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Food Security in Africa: Challenges of Climate Change and Energy Opportunities

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Abstract

Climate change is regarded as one of the most significant challenges facing humanity in the 21st century. Rising temperatures and decreasing rainfall are expected to put pressure on resources, especially for agriculture and food production. This study addresses this issue by adopting a panel data approach in an attempt to examine the impact of climatic factors on food security in Africa from 2000 to 2020 for a sample of 12 countries. In order to empirically investigate the link between the three components, climate change, food security, and renewable energy, a combination of estimation models must be implemented, including the fixed-effect model, the random-effect model, and the feasible general linear least squares (FGLS) regression model. Furthermore, a series of diagnostic tests are incorporated to assess the validity and robustness of the estimated model. Specifically, it examines the presence of the autocorrelation, heteroskedasticity, and the normality of residuals, ensuring that the model satisfies the fundamental statistical assumptions required for reliable inference. The empirical results conducted in this study confirm that the use of renewable energy has a significant negative impact on food security, while the climatic factors, temperature and precipitation, a positive influence on the food security significantly.

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1. Introduction

Climate change is regarded as one of the most significant challenges confronting the planet in the future. The adverse effects of climate change are already evident and are projected to intensify, impacting natural ecosystems, biodiversity, human health, water resources, and numerous economic sectors, including food security, human health, economies, and society. Additionally, there is a loss and damage to nature and the populations (Calvin, 2023).

Climate change is a matter of significant concern, exerting a substantial influence on economic, social, and environmental domains. The sustained increase in carbon dioxide (CO_2) emissions has precipitated rising global temperatures, thereby contributing to climate variability over extended periods. The emphasis on CO2 emissions is of the utmost importance due to its capacity to induce global warming and the myriad challenges it engenders with respect to public health and environmental sustainability. The ramifications of CO2 emissions extend beyond national borders, exerting a detrimental influence on the planet as a whole. This issue necessitates a collaborative, global, and regional response to combat and mitigate against climate change. It is beyond the capacity of any single individual to solve this problem alone (Ikram, Zhang, Sroufe, & Shah, 2020).

The determination of future climate change and associated risks, as well as their impact on agricultural production, is very uncertain for several reasons. Therefore, it is necessary to know the relationship between climate change on agricultural production and land use. The effects of climate change have a major impact on the yields and quality of agricultural. These impacts are causing challenges to agriculture for the next decades because of the increase in temperatures that wentinerait a reduction in the levels of carbon and nitrogen in the soil, which may reduce the yield potential of crops (OECD, 2022).

The agricultural sector is particularly sensitive and vulnerable to climate change. It is an industry that creates jobs and ensures food security. This sector is going to undergo fundamental changes over the next century. These changes will have an impact on the whole economy and society, as well as on the demand for food and natural resources. Therefore, it is imperative to take adaptation measures to mitigate and anticipate the effects of climate change on the agricultural sector (OECD & Food and Agriculture Organization of the United Nations, 2023).

The main objective of this study is to address the critical issue of climate change and its impact on food security in Africa. This analysis seeks to provide a comprehensive analysis of this issue by examining the impact of climatic factors and the use of renewable energy on food security in Africa using the approach of econometric panel data models. This will provide answers to the following questions:

How to renewables little frit its contribute to the strengthening of food security in Africa in the face of the challenges of climate change?

Given our concern, we seek to verify the following hypotheses.

H_1: The factors of climate change could threaten the food security in Africa.

H_2: The integration of renewable energies in agriculture can improve food security in Africa.

The present article is structured in two parts to facilitate the answering of the research question. In the first section, a brief review of the literature on the relationship between the three components of food security, renewable energy, and climate change is presented. This literature review is conducted to enhance comprehension of the current major draws. In the second section, the empirical results of the study are analyzed and discussed.

2. Literature Review

2.1. Food Security and Change Climate

Food security is a pressing concern for the world in the 21st century. It is closely linked to other pressing global challenges, such as climate change. Changes in climate have a direct impact on crop yields, reducing the availability of adequate food for populations in affected countries (Kogo, Kumar, & Koech, 2021).

The World Food Conference, which was convened by the Food and Agriculture Organization of the United Nations (FAO) in 1974, is widely considered to be a seminal occurrence within the domain of food security. In the context of this conference, the significance of food availability as a factor influencing food security was formally acknowledged. The term "food security" was formally defined in 1986 by the World Bank as "the access of all people to sufficient food to lead an active and healthy life at any time." However, this definition overlooked the considerations of accessibility and availability of food (Al-Sulaiti & Baker, 1998). According to the 1996 definition established by the Food and Agriculture Organization (FAO), food security is defined as "a situation in which all people, at all times, have access to physical, social, and economic resources that are sufficient, safe, and nutritious, and that meet their dietary needs and their food preferences for an active lifestyle and healthy" (FAO, 1996). The attainment of food security is predicated on the fulfillment of four conditions pertaining to the food system: availability, access, stability, and utilization (Ghattas, 2014).

According to Abd-Elmabod et al. (2020) one in ten people worldwide is facing severe food insecurity, despite the efforts to establish practices and policies to ensure global food security. Thus, an extensive exploitation of resources can lead to land degradation and a reduction of their productivity, while malnutrition is expected to increase with population growth. Climate change has been linked to an increase in pest and disease problems, as well as to increasingly extreme weather events, including droughts and floods. These conditions can lead to crop failure or loss (Abd-Elmabod et al., 2020).

In addition, the growing demand for products and changes in dietary habits are leading to an increasing usage of land and water resources, as well as challenges for ensuring enough food for everyone. Therefore, the global program Food Security requires international action fast, and a global food safety insurance (Ruben, Verhagen, & Plaisier, 2018).

The repercussions of climate change on agriculture will result in a decline of the global GDP by 2050 due to the direct and indirect ramifications on agricultural production, stemming from alterations in water availability, potential evapotranspiration, and irrigation. In addition, the traditional agricultural practices, development, inadequate infrastructure and transportation issues, contributes to the susceptibility of the country to the climate. Therefore, an assessment of the effect of climate change on agriculture is imperative for enhancing awareness of the issue, quantifying its impact, and facilitating the development of adaptation strategies that can maximize opportunities while minimizing costs, with the aim of promoting sustainable agricultural development (Liu, Lan, Chien, Sadiq, & Nawaz, 2022).

2.2. Food Security and Renewable Energy

The production of renewable energy is regarded as a sustainable strategy to replace fossil fuels and mitigate climate change, while increasing global demand for energy. For this reason, many countries have set the goal to increase the share of renewable energy production in the coming decades (Schweiger & Pataczek, 2023).

The nexus between energy and sustainable agriculture extends beyond the utilization of renewable energy sources, encompassing a broader array of practices. The objective of sustainable agricultural practices is twofold: first, to minimize the environmental impact, and second, to improve long-term productivity. The role of energy in achieving these objectives is pivotal. The adoption of energy-efficient technologies, such as precision agriculture and advanced irrigation systems, has the potential to optimize resource utilization, minimize waste, and decrease emissions (Majeed et al., 2023).

The rising price of food and oil prices in 2008 has deepened the debate between the food and energy, although it has existed since the 1970s. The competition for resources to use in food and nutrition is relevant in this debate. Energy security is an important factor for the development of bioenergy, but the competition in this context has two dimensions: first, the competition between food and food uses, and second, the competition with the agricultural resources (Koizumi, 2013).

The production of energy threatens food security by reducing the land available for agriculture due to the extraction of fossil fuels or deforestation to produce biofuels. To mitigate the competition between biofuel and food production for access to land and water, biofuels could be produced on marginal lands and degraded. Energy crops cultivated on abandoned land can help revitalize these areas while ensuring food security and strengthening food production systems (Fritsche, Barth, Jugert, Masson, & Reese, 2018).

Renewable energy systems have the potential to provide decentralized energy sources and reliability to farming communities and rural areas, thereby improving their resilience to external perturbations and generating economic opportunities. Furthermore, the relationship between renewable energy and agriculture is crucial for the development of a sustainable food production system that is environmentally friendly, economically viable, and resilient in the face of future challenges (Zlaoui et al., 2023).

The integration of renewable energy sources within agricultural practices has the potential to help farmers reduce carbon dioxide emissions, enhance energy autonomy, and contribute to climate change mitigation. Renewable energy solutions in agriculture offer a multifaceted benefit, including environmental advantages, cost savings, energy independence, and enhanced resilience in the face of energy market volatility. This contributes to the promotion of a sustainable agricultural sector and a resilient energy infrastructure, while facilitating the transition to a future low-carbon and energy-efficient economy (Yu et al., 2023).

In the context of agriculture, the dearth of adequate infrastructure imposes limitations on the capacity to conduct large-scale experiments, field trials, and long-term monitoring. Consequently, this hampers the generation of robust data and evidence-based solutions. Indeed, conducting a review of research in the agricultural sector is of utmost importance for reasons that extend beyond the aforementioned limitations. A thorough review facilitates a re-evaluation and systematic updating of key indicators. The agricultural sector is distinguished by its dynamism and vulnerability to constant change in environmental conditions, technological developments, and market forces (Bathaei & Štreimikienė, 2023).

2.3. Review Empirical

In the extant literature, numerous studies have been conducted to examine the impact of factors such as climate change, economic growth, and renewable energy, along with other relevant variables, on food security. These studies have employed various relations to analyze the impact on developing countries and developed countries in the short and long term. Many studies have been initiated to examine the relationship between climate change and agriculture, as determined by precipitation and temperature metrics, across diverse economic systems and employing various econometric methodologies. Additionally, other researchers are exploring the nexus between renewable energy and agriculture (Chandio, Jiang, Rehman, & Rauf, 2020; Máté, Rabbi, Novotny, & Kovács, 2020; Tagwi, 2022).

In their study, Rehman, Ozturk, and Zhang (2019) employed the ARDL model to examine the relationship between agricultural productivity and carbon dioxide (CO_2) emissions in Pakistan. Their findings indicated a substantial correlation between CO_2 emissions and the cultivated area, energy consumption, fertilizer usage, and GDP per capita water availability. Conversely, they observed a negative association between CO_2 emissions and the distribution of seeds and total food grains in Pakistan (Rehman et al., 2019).

Attiaoui and Boufateh (2019) study employed the average aggregate panel data method (PMG) to evaluate the impact of climatic variables, precipitation, and temperature on cereal production in Tunisia. Their findings indicate that precipitation has a substantial positive effect on cereal production in Tunisia, while the temperature, despite its low elasticity, exerts a significant negative impact (Attiaoui & Boufateh, 2019).

The Vysochyna, Stoyanets, Mentel, and Olejarz (2020) study investigated the impact of renewable energy use and environmental factors on food security. The study used the average group estimation method for 28 postsocialist countries from 2000 to 2016, and it found that CO_2 emissions have a negative impact on food security and a positive impact on renewable electricity production. The researchers concluded that governments should promote the use of renewable energy and clean fuels to control CO_2 emissions and ensure long-term food security (Vysochyna et al., 2020).

In another study, Sibanda and Ndlela (2020) examined the relationship between agriculture, industrial production and carbon dioxide emissions in South Africa from 1960 to 2017. Their findings reveal that the rise in climate change factors has led to a decline in food security, resulting from alterations in global temperature and precipitation patterns (Sibanda & Ndlela, 2020).

In addition, Ceesay et al. (2021) have tested the link of causality between climate change, the value added of agriculture, food production and economic growth in the Gambia for the period 1960–2017 approach using the ARDL. Their findings have demonstrated that the growth of imports of food and agricultural growth exert a negative influence on economic growth in the short and long term (Ceesay et al., 2021).

In a similar study, Chandio et al. (2020) used the cointegration test model ARDL to examine the link between climate change and agriculture in China. Their findings, based on this model, revealed that CO2 significantly improves agricultural development in the short and long term. However, temperature and precipitation have adverse long-term effects on agriculture (Chandio et al., 2020).

Chandio et al. (2020) have conducted a study of the emissions of CO2 and temperature, on the one hand, and the grain yields and precipitation, on the other hand, in Turkey using the model ARDL. Their findings revealed a negative relationship between carbon dioxide emissions and temperature, on the one hand, and grain yields, on the other hand. Additionally, precipitation exhibited a positive association with cereal yield in both the short-term and long-term (Chandio et al., 2020).

Another study employed the Autoregressive Distributed Lag (ARDL) Model with the Pooled Mean Group (PMG) approach to investigate the relationship between several variables, including renewable energy consumption, agriculture, economic growth and urbanization for 12 African countries from 1990 to 2014. The findings of this study indicated the presence of a long-run equilibrium relationship between the variables of the model. These findings suggest that an increase in the consumption of non-renewable energy leads to a decrease in the consumption of renewable energy (Bekun & Alola, 2022).

3. Methodology

The objective of the present study is to analyze the impact of climate change and renewable energy on food security in Africa. The selection of countries for this study was based on a variety of criteria, including the availability of reliable data over the study period, the level of development, and the geographical area. Data are analyzed using the random effects regression model and feasible general linear least squares (FGLS). The fixed effects and random effects methods are specific to panel data and address unobserved heterogeneity rather than autocorrelation or heteroscedasticity directly. FGLS regression deals with unobserved heterogeneity, not autocorrelation or heteroscedasticity. It has broader applications, including cross-sectional and panel data, and is preferred when it is asymptotically equivalent to generalize squared error loss, handles large data sets, and provides more reliable estimates than other methods. To this end, a panel data econometric approach was employed, using a sample of 12 countries spanning the period from 2000 to 2020 (FAO, 2024; Hsiao, 2014).

3.1. Model Specification

According to the literature, this study takes a model in which the factors influencing agriculture, which depends mainly on the climate change, renewable energy, and economic growth (Behera, Haldar, & Sethi, 2024; Zhuang et al., 2022). Our econometric model is written in the Equation 1 as is the fourme following:

$$FS_t = f(GDP, RE, TEMP, PREC)_t \qquad (1)$$

Where FS represents the food security, ER represents the renewable energy consumption, GDP is the income per capita and the variables of the climate change, $TEMP$ is the temperature and $PREC$ precipitation.

In order to estimate the relationship between food security, climate change, and renewable energy sources using empirical methods, it is advisable to incorporate variables based on the empirical literature and various studies that have been established (Ozturk, 2017).

In this case, we use the agricultural production as the dependent variable approximated to measure the food security and economic growth, renewable energy consumption and climatic factors such as temperature and precipitation as independent variables. The data are transformed in logarithmic form, our empirical model is presented below in the following form in Equation 2:

$$LFS_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LRE_t + \beta_3 LTEMP_t + \beta_4 LPREC_t + \varepsilon_t \qquad (2)$$

Where ε_t Error term.

3.2. Description of Variables

The data used in this study were obtained from the World Bank database, Our World in Data, and the University of East Anglia presented in Table 1.

Table 1. Description of variables in the model.

Variable	Source	Description
Food security (FS)	World bank	Food security measures are changes in how food crops are produced. These crops are considered edible and contain nutrients in the course of a year compared to the reference year. This is expressed in tones.
The gross domestic product (GDP)	World bank	Gross domestic product per capita is a way to measure economic growth and the level of economic activity. It is the value of the dollar GDP divided by the total population.
Renewable energy consumption (RE)	Our world in data	The consumption of renewable energy encompasses the consumption of energy derived from all renewable resources.
Temperature (TEMP)	University of East Anglia,	The temperature anomalies are expressed in degrees Celsius, relative to the average temperature.
Precipitation (PREC)	University of East Anglia,	This indicator shows the anomalies of annual, or differences, compared to the average for precipitation.

This study is carried out over a period ranging from the years 2000 to 2020 for a panel of 12 countries in Africa (Morocco, Tunisia, Togo, Côte d'Ivoire, Gabon, Ghana, Nigeria, Zambia, Libya, Senegal, Egypt and Congo), is a sample of 252 observations.

4. Results and Discussion

4.1. Descriptive Statistics

The following table presents the statistical description of all variables. The dependent variable (LFS) is on one side, and the independent variables (LGDP, LRE, LTEMP, and LPREC) are on the other.

Table 2. Descriptive statistics.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
FS	252	87,058	20,843	43.48	181.33
GDP	252	2997.27	2,954,912	322.44	13,729.162
RE	252	52,423	34,095	2.04	98.34
TEMP	252	24.65	3,247	17.4	29.5
PREC	252	905,234	595,787	13	2242.4

Source: Our results obtained from STATA.

According to Table 2, the average value of the food safety (FS) is 87,058, with a minimum of 43.48, a maximum value of 181.33, and a standard deviation of 20,843. The GDP is on average equal to 2997.27, with a minimum of 322.44, a maximum value of 13,729.162, and a deviation of 2,954,912. Renewable energy (RE) consumption demonstrates an average of 52,423, with a minimum value of 2.04, a maximum value of 98.34, and a standard deviation value of 34,095. Finally, the temperature (TEMP) and the precipitation (PREC) were analyzed, and the results show that they have, respectively, an average of 24.65 and 905,234, with the values minimums of 1. 7.4 and 13, the values of maximums of 29.5 and 2242.4, and of the values of gap-type of 3,247 and 595,787.

4.2. Analysis of the Correlation

The presence of multicollinearity is identified as one of the most recurrent risks in the regression of the panel. Multicollinearity is defined as a correlation between the explanatory variables. An analysis of the correlation matrix can be used to reflect the intensity of the correlation between the dependent and independent variables in a multiple regression model.

Table 3. Correlation between food security and independent variables.

Variables	(1)	(2)	(3)	(4)	(5)
(1) FS	1,000				
(2) GDP	0.245	1,000			
(3) RE	-0.234	-0.455	1,000		
(4) TEMP	0.006	-0.285	0.519	1,000	
(5) PREC	-0.135	-0.316	0.905	0.539	1,000

Source: Our results obtained from STATA.

Table 3 indicate that the correlation analysis indicates that food security is influenced by the variables comprising the model. The primary variable demonstrates a positive correlation with economic growth and temperature. Conversely, renewable energy consumption and rainfall exhibit a negative correlation with the dependent variable, though the intensity of this correlation is less pronounced compared to the correlation with temperature.

4.3. Stationarity Test

Two generations of unit root panel tests have been developed. The first generation of tests assumes that the cross-disciplinary units are independent by cutting cross-section, while the second generation of unit root panel tests relaxes this assumption and allows for dependence on a cross-section. For the application, we use this test via the approach of Levin, li, and Chu and the Table 4 shows the different results:

Table 4. Stationarity test.

Variables	Statistic	P value	Decision	Stationarity level
Food security (FS)	-1.824	0.034	Stationary	At level
The gross domestic product (GDP)	-3.161	0.000	Stationary	At level
Renewable energy consumption (RE)	-1.879	0.030	Stationary	At level
Temperature (TEMP)	-3.938	0.000	Stationary	At level
Precipitation (PREC)	-5.568	0.000	Stationary	At level

Source: Our results obtained from STATA.

According to the table of the test of stationarity, the results of the test of Levin li and Chu indicate that the variables are stationary, which pushes us to continue in our analysis.

4.4. The Fixed-Effect Model

A fixed effects model is defined as a regression model in which either the group means are fixed or the group means are not random. The estimation of the fixed effects model of our study gives the following results.

Table 5. Fixed effect regression.

LFS	Coef.	St.err.	t-value	p-value	[95% Conf	Interval]	Sig
LGDP	1.03	0.088	11.64	0	0.856	1,204	***
LRE	-0.148	0.121	-1.23	0.221	-0.386	0.09	-
LTEMP	0.453	1.02	0.44	0.657	-1,557	2,464	-
LPREC	0.164	0.078	2.09	0.038	0.009	0.318	**
Constant	-5,351	3,422	-1.56	0.119	-12,093	1,391	-
Mean dependent var	4,436		SD dependent var		0.252		
R-squared	0.526		Number of obs		252		
F-test	65,575		Prob> F		0.000		
Akaike crit. (AIC)	-185,259		Bayesian crit. (BIC)		-167,611		

Note: *** p <.01, ** p <.05.
Source: Our results obtained from STATA.

Table 5 presents the detailed results of the fixed effects model estimation.The findings of this estimation are quite significant, as they demonstrate that the coefficients associated with the variable economic growth (LGDP) and precipitation (LPREC) are statistically significant and positive at the 5% threshold, given that their p-value is less than 0.05. However, in the case of the variables of renewable energy and temperature, this is not observed. The coefficient of determination tests yielded a result of 52.6%, which is a noteworthy finding. The probability of the F-statistic is zero, indicating that the model is highly significant.

While the fixed effects model has yielded satisfactory results, it is imperative to apply the random effects model and Hausman's test to select the most suitable model for our data.

4.5. The Random Effects Model

The regression model under consideration involves a random sample of individuals of average size drawn from a population. In contrast to the fixed effects models, the entities vary randomly and are uncorrelated with the independent variables. The results of the random effects model are presented in the following Table 6:

Table 6. Random effects regression.

LFS	Coef.	St. err.	t-value	p-value	[95% Conf	Interval]	Sig.
LGDP	0.1	0.026	3.84	0	0.049	0.152	***
LRE	-0.138	0.051	-2.71	0.007	-0.238	-0.038	***
LTEMP	0.441	0.15	2.95	0.003	0.148	0.735	***
LPREC	0.09	0.036	2.47	0.013	0.019	0.161	**
Constant	2,185	0.509	4.29	0	1,188	3,182	***

Mean dependent var	4,436	SD dependent var	0.252
Overall r-squared	0.181	Number of obs.	252
Chi-square	51,348	Prob> chi2	0.000
R-squared within	0.435	R-squared between	0.712

Note: *** p <.01, ** p <.05,.
Source: Our results obtained from STATA.

The results of the estimation of the random effects model reveal that the coefficients associated with the variables of economic growth, the temperature and the precipitation, except that the variable of energy's renewables is negative and statistically significant. The coefficient of determination from within is of the order of 43.5%. Thus, the probability of f-statistics indicates that the model is also very robust, since their p-value is less than 0.05.

Although the two models are robust and give meaningful results, one must be taken into account and the test that will help us to validate the effects model with fixed or random is the test of Hausman (1978).

4.6. Hausman Test

The Hausman test is a method used in econometrics to identify and correct for mis-specification in an econometric model. This test involves a comparison of two estimators, each designed to estimate different parameters of the model. In order to ensure the validity of the test results, the estimators compared must possess specific properties. First, under the null hypothesis of the correct model specification, the two estimators are required to be consistent for the "true" parameter of the model. That is to say, the estimators must correspond to the generation process of the data. Second, in a scenario of bad specification (The alternative hypothesis).

Table 7. Hausman test.

	Coef.
Chi-square test value	112.297
P-value	0

Source: Our results obtained from STATA.
Hausman (1978).

The test follows a law of Chi-square with 4 degrees of freedom. The results of the Hausman, as presented in Table 7, indicate a probability of less than 5% for the test, suggesting that the model with a fixed effect is the most appropriate. Therefore, it is preferable to retain the estimators of the fixed-effect model.

4.7. Heteroskedasticity Test

4.7.1. Heteroskedasticity Test Inter-Individuals

This hypothesis tests whether the variance of the errors is the same for all individuals. To verify this hypothesis, we used the test of Wald as follows.

Table 8. Wald test for heteroskedasticity (Between individuals).

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model
H0: sigma (i)^2 = Sigma^2 for all i
chi2 (12) = 6870.17
Prob> chi2 = 0.0000

Source: Our results obtained from STATA.

The probability of the Wald test, as shown in Table 8, is well below 5%. This indicates that the variance of the errors varies between individuals. Hence the presence of heteroskedasticity between individuals.

4.7.2. Heteroskedasticity Test Intra-Individuals

The heteroskedasticity tests if the variance of the errors is constant in time for each individual.

Table 9. Breusch-Pagan test (Intra-individual).

Breusch-Pagan LM test of independence: chi2(66) = 323,059, Pr = 0.0000
Based on 21 complete observations over panel units

Source: Our results obtained from STATA.

The results of the Breusch-Pagan probability of heteroscedasticity tests, as demonstrated in Table 9, are less than 5%, which confirms the presence of intra-individual heteroscedasticity. In other words, the variance of the errors changes over time.

4.8. Autocorrelation Test

4.8.1. Autocorrelation Test Inter-Individuals

This test is to check if there is the independence of the residuals between the individuals.

Table 10. Breusch-Pagan autocorrelation test (Inter-individual).

Pesaran's test of cross-sectional independence = 5,798, Pr = 0.0000
Average absolute value of the off-diagonal elements = 0.415

Source: Our results obtained from STATA.

According to the results of the autocorrelation test and Breusch-Pagan in Table 10, the probability of the test is found to be less than 5%, thereby confirming the dependence of the residues between individuals.

4.8.2. Autocorrelation Test Intra-Individuals

This test is to check if there is an absence of autocorrelation of the errors of individuals.

Table 11. Wooldridge autocorrelation test (Inter-individual).

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F(1.11) = 18,983
Prob> F = 0.0011

Source: Our results obtained from STATA.

According to Table 11, the probability of the test is less than 5%. This assumes the presence of the autocorrelation of individual errors.

4.9. Normality Test of the Errors

The test of Jarque-Bera is a test that seeks to determine if the errors follow a normal law.

Table 12. Jarque-Bera test.

Variable	Obs.	Pr (skewness)	Pr (kurtosis)	Adj	chi2(2)	Prob> chi2
Residu	252	0.264	0.282	2,420	0.298	0.2980

Source: Our results obtained from STATA.

The results of Table 12 show that the test of Jarque-Bera says the presence of the normality of errors (P-value>5%), so the residuals are normally distributed.

4.10. Estimation Model of FGLS

Thus, in order to make our econometric model is robust, we used the estimator of the method of generalized least squares achievable, called FGLS (feasible generalized least squares). This estimator allows us to address the problem of the regression invalid and make our estimators stable and close to the economic reality.

Table 13. Estimation of cross-sectional time-series FGLS.

LFS	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig.
LGDP	0.083	0.006	13.64	0	0.071	0.095	***
LRE	-0.101	0.007	-14.11	0	-0.115	-0.087	***
LTEMP	0.343	0.037	9.17	0	0.27	0.417	***
LPREC	0.059	0.005	11.06	0	0.049	0.07	***
Constant	2,697	0.162	16.60	0	2,379	3,016	***
Mean dependent var	4,436		SD dependent var		0.252		
Number of obs.	252		Chi-square		364,292		

Note: *** p <.01.
Source: Our results obtained from STATA.

The findings of the regression model estimation of panel data using the method of generalized least squares (FGLS), as illustrated in Table 13, demonstrate that the elasticity of food security exerts a positive and significant influence on economic growth. Consequently, a 1% increase in GDP is anticipated to have an approximate impact of 0.083% on food security. The study found a negative and statistically significant relationship between the elasticity of food security in relation to renewable energy. Nevertheless, these results do not offer empirical evidence to support the initial hypothesis (H2). The investigation also reveals a positive and statistically significant relationship between temperature and food security. This relationship suggests that a 1% increase in economic growth exerts a 0.343% influence on food security. Furthermore, the study identified a positive and statistically significant correlation between precipitation and food security, indicating that a 0.059% change in precipitation has a substantial impact on food security. Therefore, the findings indicate that climate change may potentially compromise the food security of African countries, thereby validating the initial hypothesis (H1).

5. Conclusion

The present study is devoted to model empirically the impact of the factors of climate change and renewable energy on food security for a sample of 12 countries in Africa in the period 2000 to 2020. This methodological approach is based on panel data by using the estimator of fixed effects, random effects, and the method of generalized least squares achievable, and testing the diagnostic autocorrelation, heteroskedasticity and normality of the errors of the model estimated.

In order to test the aforementioned hypothesis, the empirical analysis yielded three key findings. First, the coefficient associated with renewable energy consumption demonstrates a negative and statistically significant relationship with food security, suggesting that increased reliance on renewable energy does not necessarily enhance food security outcomes. Second, climatic variables, particularly temperature, demonstrate a statistically significant and positive association with food security. This result implies that temperature fluctuations linked to climate change may exacerbate food insecurity. Lastly, precipitation, as an indicator of the extent of climate change, emerges as a critical factor influencing food security across the countries included in the sample.

The findings of this study are similar to those of Attiaoui and Boufateh (2019); Vysochyna et al. (2020) and Sibanda and Ndlela (2020) state that the rainfall significantly improve food security, the production of renewable electricity has a positive impact on food security and shows that the factors of climate change, worsening food security in changing global conditions, temperatures and rainfall patterns.

The adverse effects of climate change are felt more acutely in developing countries, where the agricultural sector, water scarcity, and limited technological advancement present ongoing and substantial challenges. Nevertheless, the deleterious effects of climate change on food security can be mitigated, or even prevented, through the implementation of effective adaptation strategies. In the agricultural sector, these strategies aim to reduce vulnerability and strengthen the sector's resilience and adaptive capacity to climate-related stressors.

In several countries, prolonged climatic events are changing agro-ecological zones. Adaptation to extreme climatic events is aimed at minimizing damage, modifying risks and avoiding detrimental effects or sharing losses, thereby engendering a more flexible system. Moreover, in order to adapt to climate change, it is necessary to implement technological solutions. Such as introducing new systems to conserve and recycle water, promoting energy savings in agriculture and reforestation.

The water deficit is regarded as a pressing concern in the contemporary context. Given the global distribution of water resources, which is characterized by significant disparities, there is an imperative for innovative solutions in the agricultural sector to achieve further productivity gains. The adoption of precision agriculture methodologies holds considerable potential for comprehensive process monitoring and control. This will require the formulation of sophisticated strategies encompassing the full value chain of food, necessitating the cultivation of a new generation of farmers who are versed in "agriculture intelligence" and can adapt to climate change in both the present and future.

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