's road transportation system was in bad condition. Due to the ineptitude of the body in charge of road maintenance in the area, inadequate road transportation is impeding agricultural production.

"Nigerian transport system, a threat to food security," according to Agramondis (2017) who worked on descriptive position paper. He believes that transportation is critical for agricultural product distribution and that enhanced rural transportation is critical for the preservation of fresh agricultural products in good condition. Furthermore, a well-functioning transportation system will boost agricultural output and boost agricultural product profitability. Similarly, terrorism in Northern Nigeria:

A Threat to Food Security in Maiduguri was examined by Awodola and Oboshi (2015). They looked at how Boko haram's terrorist actions in Maiduguri, Nigeria, have posed a danger to food security. In Maiduguri, a cross-sectional survey of 400 people was conducted. Primary data was gathered using administration questionnaires, interviews, observation, and elicitation. In order to analyze the data, descriptive statistics were used, such as frequency tables and percentage analysis. The findings of the data analysis revealed that Boko Haram's activities has an impact on the agricultural sector as a result of movement restrictions caused by a sense of insecurity brought on by terrorist activities.

Osundahunsi et al. (2016) looked into the "impact of food safety and security on Nigeria's economic change." They discovered that the biggest impediments to food security include conflicts, natural catastrophes, unemployment, insufficient technological deployment, and substantial post-harvest losses. It was urged, among other things, that gains in food and nutrition security should be adequately communicated, as well as their importance for the wellbeing of all members of society.

The above studies cover aspects of food security, including climate change, contract farming, consumer behavior, transportation challenges, and the impact of terrorism. While they provide valuable insights into these specific areas, there are still some gaps in the overall understanding of food security. Several of these studies focus on country-level or specific region research. Moreover, there is a need for a broader range of countries with diverse factors influencing food security. Also, one common weakness among the few panel studies is that none of them accounted for economic disturbance (common shocks' transmission) in their analysis, which in turn serves as a limitation. Thus, bridging these gaps can contribute to a more comprehensive understanding of the impact of climatic change on food security and inform the development of effective policies and interventions to ensure food availability, accessibility, and utilization for all.

THEORETICAL FRAMEWORK AND RESEARCH METHODOLOGY

3.1 Methodology

This study is focusing on determination of the impact of climate change on food security in SANE countries with the use of descriptive and quantitative methods of analysis using panel series data from 1990 to 2020. This study employed the following econometric method; (i) Three different Cross-sectional dependence (CD) tests to examine the existence of common shocks among the variables (ii) the paper employ Slope Homogeneity test suggested by Blomquist and Westerlund (2013)[1] to the validate whether or not homogeneity exist in the coefficients among cross-section (iii) Cross-sectional augmented Dickey-Fuller (CADF) tests suggested by Pesaran (2007) for its appropriateness in testing the order of integration for unbalanced data (iv) Panel cointegration test put forward by Westerlund (2007)[2], (v) Augmented mean group estimator (AMG)[3] proposed and developed by Eberhardt and Bond (2009), and Eberhardt and Teal (2010).

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[1] This test (applicable for small N relative T) is an extension of Pesaran and Yamagata (2008) Δ test due to its replacement of conventional contemporaneous covariance estimator with heteroskedasticity and autocorrelation consistent (HAC).

[2] This test is appropriate for series with the presence of common shocks.

[3] AMG estimator implements the inclusion of common dynamic process as the improvement of the standard mean group that utilises the first differenced pooled ordinary least squares (OLS) regression year dummies and group-specific regression, respectively, performing well for non-stationary variables with or without the presence of cointegration (Eberhardt, 2012).

3.2 Model Specification of the Study

From the foregoing theoretical framework, the model employed in this study is formulated in line with the objectives earlier stated in section one. The model specification for the study follows Pickson and Boateng, (2021) and Affoh et al., (2022). However, this study will adapt the model and modify it as follows:

$$FOSE_{it} = f\,(LCP_{it}, POP_{it}, GDPPC_{it}, CO2_{it}, TEMP_{it}) \qquad (1)$$

Where FOSE is food security and Cereal Yield is used as a proxy for FOSE in each country. LCP represents the cultivated area under cereal production, POP indicates population growth, GDPPC denotes GDP per capita, CO2 refer to carbon dioxide emission, and TEMP refers to average temperature used as a proxy for climate change. There is a need to take the natural logarithm of the selected variables so as to efficiently remove scale bias values in the panel series and to interpret the results in relation to their elasticity (Akam et al., 2021). As such, the research linearized and transformed equation 1 to obtain equation 2 given as;

$$\ln(\mathrm{FOSE})_{i,t} = \xi_0 + \xi_1\ln(\mathrm{LCP})_{i,t} + \xi_2\ln(\mathrm{POP})_{i,t} + \xi_3\ln(\mathrm{GDPPC})_{i,t} + \xi_4\ln(\mathrm{CO2})_{i,t} + \xi_5\ln(\mathrm{TEMP})_{i,t} + \mu_{i,t} - -(2)$$

$\xi_1 - \xi_4$ are expected to be positive while ξ_5 is expected to be negative in these countries.

3.3 Estimation Technique

The specified multiple regression models will be estimated using the AMG technique. The following econometrics and statistical diagnostic tests will be performed in order to ascertain the validity of the regression results:

Cross-sectional Dependence (CD) Test

This test is essential due to the fact that dependence among cross-sections is as a result of the unobserved common factors such as wide shocks in an economy (Chudike & Pesaran, 2013). Thus, ignorance of the CD can bring about inconsistent estimators and meaningless results (Dong et al., 2018; Nathaniel & Khan, 2020). In agreement with this, we employ the test LM based statistic of Breusch and Pagan (1980), the scaled LM_S test of Pesaran (2004), and the CD_P test of Pesaran (2004) are used[4]. Given the H_0 of weak cross-sectional dependence, the procedure of the asymptotically distributed CSD test is as follows:

$$CSD = \sqrt{2/N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\sqrt{T_{ij}}\,\hat{\rho}_{i,j}\right) - - - - - - -(3)$$

Where: $\hat{\mathrm{P}}_{ij} = \hat{\mathrm{P}}_{ji} = \dfrac{\sum_{t\in T_i\cap T_j}(\hat{\mathrm{U}}_{it}-\overline{\hat{\mathrm{U}}}_{\iota})(\hat{\mathrm{U}}_{jt}-\overline{\hat{\mathrm{U}}}_{J})}{\{\sum_{t\in T_i\cap T_j}\left(\hat{\mathrm{U}}_{it}-\overline{\hat{\mathrm{U}}}_{\iota}\right)^2\}^{(1/2)}\{\sum_{t\in T_i\cap T_j}\left(\hat{\mathrm{U}}_{jt}-\overline{\hat{\mathrm{U}}}_{J}\right)^2\}^{(1/2)}}$, $\overline{\hat{\mathrm{U}}}_{\iota} = \dfrac{\sum_{t\in T_i\cap T_j}\hat{\mathrm{U}}_{it}}{T_{ij}}$, and $T_{ij} = \#(T_i \cap T_j)$

$\hat{\mathrm{P}}_{ij}$ represents the correlation coefficient, $T_i \cap T_j$ represents the common periods of units j and I, and $\#(T_i \cap T_j)$ represents the numbers of $T_i \cap T_j$.

Slope Homogeneity Test

Since the evidence against the tradition assumption of homogeneous coefficient among cross-section of a panel analysis, the issue of whether or not constant coefficient holds has become more imperative in the empirical literature. For this reason, we employed the slope homogeneity test of Blomquist and Westerlund (2013) to establish whether the homogeneity assumption is satisfied. The test is beneficial to this paper because it handles the issue of heteroscedasticity and serial correlation, which till date cannot be overlooked in the panel literature. More importantly, the test reduces small sample bias by adding prewhitened HAC estimator.

Panel Unit Roots

Generally, it is imperative to ascertain the integration order of any series before employing any regression. This will give guidance to the application of subsequent techniques to be employed. For this reason, we estimate the second-generation (cross-sectional augmented Dickey-Fuller (CADF)) unit root test proposed by Pesaran (2007) to determine the order of integration among the variables of this paper. The choice of these tests is justified by their appropriateness in the presence of an unbalanced panel dataset (Firat, 2016). Besides, the second-generation unit root test has higher power in testing for non-stationarity among the cross-sections with common shocks (Baltagi, 2008). The H_0 this test indicates the existence of unit root in the series against the alternative hypothesis (H_1) of at least one stationary series. The standardized Im-Pesaran-Shin test can be expressed as follows:

$$Z_{IPS} = \frac{\sqrt{N}\left[\hat{\tau} - N^{-1}\sum_{i=1}^{N}E(\tau_i T_i)\right]}{\sqrt{N^{-1}\sum_{i=1}^{N}Var(\tau_i T_i)}} - - - - - - - - - - - - - - (4)$$

Where $Var(\tau_i T_i)$ and $E(\tau_i T_i)$ are the variance and exact mean of the Dickey-fuller statistics based on time dimension observation. As N moves towards infinity, $Z_{IPS} \overset{d}{\rightarrow} N(0,1)$ and $T_i > 6$[5]. Also, the CADF statistics is given as:

$$\Delta y_{i,t} = \beta_i + \rho_i y_{i,t-1} + c_i\bar{y}_{t-1} + d_i\Delta\bar{y}_t + u_{i,t} - - - - - - - - (5)$$

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[4] These tests are applicable for unbalanced heterogeneous panels. The benefit of Breusch and Pagan (1980) LM test over the Pesaran (2004) CD_P and LM_S tests, is a result of it application for small cross-sectional unit (N) relative to large time variation (T). However, Pesaran (2004) LMs test is applicable for N →∞ and T →∞ while Pesaran (2004) CD*p* test have a good property when N and T is small.

[5] See Im et al. (2003) for the additional complication of applying unit root tests with panel data.

Where y_{it} represents the variable being tested. The delay of t-statistics mean value in the CADF regression, produces a cross-sectional augmented Im, Pesaran, and Shin (CIPS) value, which is the augmented variant of Im, Pesaran, and Shin (2003) unit root test. This can be written as:

$$CIPS(N,T) = \bar{T} = N^{-1}\sum_{i=1}^{N} t_i(N,T) ------------ (6)$$

Where N and T are the numbers of cross-sectional dimension and time dimension, respectively. $t_i(N,T)$ represents the cross-sectional augmented Dickey-Fuller (CADF) statistics, given the t-ratio of the coefficient. The CADF statistics is seen as a modified version of the t-bar of Im et al. (2003) unit root test, Z test (inverse normal test) of Choi (2001), and the P test (inverse chi-square test) of Maddala and Wu (1999)[6].

Panel Cointegration Test

To ensure accuracy in the findings of the long-run relationship among the variables, we analyse the second-generation cointegration test proposed by Westerlund (2007). With a good small-sample performance, the test is suitable for unbalanced series (Odhiambo et al, 2019). The test assumes H_0 of no co-integration against the H_1 of at least one co-integration in the panel. In a broad view, the test is essential given the existence of common shocks, non-existence of common shocks, and integrated variable with heterogeneity degree both in short-run dynamics and long-run relationships (Westerlund, 2005; 2007; Westerlund & Edgerton, 2007; Persyn & Westerlund, 2008). For simplicity, the model is summarised as:

$$\Delta y_{it} = \delta'_i d_t + \alpha_i y_{i,t-1} + \lambda'_i x_{i,t-1} + \sum_{j=1}^{P_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{P_i} \gamma_{ij} \Delta x_{i,t-j} + e_{it} --(7)$$

Where: i, t and δ'_i denote the cross-sectional units, time-series, and the vector parameter respectively. d_t contains three deterministic components; $d_t = 0$ (deterministic term), $d_t = 1$ (constant term), and $d_t = (1,t)'$ (both constant and trend). Hence, Δy_{it} generates absence of d_t. Also, α_i is the error correction parameter. $\alpha_i < 0$ and $\alpha_i = 0$ implying that co-integrating and non-co-integrating relationship exist between y_{it} and x_{it} respectively.

Long-run Estimator

To estimate the long-run impact among the variables, we employ the augmented mean group (AMG) estimation proposed and developed by Eberhardt and Bond (2009), and Eberhardt and Teal (2010). AMG estimator implements the inclusion of common dynamic process as the improvement of the standard mean group that utilises the first differenced pooled ordinary least squares (OLS) regression year dummies and group-specific regression, respectively, performing well for non-stationary variables with or without the presence of cointegration (Eberhardt, 2012). The benefit of using this estimator is due to the allowance of CD in the panel estimates while eliminating asymptotical bias resulting from endogeneity of the variables (Pesaran, 2015; Fotis & Polemis, 2018). The AMG estimator requires a two-step procedure:

AMG - Step 1: $\Delta y_{it} = \alpha_i + b_i \Delta x_{it} + c_i f_t + \sum_{t=2}^{T} d_t \Delta D_t + e_{it} --- (8)$

AMG - Step 2: $\hat{b}_{AMG} = N^{-1}\sum_{i=1}^{N} \hat{b}_i ----- (9)$

The observables are represented by y_{it} and x_{it}, while f_t and $\hat{b}_{AMG}$ are the unobserved common factor and the AMG estimator respectively.

3.4 Sources and Measurement of Data

The study employed secondary data obtained from the World Development Indicators (WDI, 2022) and Climate Knowledge portal (2022). The data were available from 1990 to 2020. The dependent variable is food security (FOSE) proxied by Cereal Yield and the independent variables are land size under cereal production (LCP), Gross Domestic Product Per Capita (GDPPC), CO2 Emission (CO2), Temperature (TEMP), and population growth (POP). The inclusion of population growth was to capture the effect of population growth on Food Security and its impact economic development from the theoretical and empirical review point view.

The variables, interpretation, measurement and the source are shown on the table 3.1 below.

Table 1: Data Sources and measurement

Variable	Description	Measurement	Units	Source
FOSE	Food security	Cereal Yield	Kg per hectare	World Development Indicators (2022)
POP	population	Total population for each country	Millions	World Development Indicators (2022)
LCP	Area of Land use for Cereal production	Area of Land use for Cereal production	Hectare	World Development Indicators (2022)
GDPPC	Gross Domestic Product Per Capita	Gross Domestic Product divided by total population.	Percent	World Development Indicators (2022)
CO2	Carbon Dioxide	CO2 emission	Metric tons per capita	World Development Indicators (2022)

Sources: World Development Indicators WDI (2022) and Climate Knowledge portal. World Bank (2022)

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[6] See Pesaran (2007) for the full information on the modification of these test.

DATA PRESENTATION AND DISCUSSION ON THE RESULT

4.1 Descriptive Statistics

Based on the descriptive result, table 2 reveals that the mean values of CO_2 and TEM for the overall SANE countries are 0.82 metric tons and 23.1 °C, respectively. However, as seen by individual countries in SANE community, Algeria has the maximum value of CO_2 emissions (3.04 metric tons) and Nigeria has the maximum value of temperature (27.3 °C), while Egypt has the minimum value of CO_2 emissions (0.65 metric tons) and South Africa has the minimum value of temperature (18.4 °C). The mean values of cereal yield (FOSE) and area of land use for cereal production (LCP) for the SANE countries are 3,167.89 Kg per hectare and 6,802,894 hectare, respectively. Amongst these countries, Egypt appears to have more FOSE (6,875.94 Kg per hectare) and Nigeria has more LCP (17,367,464 hectare), while Algeria appears to have less FOSE (1,243.139 Kg per hectare) and LCP (2,633,378 hectare).

Table 2: Descriptive statistics

	Statistics	FOSE	GDPPC	LCP	POP	CO2	TEM
South Africa	Mean	3181.461	5360.038	4329391	49427211	1.954209	18.4129
	Maximum	5331.8	6263.104	6184004	58801927	2.132899	23.88
	Minimum	944.7	4269.7	2933838	39877570	1.743764	17.33
	Standard D.	1124.521	766.0811	1020879	5373506	0.129132	1.104123
	observation	31	31	31	31	30	31
Algeria	Mean	1243.139	3568.347	2633378	33701063	3.041631	23.60452
	Standard D.	1952	4246.244	3663945	43451666	4.010025	24.1
	Maximum	687.7	2810.728	1058184	25518074	2.466385	22.78
	Minimum	356.7736	502.3358	727224	5204753	0.540442	0.301428
	observation	31	31	31	31	30	31
Nigeria	Mean	1371.039	1988.274	17367464	145000000	-0.38722	27.29903
	Standard D.	1733.4	2679.555	19410000	208000000	-0.08727	27.86
	Maximum	1094.1	1429.012	13890000	95214257	-0.71052	26.59
	Minimum	195.5817	465.1341	1276647	34602950	0.177913	0.292351
	observation	31	31	31	31	30	31
Egypt	Mean	6875.942	2812.466	2881343	80361682	0.646934	23.11387
	Standard D.	7556.2	3836.091	3624914	107000000	0.871186	24.56
	Maximum	5613	1987.037	2283426	57214630	0.336643	21.9
	Minimum	627.8318	584.7222	320478.1	15221426	0.192183	0.523556
	observation	31	31	31	31	30	31
Panel	Mean	3167.895	3432.281	6802894	77065773	0.827952	23.10758
	Standard D.	7556.2	6263.104	19410000	208000000	2.132899	27.86
	Maximum	687.7	1429.012	1058184	25518074	-0.71052	17.33
	Minimum	2378.608	1380.028	6223711	46763224	0.864049	3.232958
	observation	124	124	124	124	120	124

4.1.2 Cross-sectional Dependency (CD) Tests

Table 3 presents the evidence of CD among the SANE countries. The implication of this is that FOSE, GDPPC, LCP, POP, CO2, and TEM exhibit transmission of shock across the SANE countries. Due to the existence of heterogeneity and CD, the study considers the second-generation estimation approach in subsequent sections.

Table 3: Cross-sectional Dependence Results

Variables	*Breusch-Pagan LM*	*Pesaran scaled LM*	*Pesaran CD*
FOSE	60.57***	15.75***	7.55***
GDPPC	168.85***	47.01***	12.99***
LCP	26.42***	5.89***	-2.75***
POP	185.03***	51.68***	13.6***
CO2	128.99***	35.50***	-0.11***
TEM	47.66***	12.02***	5.47***

Note: *** implies statistical significance at 1% level.

4.1.3 Second-Generation Unit Root Test

The result in Table 4 suggests the existence of unit root among panel series. The outcomes of all variables show that we fail to reject the null hypothesis of unit root at level but reject ($p < 0.01$) afterward, at their first difference. Thus, the variables exhibit the first-order integration i.e., I (1).

Table 4: Unit Root Results

Variables	***Level***		***First Difference***	
	T-bar	***Z(T-bar)***	***T-bar***	***Z(T-bar)***
FOSE	-1.364	-0.154	-5.131***	-6.022***
GDPPC	-2.685	-1.761	-5.237***	-6.485***
LCP	-3.294	-3.16	-4.163***	-4.250
POP	-2.498	-0.304	-3.518***	-4.654***
CO2	-3.133	-1.526	-5.154***	-6.156***
TEM	-2.061	-0.522	-4.712***	-5.219***

Note: indicate statistical significance at the 1% level.***

4.1.4 Second-Generation Cointegration Test

Table 5 reveals the rejection of the null hypothesis of no cointegrating relationship for the equation in chapter 3 at a $p < 0.01$ significance level. Hence, this validates steady long-run relationships among the included series for model. More so, the result in Table 5, allows the study to reject the first null hypothesis of no long-run relationship between climate change and food security in SANE countries. The implication of the result is that there is a persistent and stable movement among FOSE, GDPPC, LCP, POP, CO2, and TEM in the long-run, and correction will be applied in case of any deviation from that long-run trend. Also, if there is a change in any of these variables, it will have a lasting impact on others included in the study.

Table 5: **Results of the Westerlund Co-integration Test**

Variables	**Estimate**	**Statistics**
Log (FOSE), log (RGDP), log (LCP), log (CO2) and log (TEM)	Variance Ratio	-1.6673**

Note: ** denote significance at 5 %.

4.1.5 Second-Generation Long-run Impact Test

Table 6 presents the results of an Augmented Mean Group (AMG) model for the country of study. As seen in Table 6, the result accepts the second null hypothesis of the study (no significant impact of CO_2 emission on food security in SANE countries). This is because the result for Table 6 (column 1) shows that carbon emission *(CO2)* negatively but insignificantly explains food security (FOSE), on average, *ceteris paribus*. The outcome suggests that the reduction of CO2 is insufficient and inadequate to an extent to speed up and enhance food security performance across SANE countries. Contrarily, the research rejects the null hypothesis (second hypothesis) of no significant impact of climate change proxied as temperature on food security in SANE countries. This is evidenced in Table 6 (column 1). For instance, the outcome suggests that temperature exert negative and significant (at 5% level) impact on food security across SANE countries. Thus, a negative temperature elasticity coefficient of approximately 2.17 indicates that a rise in temperature leads to a greater than one rise in food security, in the long run. The outcome suggests that high temperature is sufficient to an extent to speed up and enhance food insecurity across SANE region. Similar to the result of the overall SANE countries, CO_2 emission does not significantly impact individual countries within SANE. However, two (2) out of the member countries (Algeria and South Africa) exert a negative and significant temperature and food security relationship. The elastic coefficients of temperature varies across these two countries, ranging between -8.05 (Algeria) and -0.9 (South Africa). The suggested outcomes suggest that high temperature is sufficient to an extent to speed up and enhance food insecurity in both Algeria and South Africa.

Further, in relation to other variables, land size used for cereal production (LCP) has a significant positive impact on cereal yield (proxy for food security) in the overall SANE region and two of its individual countries (Algeria and Nigeria). Also, population size has a negative and significant impact on food security in the overall SANE region and two of its individual countries (Algeria and South Africa).

Table 6: AMG Results

Variables	***Log (FOSE)***				
	SANE	ALGERIA	NIGERIA	EGYPT	SOUTH AFRICA
log (RGDP)	0.39	0.08	0.14	-0.63	1.99
	(0.71)	(0.13)	(0.71)	(-0.9)	(2.57)
Log (LCP)	0.39***	0.33***	0.405**	0.53	0.76
	(2.67)	(3.49)	(2.23)	(0.21)	(2.96)
log (POP)	-3.429**	-5.5***	0.191	-1.05	-7.35***
	(1.92)	(-3.12)	(0.35)	(-1.54)	(-4.8)
log (CO2)	-0.026	0.017	-0.18	0.43	-0.38
	(-0.15)	(0.03)	(-1.22)	(1.27)	(-0.73)
log (TEM)	-2.17**	-8.05***	1.55	-1.25	-0.9**
	(-1.05)	(-2.59)	(0.96)	(-1.21)	(-0.73)
_cons	64.33**	120.41	-9.43	35.36***	111.01***
	(2.07)	(3.75)	(-0.85)	(2.91)	(4.04)\

Note: ***, ** and * show significance at 1%, 5%, and 10% levels respectively. ( ) are the t-stat.

4.2 Discussion on the Result

This section of the study is concerned with the discussion on the empirical results of the key findings of the data analysis. For instance, in table 6, the long-run impact result shows that ranging between 1% and 5% level of significance, land size used for cereal production (LCP) has a significant positive impact on cereal yield (proxy for food security). Therefore, an increase in the area of land use for cereal cultivation boosts food security for the overall SANE region and two of its individual countries (Algeria and Nigeria). This is not surprising as land availability is a critical factor input in the production process. For instance, Nigeria has a large extent of arable land for cereal production (as seen in Table 2) compared to other countries in the study. This is because land management practice plays a vital role in maintaining sustainable cereal production and meeting high demand for cereal crops (Oloyede et al., 2016). Besides, these practices are important in small-scale farming systems, which make up a significant portion of agricultural production in Nigeria. Also, efficient land use practices are essential in Algeria, as the country's diverse agro-climatic zones and varying soil conditions require careful land selection and utilization for different cereal crops (Mahdjoubi et al., 2020)

Again, the report in the Table 6 revealed that population is one of the major threats to food security in the region with Algeria and South Africa inclusive, as unit increase in population induced a decrease in cereal yield. Therefore, Malthusian theory of population of 1798 has implication for the Algeria and South Africa food security. Obviously, increase in population of these countries will be a disadvantage to food security. These results are not surprising as Tailman et al. (2011) assert that population growth present a significant challenge to food security due to its impact on global food demand. Thus, as the world population grows, the demand for food also rises, placing pressure on agricultural systems to produce more food.

Further, as reported in the Table 6, at 5% level of significance, temperature has a significant negative impact on cereal yield. Therefore, a percentage increase in temperature will lead to a decrease in cereal yield in the overall SANE region. Thus, without effective adaption and genetic improvement, each degree Celsius increase in the temperature, would, on average, reduce crop yield in the region. In term of individual countries (Algeria and South Africa), the specific impact of temperature on crop may be on the various factors such as local climatic conditions, agricultural practices, and adaptive strategies. However, it is reasonable to expect that increasing temperatures would have a detrimental effect on crop production of these countries, given the negative relationship between temperature and crop yields (Zhao et al., 2017).

Remarkably, these findings are consistent with findings from previous studies. For instance, this study found that there is a long run negative and significant impact of temperature on food security in the overall SANE region and two of its countries. The finding of a negative relationship between temperature and cereal crop production this study is consistent with several other studies. Asseng et al. (2014) found that rising temperatures have a negative impact on global wheat production. They reported that increasing temperatures are a major source of uncertainty in simulating the impact of climate change on crop yields. Similarly, Jabbi et al. (2021) observed a negative correlation between temperatures and cereal crops in the Gambia. They attributed this negative relationship to increased evapotranspiration and reduced soil moisture.

Other studies have also reported the adverse effects of temperature on cereal crop production. Htoo (2022) found that higher temperatures negatively affect cereal production in Myanmar. Asfaw & Beyene (2022) identified a negative impact of temperature on cereal crops in Ethiopia. Additionally, Shirazu et al. (2022) found that cereal crop yields in northern Ghana are adversely affected by temperature variability.

CONCLUSION AND RECOMMENDATIONS

Conclusion

In conclusion, the study did not find a significant impact of CO_2 emissions on food security in most SANE countries. This highlights the localized nuances of environmental impact on food security. Further, larger land size dedicated to cereal production positively influences food security, emphasizing the importance of optimizing land resources for agricultural purposes. Conversely, higher population sizes were found to have a negative impact on food security, underscoring the need for responsible population management. In addition, the study underscores the intricate interplay between multiple factors influencing food security, including climate variables, economic indicators, land use, and population. These findings emphasize the need for holistic and multifaceted approaches to address food security challenges.

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