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THE IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION IN NIGERIAN ECONOMY

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Abstract: This paper examined the challenges posed by climate change in relation to crop production as it affects economic growth in Nigeria. Climate change presents a window of opportunity to open up policy spaces for dealing with uncertainty and complexity of agri food systems. The work used time series secondary data covering 1984 – 2021, obtained from the various editions of the Central Bank of Nigeria's (CBN) Statistical Bulletin and World Development Indicators (WDI) as its main source of data. For our analysis, the autoregressive distributed lags (ARDL) technique was adopted in the estimation of the relationship between climate change and crop production. At the end of the study, it was discovered that climate change has an unequivocal deleterious effect on crop production, both in the short run and in the long run. There is also clear evidence from the study that crop production has significant and positive intertemporal effect on economic growth in Nigeria. Arising from these findings, the paper offers the following recommendations: adaptation strategies for climate change should be considered both in short-term and long-term to cope with the expected unpredictability of rainfall both in terms of periodicity and amount; the Nigerian Meteorological Services (NIMET)should adopt early warning system to guide farmers and other stakeholders on the appropriate time to plant in cases of drought or flooding; stakeholders and policymakers should focus on risk management in the most vulnerable areas and among the most vulnerable groups in order to reduce loss.

Keywords*:* Autoregressive Distributed Lags, Climate Change, Crop Production, Economic Growth

1. INTRODUCTION

Agriculture, as defined by Foley *et al*. (2005), is crucial to human survival, providing food and fuel which are vital sources of livelihood. Apart from

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playing a crucial role in economic development, it is also a major factor contributing to climate change, depleting freshwater resources, degrading soil fertility and polluting the environment through fertilizer and pesticide use. Paradoxically, food production is critically dependent on the very natural resources it is degrading (environmental degradation).Sustainable food security not only requires that all people at all times have access to sufficient food but also that this food be produced with minimal environmental impact (Pinstrup-Andersen, 2009; Godfray *et al*. 2010; FAO, IFAD & WFP, 2015).

Given that the world has not achieved sustainable food security today, and that we will probably need to double food production by 2050 to feed nine billion people (Kennedy, 2013; Tilman, *et al* 2011), there is a drastic need for changes in the food system. From an agricultural perspective, we need to produce more. Food security is a balance between taking advantage of the ecosystem service of food production for human use and preventing the exploitation of natural resources to a degree that undermines the ability of the ecosystem to sustain the production. Sustainable food security therefore requires that sufficient food is produced for nourishing present generations without compromising the ability of future generations to produce sufficient and nutritious food for their own needs (Verena, 2015; Ozor, 2020).

Climate change is likely to directly impact on global agriculture in general and crop production, in particular. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce final yield. In areas where temperatures are already close to the physiological maxima for crops, warming will impact yields more immediately (IPCC, 2007; Ochieng, *et al* 2016).

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% (Anupama 2014; Ochieng, *et al* 2016).

Studies on the threat of climate change to crop production, food security and livelihood in selected states in Nigeria and the effects of climate change on food productivity in the Niger Delta show that climate change impacts significantly on all aspects of crop yields, availability of seeds, and access and utilization of foods. It was discovered that decreases in crop yields were linked to decreases in temperatures in the study areas and that most of the farmers had low level of awareness on the dangers of climate change (Ubachukwu, 2005; Efe, 2009).

Crop production and food security are 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 the quantity of food produced. Indirect linkage pertains to catastrophic events such as flood and drought 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.

2. LITERATURE REVIEW

Odejimi & Ozor (2019) in their study, 'Can climate change affect agricultural output in Nigeria?' using the Ordinary Least Squares techniquecovering a period of 1981 – 2017, revealed that the impact climate change has on agricultural production has a positive relationship with government expenditure, exchange rate, rainfall and agricultural output,buta negative relationship with temperature and inflation.

In another study, Ewetan, *et al* (2017) examined the long run relationship between agricultural output and economic growth in Nigeria for the period between 1981 – 2014, using time series data. Results from Johansen maximum likelihood co-integration approach and Vector error correction model support evidence of long run relationship between agricultural output and economic growth in Nigeria. The researchers recommend that the government should further strengthen agricultural policies in the area of funding, storage facilities, and market access to enhance agricultural production.

Also, Ismail & Kabuga (2016) discussed the impact of agricultural output on economic growth in Nigeria using an ARDL bounds test for cointegration. The study explored the short- and long-term effects of agricultural output on growth in Nigeria using annual time series over the period 1986 - 2015. In the short run, the result established that agricultural output is positively related to economic growth. The result also revealed that first and second lagged values of agricultural output have a significant impact on economic growth. The finding also provided strong positive and statistically significant evidence of a long run relationship between agricultural output and economic growth, as well as positive and statistically significance relationship between gross capital formation and economic growth. The result also indicated that labour force has a strong negative relationship with economic growth in the long run. This particular result suggests either one percent fall in labour force will increase economic growth or low productivity of agriculture is related to abundance of cheap labour in the long run. The study concludes that agricultural output is an indicator of economic growth in Nigeria. These findings highlight the importance of improving agricultural sector and underscore the reasoning behind the call for more support for the agricultural sector to improve productivity and reduce food import dependence in Nigeria.

Odusola & Abidoye (2015) examined the impact of temperature and rainfall volatility on economic growth in 46 African countries. They employed the Bayesian hierarchical modelling 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° Celsius increase in temperature leads to 1.58 percent points decline in economic growth while temperature shock reduces economic growth by 3.22 percentage points. A 1 percent change or shock in rainfall leads to a 6.7 percent change in economic growth. The impact of temperature changes across the 46 countries ranges from -1.24 percent to -1.82 percent in GDP. There are proximity effects on the impact.

Olutoye and Olutoye (2014) examined the contribution of agricultural sector to Gross Domestic Product (GDP) between 1990 and 2013. The Ordinary Least Square (OLS) multiple regression method was used to analyse the data. The results revealed a positive cause and effect relationship between agricultural output and Gross Domestic Product (GDP) in Nigeria. The study precisely shows that Agricultural Output has a strong influence on the Gross Domestic Product (GDP) with an estimated contribution of 30.2% between 1970 and 2000 before the neglect of this sector during the oil boom in the 1970s. The study concluded that, in order to improve agriculture, government should see that special incentives are given to farmers and basic infrastructural facilities improved upon.

In a similar vein, Odetola and Etumnu (2013) investigated the contribution of agriculture sector to the economic growth in Nigeria, using the growth accounting framework and time series data from 1960 to 2011. The study found that the agricultural sector has contributed positively and consistently to the economic growth in Nigeria, reaffirming the sector's importance in the economy. The contribution of agriculture to economic growth is further affirmed from a causality test which showed that agricultural growth Granger-causes GDP growth. However, no reverse relationship was found. The resilient nature of the sector is evident in its ability to recover more quickly than other sectors from shocks resulting from disruptive events e.g. the Nigerian Civil War (1967-70) and economic recession (1981-85) periods. The study also found that the crop production subsector contributes the most to agricultural sector growth and that growth in the agriculture sector is overly dependent on growth of the crop production subsector. This indicates the importance of this subsector and probably, lack of attention or investment to the other subsectors.

A study by Zhai, *et al* (2009) examined the long-term potential effect of global climate change on agricultural production, and by implication crop production, and trade in China. Utilizing an economy-wide, global 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 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.

3. METHODOLOGY

The particular model specified in this study is based on the formulation by Ekpenyong & Ogbuagu (2015) which focuses at verifying the long run and short run effects of climate change variables on agricultural productivity. The functional form of the model is:

CROP = f (TEMP, RFALL, GEA, INF, EXR, GFCF, LABF) (1)

Where:

CROP = Crop Production, TEMP = Average Annual Temperature, RFALL = Average Annual Rainfall, GEA = Government Expenditure on Agriculture, INF =Inflation Rate (measured as the consumer price index), EXR = Exchange Rate, GFCF = Gross Fixed Capital Formation

LABF = Labour Force

In the econometric form, the model is specified as:

Crop Production Model

CROPt= β0 +β1TEMPt + β2RFALLt + β3GEAt + β4INFt + β5EXRt + β6GFCFt + β7LABFt + Ut (2)

Apriori expectation: β1, β2, β3, β4, < 0; β5, β6> 0

The ARDL model for crop production is specified as:

$$\begin{aligned}\Delta crop_t = {} & \alpha_0 + crop_{t-1} + \delta_1 temp_{t-1} + \delta_2 r\ fall_{t-1} + \delta_3 gea_{t-1} + \delta_4 \inf_{t-1} + \delta_5 exr_{t-1} \\ & + \delta_6 dfcf_{t-1} + \delta_7 labf_{t-1} + \sum_{i=1}^{p-1} \psi_i \Delta crop_{t-i} + \sum_{i=1}^{p-1} \varphi_1 \Delta temp_{t-i} \\ & + \sum_{i=1}^{p-1} \varphi_2 \Delta rfall_{t-i} + \sum_{i=1}^{p-1} \varphi_3 \Delta gea_{t-i} + \sum_{i=1}^{p-1} \varphi_4 \Delta \inf_{t-i} + \sum_{i=1}^{p-1} \varphi_5 \Delta exr_{t-i} \\ & + \sum_{i=1}^{q_1-1} \varphi_6 \Delta gfcf_{t-i} + \sum_{i=1}^{q_1-1} \varphi_7 \Delta labf_{t-i} + \delta ECM_{t-1} + \xi_t\end{aligned}$$

Data Sources

The data for this work was sourced from the Central Bank of Nigeria statistical bulletin and World Bank (WDI) databases. The periodic range for this work is from 1984 to 2021.

4. PRESENTATION AND INTERPRETATION OF RESULTS

The descriptive statistics of the data used in the analysis are presented in Table 1

Table 1: Descriptive Statistics

Variable	*Mean*	*Max.*	*Min.*	*SD.*	*Skew*	*Kurt.*	*J-B*	*Pr.*	*Obs*
GCROP	6.39	65.26	-4.54	10.95	4.42	24.14	809.4	0.00	37
GAGEX	41.31	335.85	-42.82	83.69	2.16	7.08	54.34	0.00	37
GGEA	15.56	65.40	0.01	18.90	1.01	2.79	6.34	0.04	37
RFALL	93.95	112.25	72.07	8.31	-0.41	3.08	1.04	0.60	37
GRFALL	1.01	26.93	-20.91	12.12	0.37	2.72	0.98	0.61	37
TEMP	27.22	27.86	26.52	0.32	0.04	2.48	0.43	0.81	37
GTEMP	0.02	3.32	-1.99	1.29	0.43	2.76	1.25	0.54	37
GGFCF	32.76	945.34	-36.40	156.58	5.56	32.94	1572.94	0.00	37
GLABFP	0.24	4.49	-2.73	1.15	0.95	7.25	33.35	0.00	37
EXR	93.749	306.921	0.672	90.735	0.826	3.022	4.208	0.122	37
INF	64.169	111.72	35.2	20.646	0.812	2.616	4.29	0.117	37

Source: Author's computation Using E-Views Version 10

Average growth in crop production is 6.39 percent with a high maximum value of 65.26 percent. The standard deviation of growth rate of crop production is much higher than the average value at 10.95, which indicates high level of variations. This is one area the system may have to focus on in the future, given that the standard deviation suggests that output growth has been relatively more stable over the years, irrespective of climatic or other conditions. Average Growth Rate in Agricultural Export (GAGEX) is high at 41.31 percent, and a maximum value of over 300 percent in a single year. The standard deviation is however very high (resulting in a coefficient of variation of over 2 percent). This shows that export activities in the agricultural sector have been plagued with a lot of inconsistency and variability that hurt both market prospects and supply capabilities.

Average rainfall was 93.95 millimetres over the period, with a standard deviation of 8.31 suggesting that the levels did not change drastically over the period. In terms of growth rate, the average annual rate was 1.01, although the standard deviation of 12.12 indicates serious variability over the years. 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; Agarwa *et al*, 2019). Average temperature was 27.22 degrees Celsius for the period and the standard deviation is very low (though not much temperature changes are expected for a period of less than 40 years). However, the standard deviation value of 1.29 (compared with the mean value of 0.02 percent) shows that temperature changes has experienced a high level of variability. Indeed, the coefficient of variation for the temperature changes was over 600 percent, which indicates a particularly worrisome process of temperature changes in the country.

The mean government expenditure on agriculture is 17.0 billion naira, while the mean exchange rate and INF are 93.74 and 64.17 respectively. This shows that the price level has been high over the period. Average growth rate of capital formation is 32.1 percent, which is quite high, while average growth rate of labour force participation rate is 0.24 percent.

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*	
LCROP	-0.128	-5.881*	-2.153	-5.792*	-0.126	-5.885*	-2.203	-5.93*	I(1)
LAGEX	-0.893	-7.154*	-2.555	-7.214*	-1.154	-8.07*	-2.668	-13.39*	I(1)
LGEA	-0.002	-5.393*	-2.156	-6.834*	-0.002	-6.393*	-1.878	-14.45*	I(1)
LTEMP	-3.91*	-8.57*	-4.95*	-8.453*	-3.97*	-10.90*	-4.83*	-10.62*	I(0)
LRFALL	-5.10*	-12.00*	-5.66*	-11.83*	-5.18*	-18.67	-5.17	-17.38*	I(0)
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 percent. Source: Author's computations using E-views version 10

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 percent critical values for the level series and greater than the critical value for the differenced series. In all cases, the variables in level form were non-stationary 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 the two climate variables are integrated of order 0, while all the other variables (including agricultural output and economic growth) are integrated at order 1 (i.e. the variable are both I[0] and I[1]). It is, therefore, appropriate to use the ARDL-based cointegration analysis to estimate the relationships between the variables (Ighodaro & Adegboye, 2020). Interestingly, the results for the stationarity tests are similar for both the series with trend and without trend. Thus, the trending patterns of the variables do not essentially affect their pattern of time-variations over time.

It is therefore shown, from the unit root tests, that the climate datasets are stationary (or stationary in levels), suggesting that the series are mean reverting over time. There is the tendency for annual rainfall and temperature levels to hover around a single mean value over a long period of time. This outcome further validates findings by Gangulil and Coulibaly (2017), Sun *et al.* (2018) that climate variables of rainfall and temperature are stationary, especiallyin regard to mean changes. In terms of the overall effects of the climatic changes on other variables of both agricultural and macroeconomic performances, the study proposed the test of long-term autoregressive pattern of relationship. The first analysis therefore is to examine whether a long run relationship exists between dependent variables and independent variables. Given that the study focuses on error correction processes, test for a common stochastic trend is also conducted in this study. This involves testing for the existence of a cointegrating relationship between economic growth and climate change variables.

Table 3: Results of Bounds Approach to Cointegration Test

CROP equation		
Test Statistic	*Value*	*K*
F-statistic	20.93	7
Significance	I0 Bound	I1 Bound
10%	2.03	3.13
5%	2.32	3.5
2.50%	2.6	3.84
1%	2.96	4.26

Source: Author's computations Using E-Views Version 10

The evaluation of the results shown in Table 3 is based on the critical F-statistic values for the lower and upper bounds as also reported in the results. In order to determine that climatic changes and other independent variables are forcing variables, it is important to conduct a Bounds test that includes all the variables as on the LHS (Ahmed, *et al* 2013). Strong cointegration is only observed when only the equations with agricultural production (or economic performance) as dependent variable pass the cointegration test. Table 4 shows the result of the Bounds test of long run effects for the ARDL specifications for all the four major equations in the study. The evaluation of the results is based on the critical F-statistic values for the lower and upper bounds are also reported in the results.

Table 4: Lag Length Selection Criteria

	Test statistic				
	Lag	*LR*	*AIC*	*SC*	*HQ*
CROP	k = 0	NA	NA	NA	NA
	k = 1	366.74	-6.23	-5.08	-5.79
	k = 2	12.76	-5.53	-3.39	-4.72
	k = 3	10.48*	-7.93*	-5.09*	-7.02*
	k = 4	99.21*	-7.82	-3.73	-6.27

Source: Author's computations, Using E-Views Version 10

Thus, a lag structure of three periods is selected as representing the structure that will ensure more stable coefficient estimates. In the lag selection, optimality of the model was determined using both the Akaike Information Criterion (AIC) and Schwarz–Bayesian Criterion (SBC). It should be noted that the results from the Bounds cointegration testing suggest that causality may occur only from the direction of climate variables to crop variables (but not vice visa). The outcome is further strengthened by noting that the two climate variables are stationary in levels, not in differencing.

Table 7: Climate conditions and crop production

Variable	*ARDL*			*FMOLS*		
	Coefficient	*t-Statistic*	*Prob.*	*Coefficient*	*t-Statistic*	*Prob.*
LTEMP	-1.733	-0.546	0.600	3.511	1.085	0.287
LRFALL	-0.982	-5.825	0.000	-0.170	-0.452	0.654
LGEA	0.130	5.340	0.001	0.240	4.399	0.000
LINF	-0.452	-6.896	0.000	-0.683	-4.300	0.000
LEXR	0.064	1.855	0.101	-0.122	-1.476	0.151
LGFCF	0.160	5.480	0.001	0.087	1.538	0.135
LLABFP	2.010	3.580	0.007	4.405	3.602	0.001
C	10.794	0.964	0.363	-17.823	-1.451	0.157
Adj. R-sq				0.933		
L-R var				0.031		

Note: ***, **, * indicate significance at the 1%, 5% and 10% levels respectively.
Source: Author's computations using E-Views Version 10

The result for crop production is shown in Table 7 where only the coefficient of rainfall is also significant among the climate variables, though both are negative. This result also shows that increased rainfall has the tendency to reduce crop production in the country by 0.98 percentage point for every one percent rise. This is very critical since the elasticity is approximately unitary and shows that every inch of excess rainfall directly translates to poorer crop output each year. The coefficients of the other explanatory variables have similar outcomes like the previous results. Thus, government expenditure on agriculture, infrastructure and labour force are essential for boosting crop production in Nigeria.

Table 8: Post Estimation Test Results

Variable	*CROP*
	CVIF
LTEMP	1.68
LRFALL	1.35
LGEA	2.32
LINF	4.87
LEXR	1.66
LGFCF	2.59
LLABFP	2.73

Source: Author's computations using E-Views Version 10

In order to check for the robustness of each of the estimates in the study, the multicollinearity, normality and serial correlation tests are conducted, and the results are presented above. The regressors in the models used in the study are numerous with outcomes that may measure the same effects. Multicollinearity tests are therefore conducted on each of the models to ensure that the explanatory variables are not excessively collinear. Apparently, high collinearity tends to amplify the standard errors of the estimates and render the reliability of the estimated models quite low. In Table 8, the results of the multicollinearity test for each of the model results are presented. In the result, only the centred variance inflation factors (CVIF) for each of the variables are reported since each of the equations contains a constant term. The CVIF value must be less than 10 for the variable in an equation to be free from collinearity. For each of the estimates, it can be seen that the variables of interest (i.e., climate changes) all have CVIF values that are less than 10, suggesting that the estimated coefficients for each of the equations are reliable and stable over time.

Table 9: Test of Stability of Cointegration Parameters

Variable	CROP
L_c value	0.412
Bootstrap p value	0.078
Normality test (J-B)	0.404 (p = 0.132)
Serial Correlation LM Test	0.943 (p = 0.404)

Source: Author's computations using E-Views Version 10

In order to test the stability of cointegration parameters, the L_c test formulated by Nyblom (1989) and Hansen (1992) is employed based on the FMOLS estimations. According to Balcilar *et al.* (2013), the "Nyblom-Hansen statistic tests for parameter constancy against the alternative hypothesis shows that the parameters follow a random walk process" (pg number). From the results in Table 9, there is clear indication of parameter stability in each of the equations. This is demonstrated by the insignificant values for the Hansen L_c coefficients in the estimation. Thus, a significant and stable long run relationship is shown to exist between climate changes and both agricultural performance and economic growth in Nigeria. Also, the respective J-B and LM tests for the normality and serial correlation show that the residuals are normally distributed and are devoid of serial correlation.

5. CONCLUSION AND RECOMMENDATIONS

In this study, the relationships among climate change and crop production in Nigeria were examined. In particular, crop production was presented as a target variable for climate change as it affects economic performances. It is argued that climate change can affect the crop production, which, in turn affects the growth prospects in the Nigerian economy. Annual data for the period 1984 to 2021 was used in the analysis. The effects of climate change are continuous, which implies that the structure of the relationships is dynamic. Thus, the autoregressive distributed lags (ARDL) technique was adopted in the estimation of the climate change on crop production.

The elasticity of long run impact of rainfall on crop production was shown to be close to one, indicating that any excess inch in rainfall would likely reduce crop production by the same proportion. This is particularly true for Nigeria which relies heavily on rainfall for her crop production. Apparently, the effects of climate change on this sector are continuous, which implies that the structure of the relationships is dynamic.

The paper offers the following recommendations towards tackling the increasing problems posed by climate change to optimal crop productivity. In the first place, with rainfall expected to be unpredictable both in terms of periodicity and amount, adaptation strategies for climate change should be considered both in short-term and long-term.

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