Relationship Between Climate Change and Food Security in Sub-Saharan Africa

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ABSTRACT
The soaring cases of coronavirus pandemic coupled with unpredictable climatic variations posed danger to human lives and food security. This work examined "Relationship between climate change and food security in sub-Saharan Africa." Using the Generalized Method of Moments technique with preliminary diagnostic tests on panel data across the 17 sub-Sahara African countries, the dependent variable is agricultural output, while the independent variables are temperature, rainfall, government expenditure on agriculture, inflation, exchange rate, gross fixed capital formation, and labor force. The findings revealed that climate change exerts negative impact on food security through temperature variations which degenerated during the period under review. The results also showed positive significant impact on government expenditure which increased during the period. The work recommended that government should embark on massive productive investments to reinvigorate and re-engineer the economy. The government and appropriate agencies should also put in place hybrid technology of high yield crops adaptive to change in climate as well as effective mechanism for food storage to secure food for the future.

KEYWORDS: Food Security, Climate Change, COVID-19, Economic Growth, GMM.

1. INTRODUCTION

Climate change has ignited global uncertainty, and the unpredictable climatic variations posed danger to human lives, animals, plants, and economic activities in global and national economies including the sub-Sahara Africa. This debilitating climate change has implications on the economies of nations across the globe with excruciating effects on the sub-Saharan Africa. Climate change has also affected human lives and food security in Africa. This has become worrisome and a source of deep concern to economists, policy makers, and the citizens at all levels. Climate change has become one of the most prominent problems facing the contemporary global community. The attention it has drawn from international organizations, such as the United Nations, the European Union, the African Union, through treaties, agreements, and action plans to combat its growing threat, coupled with the growing body of research on the issue attests to its gravity. Among other institutional frameworks, the UN Framework Convention on Climate Change, the European Climate Change Programme of the EU, and the Climate Change and Desertification Unit of the African Unions constitutes some of the most elaborate responses from the global community. From the foregoing, it is obvious that climate change is a global problem, and it also has devastating imprints that affect the economic, social, political, and environmental aspects of local communities (Ezemonye, 2019). In Nigeria, for instance, climate change has been linked with increasing cases of flooding, desertification, cattle movement toward the South-South (which in turn instigates crises among farmers and herdsmen), low level of rainfall ,or irregular rainfall, low agricultural productivity, among other problems. The implication for agricultural sector, which in Nigeria is largely rain-fed, is of paramount significance to this study.

The economic landscape of most African countries depends essentially on the dynamics of climate change. Key sectors driving their economic performance and livelihoods such as agriculture, forestry, energy, tourism, coastal, and water resources are highly vulnerable to climate change (Ebele and Emodi, 2016; Odusola and Abidoye, 2015).

Going by the impact (established and projected) of climate change on agricultural production, it is safe to contend that in addition to the issue of food security and the survival of smallholder farmers with minimal livelihood alternatives (Abdul-Razak and Kruse, 2017), also at stake, on a larger scale, is the economic growth of nation states, particularly in sub-Saharan Africa where the agricultural sector forms the backbone of most countries' economies. This is so because agriculture remains the engine of economy-wide performance, owing to the fact that the sector growth exhibits a higher multiplier than growth in other sectors, especially in countries where its sector share is large (Tiffin and Irz, 2006). In the long run, decreased performance in the agricultural sector posted a negative effect on the strength of the economy.

Reports from National Centre for Disease Control and Worldometer information show a rising trend in the cases of infected persons on daily basis depicting the catastrophic transmission nature of the COVID-19 pandemic in Africa and global experiences. COVID-19 has spread across the world since its presence was first reported in Wuhan, China, in December 2019. With its far-reaching geographical spread, the pandemic is projected to have devastating effects on the global economy, as attested by the projection of the International Monetary Fund in April 2020 that the world economy would contract sharply by 3%, and that the economy of Africa would contract by 1.6% in 2020 (World Bank, 2020). Furthermore, ADB (2020) has projected that, in a worst case scenario, economic activity for Africa as a whole would contract by 2.6%, with negative impacts on the employment rate, and that estimated that four out of five businesses in Africa would be significantly affected by the COVID-19 pandemic. ADB (2020) predicted an economic contraction for the continent of 3.4%. Hunger and shortage of food supply loom the survivors of the coronavirus pandemic. Hence, the need for proactive strategies on food security is absolutely necessary.

Although many countries including the sub-Saharan economies have implemented a number of containment measures to curb the spread of the virus, including closing schools, restricting domestic and international travel, promoting the use of protective gear and hand hygiene, and imposing curfews and lockdowns (NCDC, 2020). These measures have affected these economies in various ways and have disrupted air travel, tourism, trade, business operations, agriculture, food security, and global supply chains. The question that comes to mind is how to evaluate the impact of climate change on agricultural output in sub-Saharan Africa and stimulate these economies against the adverse consequences. To address these issues, the following research questions are raised.

i. Does climate change affect agricultural output in sub-Saharan Africa?
ii. Does climate change affect economic growth in sub-Saharan Africa?
iii. What have been the contributions of agriculture to the sub-Saharan Africa economies.

In search of solution to the above questions, the researchers delve into this study with the main objective to assess the impact of climate change in terms of temperature rise, rainfall, among others on agricultural output, food security, and economic growth in sub-Saharan Africa. Climate change has remained as one of the most vital and controversial issues at the global forums. The world is now reeling under COVID-19 and it is expected that once it ends or partially ends, the new normal of the world will be different. COVID-19 is going to have implications on agriculture, food security, economic, and social structure of the economies of nations. The COVID-19 pandemic coupled with climate change has pushed for unprecedented social and economic changes in many economies. The environmental impact of the digital revolution and digital waste has become a major issue. A recent study has also found a correlation between climate indicators and COVID-19 pandemic (Bashir *et al*., 2020). In the post-COVID-19 era, there are going to be numerous new issues and challenges pertaining to climate change.

Other parts of this paper are organized into four sections. Section two contains the review of relevant literature, while section three discusses the methodology; section four presents and discusses results. Finally, section five contains the summary, recommendations, and conclusion.

2. LITERATURE REVIEW

Climate change manifests itself with temperature increases, changes in precipitation, a rise in sea levels thereby increasing the intensity of such natural hazards as storms, floods, and droughts. Food security is both directly and indirectly linked with climate change. Studies have shown that climate change could reduce crop yield; and areas vulnerable to drought could become marginal for cultivation thus posing a threat to national food security and exports earnings (Abul *et al*., 2011; Anupama, 2014). Increasing temperatures will result in enhanced evapotranspiration, leading to a reduction of the water availability. An increase in the magnitudes of the storms will result in an increase in the frequency of floods and flood damage which in turn will increase salt intrusion causing less amount of water available for use in agriculture. According to Adejuwon (2004), the issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but also to the totality of human existence. Overcoming challenges posed by climate change related to agricultural production which in turn affect economic development will depend on farmer's use of technology (Kurukulasuriya and Mendelsohn, 2007; Hassan and Nhemachena, 2008).

Kurukulasuriya and Mendelsohn (2006), assessing the impact of climate change on African cropland from 11 countries involving over 9000 farmers, found that net farm revenues fall as precipitation falls or as temperatures warm across all the surveyed farms. Edame *et al*. (2011) examine the economic impacts of climate change (CC) on food security and agricultural productivity in sub-Saharan Africa. They noted that agriculture is particularly vulnerable to climate change. Projections to 2050 suggest both an increase in global mean temperatures and increased weather variability, with implications for the type and distribution of agricultural production worldwide. They also stated that increased intensity and frequency of storms, altered hydrological cycles, and precipitation variance also have long-term implications on the viability of current world agro ecosystems and future food availability. Climate change has been described as the most significant environmental threat of the 21st century. World agriculture faces a serious decline within this century due to global warming. Overall, agricultural productivity for the entire world is projected to decline between 3% and 16% by 2080 (Anupama, 2014). Developing countries, many of which have average temperatures that are already near or above crop tolerance levels, are predicted to suffer an average of 10% to 25% decline in agricultural productivity in the 2080s. Rich countries, which have typically lower average temperatures, will experience a much milder or even positive average effect, ranging from 8% increase in productivity to a 6% decline. Individual developing countries face even larger declines. India, for example, could see a drop of 30% to 40% (Ochieng et al., 2016).

Ubachukwu (2005) and Efe (2009) studied the threat of climate change to food security and livelihood in selected states in Nigeria. Their findings showed that climate change posed an adverse effects on food productivity in Nigeria. The studies showed that climate change impacts significantly on all aspects of crop yields, availability of seeds, and access and utilization of foods. They noted that there were decreases in crop yields due to decreases in temperatures in the study areas and that most of the farmers had a low level of awareness of the dangers of climate change.

Food security is both directly and indirectly linked with climate change. Any alteration in the climatic parameters such as temperature and humidity which govern crop growth will have a direct impact on quantity of food produced. Indirect linkage pertains to catastrophic events such as floods and droughts which are projected to multiply as a consequence of climate change leading to huge crop loss and leaving large patches of arable land unfit for cultivation and hence threatening food security. The net impact of food security will depend on the exposure to global environmental change and the capacity to cope with and recover from global environmental change. On a global level, increasingly unpredictable weather patterns will lead to a fall in agricultural production and higher food prices, leading to food insecurity. Food insecurity could be an indicator for assessing vulnerability to extreme events and slow-onset changes. This impact of global warming has significant consequences for agricultural production and trade of developing countries as well as an increased risk of hunger. The number of people suffering from chronic hunger has increased from under 800 million in 1996 to over 1 billion recently. United Nations population data and projections (UN, 2009) show the global population reaching 9.1 billion by 2050, an increase of 32% from 2010.

Osakhede *et al*. (2016) noted that climate change has constituted a great threat to rural and urban socio-economic landscape as well as the implementation of scientific findings toward the advancement of community development in Nigeria and many African countries. It is shaping the natural landscape in the long-run and the modern plan of rural and urban social and economic environment. This, unfortunately, has become a new reality with harmful effects. Many elements of the environment in the urban, rural and the human society are sensitive to climate variability and change. Examples of climate sensitive systems are ecosystems, agriculture, water needs and supply, food production, among others.

Odejimi and Ozor (2019) in their study, using the Ordinary Least Square technique, covering the period 1981–2017, revealed that the impact climate change has on agricultural production has positive relationship with government expenditure, exchange rate, rainfall, and agricultural output while negative relationship with temperature and inflation.

Odusola and Abidoye (2015) examined the impact of temperature and rainfall volatility on economic growth in 46 African countries. They employed the Bayesian hierarchical modeling approach which allows them to estimate both country level and Africa-wide impact of climate change; an extreme event on economic growth in Africa. The finding shows that a 1°C increase in temperature leads to 1.58% points decline in economic growth while temperature shock reduces economic growth by 3.22 percentage points. A 1% change or shock in rainfall leads to a 6.7% change in economic growth. The impact of temperature changes across the 46 countries ranges from -1.24% to -1.82% in GDP. There are proximity effects on the impact.

Zhai *et al*. (2009) examined the long-term potential effect of global climate change on agricultural production and trade in China. Utilizing an economy-wide, global Computable General Equilibrium (CGE) model as well as simulation scenarios of how global agricultural productivity may be affected by climate change up to 2080, the study suggested that, with a declining share of agriculture in Gross Domestic Product (GDP), the impact of climate change on the overall macro economy may be moderate. Umar (2008) noted that the effects of global warming and climate change in Nigeria are currently of concern to governments, institutions, environmentalists, and firms. They noted that the effects of climate change in the country generally manifest as shifting weather variations or patterns involving unprecedented and overall changes in weather patterns, excessively heavy precipitation, unusual high temperature, propelling significant changes in different parts of the country, rising sea levels, disappearance of the coastal strips, and noticeable increases in the frequency of some extreme weather events in the country. The study concluded by recommending that governments have a big role in disseminating information on the potential and actual impacts of climate change as well as on forecast impacts on agriculture, water resources, and diseases.

2.1. GAPS IN STUDIES

- Most studies deal with the nexus of two variables of climate change and economic growth as seen in the studies by Osakhede *et al*. (2016) (Agricultural Output and Economic Growth in Nigeria), while this study looks at the interaction of climate change and food security.
- Single equation models are specified in most studies carried out as seen in the studies of Odejimi and Ozor (2019), while system of equations were specified in this study using Generalized Method of Moments (GMM) method of analysis for robust policy recommendations and forecast/simulation outputs.

3. METHODOLOGY

3.1. MODEL SPECIFICATION

This study adopts a panel data framework. The use of panel data enables us to account for and isolate the effects of countries specific time-unchanging characteristics specifically the level of development. Furthermore, Wooldridge (2002) has shown the relevance of using panel data to solve the problem of omitted variable. The combination of both cross-sectional and time-series data for different countries is important to avoid harmful over-generalizations.

The conventional form of panel data framework is given as:

$yit = \alpha it + \beta i\, Xit + \mu it$ .... (1)

$\mu it = \mu i + vt + \varepsilon i,t,$ ….. (2)

with *yit* as the dependent variable, while *αit*, *βi*, and *Xit* are k-vectors of nonconstant regressors and parameters for *i* = 1, 2, …, *n* cross-sectional units (here countries) and *t* = 1, 2 … *T* is time series unit; *μit* is a general disturbance, with *μi*, the country's, unobservable effect, *vt*, a time-specific factor, and *εit* an idiosyncratic disturbance.

Climate change is captured by temperature and rainfall variables as demonstrated by Kumar and Gautam (2014). In the development equation, agricultural output is taken as the dependent variable, while inflation, exchange rate, capital formation, and labor force are also included independent variables. The dynamic relationship is based on the fact that climate change may not only exert one round of effect on agricultural output or development, rather the effects may be self-reinforcing over time (Ayinde *et al*., 2011).

AGOP = f (TEMP, RFALL, GEA, INF, EXR, GFCF, LABF) ……..(3)

Using the conventional form of panel data framework, equation (3) becomes:

$AGOPi_t = \beta_0 + \beta_1 TEMPi_t + \beta_2 RFALLi_t + \beta_3 GEAi_t + \beta_4 INFi_t + \beta_5 EXRi_t + \beta_6 GFCFi_t + \beta_7 LABFi_t + U_{it}$ ………. (4)

Where:

AGOP = Agricultural Output, CROP = Crop Production

TEMP = Average Annual Temperature

RFALL = Rainfall

GEA = Government Expenditure on Agriculture

INF =Inflation Rate (measured as the consumer price index)

EXR = Exchange Rate

GFCF = Gross Fixed Capital Formation

LABF = Labor Force

Introducing the control variable such as the level of development of the countries which was captured by RGDP per capita (RGDPpc), equation 4 becomes:

$AGOPi_t = \beta_0 + \beta_1 TEMPi_t + \beta_2 RFALLi_t + \beta_3 GEAi_t + \beta_4 INFi_t + \beta_5 EXRi_t + \beta_6 GFCFi_t + \beta_7 LABFi_t + \beta_8 RGDPpc_{i,t} + U_{it}$ ……(5)

Where,

RDGPpc = Real Gross Domestic Product per capita (measure of development)

The estimation of the above model was done by engaging the single equation linear GMM. As compared to some other models Panel Least Square, maximum likelihood. The GMM has been widely used in the estimation of models as it does not necessitate full knowledge of the distribution of the data. The GMM also has the ability to correct the problems of endogeneity, heteroscedasticity, and cross-sectional dependency that are common in panel data framework (Sarafidis, 2008; Sarafidis *et al*., 2008). The consistency of the GMM estimator, however, depends on the validity of the instruments and this is usually addressed using the Sargen/Hansen test of over-identifying restrictions.

3.2. DATA SOURCES

The data for the study was obtained from the World Bank (World Development Indicators), and country-specific database of 17 countries in sub-Saharan Africa (Ethiopia, Kenya, Rwanda, Tanzania, Uganda (East Africa), Angola, Botswana, Congo DR, Lesotho, Mozambique, Namibia, South Africa (Southern Africa), Cote d'Ivoire, Ghana, Liberia, Nigeria, and Sierra Leone (West Africa). The selection of the countries was rooted on the availability of data, and at the same time, we ensured that the different parts of sub-Saharan Africa (Central, Eastern, Southern, and Western) are covered in the study. The study covers the period 2011–2020 on annual basis using three-time series panel given the limitation of data for climate change analysis.

4. RESULTS AND DISCUSSION

4.1. DESCRIPTIVE STATISTICS

The descriptive statistics of the data used in the analysis are presented in Table 1. The average growth rate of RGDPPC (Real Gross Domestic Product Per Capita) for the period is 1.63%, which is quite low, although the maximum average value of 11.75% growth rate indicates that there were some years with very impressive per capita growth rate figures. On the other hand, the minimum value of -9.89 also indicates that the income per capita figures were very low in certain years. The data show that GDP per capita has been very unsteady in the country. This is supported by the high standard deviation of the variable at 4.27 when compared to the mean value. GDP per capita has varied significantly over the years in Nigeria, thereby indicating that welfare and poverty reduction composition of the economy is highly unsteady. Indeed, there may be steady rise in the per capita GDP for most of the years, yet the rate of growth has been highly unsteady. The J–B statistic fails the significance test which shows that GDPPC is normally distributed.

The average growth rate of AGOP is 5.88, which is high and suggests that agricultural output has performed well in the country over the years. Although there were periods of negative growth rates (as shown by the minimum value of -4.38), the average value indicates that the agricultural sector has been one of the best performing sectors over the past three decades. The standard deviation is, however, large and shows a significant level of instability in the growth rate, while the skewness of 4.46 shows that most of the data series were to the left of the mean (they are lower than the reported mean value).

Table 1. Descriptive statistics (results from E-views).

Variable	Mean	Max.	Min.	SD.	Skew	Kurt.	J–B	Prob.
RGDPPC	1.63	11.75	-9.89	4.27	-0.10	3.30	0.20	0.91
AGOP	5.88	55.58	-4.38	9.18	4.46	24.72	849.6	0.00
GEA	15.56	65.40	0.01	18.90	1.01	2.79	6.34	0.04
RFALL	93.95	112.25	72.07	8.31	-0.41	3.08	1.04	0.60
TEMP	27.22	27.86	26.52	0.32	0.04	2.48	0.43	0.81
GFCF	32.76	945.34	-36.40	156.58	5.56	32.94	1572.94	0.00
LABF	0.24	4.49	-2.73	1.15	0.95	7.25	33.35	0.00
EXR	93.749	306.921	0.672	90.735	0.826	3.022	4.208	0.122
INF	64.169	111.72	35.2	20.646	0.812	2.616	4.29	0.117

Source: Author's computation using E-views.

Average rainfall was 93.95 millimeters over the period, with a standard deviation of 8.31 indicating variability over the years. This aspect of the focus on climate change influences, in particular economic characteristics. The focus on variability, rather than levels, has been a major issue argued by researchers who observe that it is variability in climate that imposes significant constraints on agricultural activities (Chen et al., 2016; Moore *et al*., 2017; Agarwal *et al*., 2019). Average temperature was 27.22°C for the period and the standard deviation 0.32 is very low (though not much temperature changes are expected for a period of less than 40 years). However, temperature has experienced a level of variability. Indeed, the coefficient of variation for the temperature changes was over 600%, which indicates a particularly worrisome process of temperature changes in sub-Sahara Africa.

The mean government expenditure on agriculture is 17.0 billion naira, while the mean exchange rates and CPI are 93.74 and 67.17, respectively. This shows that the price level has been high over the period. Labor force participation rate is 56.83 in the agricultural sector. This shows that most of the people in the country are involved in agricultural production, implying that any shock to the sector will have a big impact on the larger section of the country. Average growth rate of capital formation is 32.1%, which is quite high, while average growth rate of labor force participation rate is 0.24%.

4.2. UNIT ROOT TESTS

Two tests of stationarity were employed in this study in order to analyze stationarity status of the data series and indicate the presence or absence of unit roots. For each of the tests (i.e., Augmented Dickey-Fuller and Phillip-Peron), analysis is performed with trend and without trend. This is because the datasets that include temperature variables may exhibit certain levels of trending that may affect the tests for stationarity (Sun *et al*., 2018). Moreover, the test results are presented in levels and first differences in order to determine, in comparative terms, the unit root among the time series and also to obtain more robust results.

Table 2. Unit root test for variables.

Variables	**ADF test**				**P–P test**				**Order**
	Without trend		With trend		Without trend		With trend		
	Levels	*First difference*	*Levels*	*First difference*	*Levels*	*First difference*	*Levels*	*First difference*	
LGDPPC	1.954	-45.14*	-2.031	-39.36*	1.137	-37.67*	-1.325	-33.76*	I(1)
LGOP	-2.329	-6.155*	-2.064	-5.775*	-2.298	-6.157*	-2.101	-5.772*	I(1)
LGEA	-0.002	-5.393*	-2.156	-6.834*	-0.002	-6.393*	-1.878	-14.45*	I(1)
LTEMP	-1.91	-8.57*	-2.15	-8.453*	-1.97	-10.90*	-4.83*	-10.62*	I(1)

LRFALL	-2.10	-12.00*	-2.66	-11.83*	-2.18	-18.67	-5.17	-17.38*	I(1)
LEXR	-1.054	-4.449*	-1.481	-6.004*	-0.883	-6.836	-1.782	-5.322*	I(1)
LINF	-1.74	-5.887*	-2.032	-3.622*	-1.174	-10.47*	-1.482	-9.043*	I(1)
LGFCF	-1.003	-4.924*	-4.42*	-6.494*	-1.376	-8.372*	-1.281	-7.442*	I(1)
LLABF	-1.374	-6.266*	0.132	-5.374*	-1.366	-7.843*	-1.329	-7.373*	I(1)

Note: *indicates significant at 5%.

Source: Author's computations using E-views.

Table 2 presents results of Augmented Dickey-Fuller (ADF) and Philip-Peron (PP) tests in levels and first differences. The results indicate that each of the variables (apart from the climate change variables) possesses both ADF and PP values that are less than the 95% critical values for the level series and greater than the critical value for the differenced series. In most cases, the variables in level form were nonstationary but their first differences were found to be stationary. However, the variables of climate change were stationary in levels since their tests show significance of both the ADF and PP in the levels form. This shows that all variables are integrated at order 1 (i.e., I [1]).

4.3. PANEL CO-INTEGRATION TEST

We further conduct a panel co-integration test to confirm if the variables have long-run relationships using the Kao co-integration test. The Kao test in Table 3 below reveals that there is co-integration and long-run relationship between all the variables in the model. The null hypothesis of no co-integration is rejected at the 5% level of significance indicating a co-integration among the variables.

Table 3. Kao co-integration test.

Null hypothesis: No co-integration				
			t-Statistic	Prob.
ADF			1.940174	0.0262
Residual variance			4662.212	
HAC variance			456.1776	

Source: Author's computations using E-views.

4.4. THE GMM ESTIMATION RESULTS

The model was found to pass the Hansen (1992) test of valid instrument, and the null hypothesis was accepted that all instruments are valid given Hansen/J statistics of 4.636442 and a probability of (0.052112) as shown in Table 4.

Table 4. Results GMM estimates.

Explanatory variables	Coefficient/standard error
TEMP	–0.018129/0.003813*
RFALL	0.002186/0.001155*
GEA	0.002614/0.000562*
INF	–0.001610/7.79E-05*
EXR	–0.000518/0.000351
GFCF	0.004781/0.000682*
LABF	0.004684/0.000742*
RGDPPC	–2.42E-05/1.18E-05*
C	0.583360/0.014274
Hansen test = 4.636442 (0.052112) Instrument rank = 11 R^2 = 0.6752411 Adj R^2 = 0.592332 DW = 1.321442 Number of observations = 47	

Source: Author's computation using E-views.

The fitness of the model was examined and the model was found to be well fitted given an R^2 of 0.6752411 indicating that 68% of the variation in the dependent variable is accounted for by the explanatory variables. The DW statistics was 1.321442. This however does not jeopardize the model given that the use of GMM method of estimation can also correct the problem of heteroscedasticity and serial correlation that may be present in the model.

Examining the relationship and impact of the independent variables, the result showed that TEMP, INF, and EXR came with a negative significant impact on AGOP in line with theoretical expectation while RFALL, GFCF, GEA, and LABF showed a positive significant impact on AGOP. The relationship of these variables with AGOP was found significant indicating that policy measures toward reducing effect of climate change on food security through AGOP should focus on these variables. The substantial impact of GFCF and LABF point to the need of enhancing the gross fixed capital formation and labor force because these variables will give more opportunity to be financially and technologically developed and as well as giving them the opportunity of securing better human capital development for better paid jobs for higher level of income. Rainfall posed significant impact on AGOP. Hence, seasonal variation is germane and was found to have a major impact on food security. All round season agriculture powered by technology would be the best option for sub-Saharan economies. The result also showed that inflation came with a negative noteworthy impact on AGOP.

4.5. IMPLICATION OF THE FINDINGS AND POLICY INFERENCES

i. The outcome of the study exhibited a negative and substantial impact of climate change on agricultural output and food security. Rainfall posed significant impact on AGOP. Hence, seasonal variation is germane and was found to have a major impact on food security. All round season agriculture powered by technology would be the best option for sub-Saharan economies.
ii. The results also showed that growth in government expenditure on agriculture significantly affected output and food security. Hence, a continued upsurge in government expenditure is highly recommended especially in development of hybrid yields.
iii. The level of development in these countries was also established to increase agricultural output thereby improving food security. Food security has also been found to increase the level of economic development of the affected countries.

5. SUMMARY, RECOMMENDATION, AND CONCLUSION

5.1. SUMMARY

From the empirical analysis, the following findings were reported:

That climate change has a varied effect on agricultural production in sub-Sahara Africa on the basis of climatic factors considered (temperature or rainfall) or the agricultural activity involved. In general, temperature has a more effect on agricultural production than rainfall.

At lower levels of rainfall agricultural production is low. Increase in rainfall leads to further rise in agricultural production.

Climate change has an unequivocal deleterious effect on agricultural production, both in the short run and in the long run. The elasticity of long run impact of rainfall on agricultural production was shown to be close to one, indicating that any excess inch in rainfall would likely reduce food production by the same proportion. Temperature variations were shown to have debilitating impacts on agricultural production in sub-Saharan Africa.

Climate change has an indirect and stable impact on economic growth through agricultural production channel. Climate change tends to reduce the growth of the economy by limiting expansions (inadequate expenditure in input, infrastructure and R and D) in the agricultural sector of these economies. The effects of agricultural output and export as channels of climate change influences on economic growth are relatively similar. In other words, when climatic conditions change, the shocks on both agricultural output and exportation have similar effects on economic growth in these countries.

Other factors such as government spending in agriculture, exchange rate, inflation, capital accumulation, and labor input were also shown to have long run impacts on agricultural production in sub-Sahara Africa. This invariably affects food security.

5.2. RECOMMENDATIONS

Based on this study's findings and conclusion, the following recommendations are made. The general and particular findings in this study suggest some policy directions which may provide a basis for useful recommendations for the policy authorities.

With rainfall expected to be unpredictable both in terms of periodicity and amount. This means that adaptation strategies for climate change should also be considered both short and long term, the various Meteorological Service Authorities should put up early warning system in order to monitor changes in the weather variabilities and guide farmers on the appropriate time to plant in cases of drought or flooding focus on risk management in the most vulnerable areas and among the most vulnerable groups in order to reduce loses.

The study has also shown that agricultural spending can help to boost the sector's production in the long run. This means that if government expenditures can be directed at addressing climate impacts, the effects may be more profound on the agricultural sector. Thus, a strategic spending pattern that helps to detect early signs of climatic effects as well as rapidly responding to short-term effects of climate change is needed to boost agricultural production in the face of unstable climate conditions.

In order to prepare for the future in terms of climate change, crop, and animal breeding should be focused on development of new climate tolerant varieties. Therefore, agricultural research institutions need to provide strong support for climate-resilient crops and animal breeds that are suitable for the countries.

For agricultural output, crop diversification can be done, for example, the mixed cropping, that has several crops growing at one time can help systems exhibit greater durability during periods of high water or heat stress to stimulate higher productivity.

5.3. CONCLUSION

The study focused on the relationship between climate change and food security in sub-Sahara Africa. Both statistical and econometric techniques were employed in the analysis to show the direction of changes in climatic conditions as well as the pattern of relationships and effects that the climate changes have with both agricultural production and food security. Both the statistical and econometric procedures demonstrated clearly that climate changes are becoming more profound in sub-Sahara Africa with long run effects on agricultural production. The empirical analysis showed that these patterns of effects have strong implications for economic performance in the long run.

Global warming and the attendant rapid changes in climate possess significant risks to almost all segments of livelihood. Thus, economic performances around the world are often skewed on the basis of climatic occurrences. The aspect most affected in these cases is the agricultural sector that depends on the land and climatic elements for sustenance (especially for the developing countries). In this study, the role of climate change has been shown to be essentially debilitating to both agricultural production and food security, both in the short run and in the long run. Both mitigation and adaption systems are suggested as the main responses to climate change and food security. Over time however, there is the need for a strong and significant commitment around the world to reduce global warming and reduce the level of depletion of life on the planet. The above findings are absolutely necessary for policy makers and the government of sub-Saharan Africa on the way forward to reduce gender inequality and accelerate financial inclusion.

CONFLICT OF INTEREST

None.

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