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Effect of Climate Change on Agricultural Productivity in Nigeria (1991-2022)

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ABSTRACT

This research work examines the effect of climate change on the agricultural productivity in Nigeria from 1991 to 2022, a period of 32 years. This research work applies the Sustainable Livelihood Theory as a theoretical framework and an Autoregressive Distributed Lag Model (ARDL) was estimated. The data used in the research work was sourced from Central Bank of Nigeria Statistical Bulletin of 2022 and the World Bank Data Bank on Agricultural GDP, Rainfall, Temperature and Carbon Emissions. The Unit root test and the bounds test were employed to check for the stochastic properties of the series and the presence of a long run relationship between the variables. The results showed that climate change variables (rainfall, temperature and carbon emissions) all exert a negative effect on agricultural productivity in both short and long run. The Error Correction Mechanism revealed that a disequilibrium in climate change can be corrected at a speed of 8% annually. In the light of the empirical evidence regarding the negative effect of climate change on agricultural productivity, it is recommended that there should be existence of institutional support system that will aid farmers in further understanding anticipated climate change which will help cushion the effect of climate change.

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1. INTRODUCTION

It is now widely recognized that Climate change represents one of the most critical environmental challenges of current century [1]. It covers the prolonged fluctuations in temperature and climatic conditions that are caused by human related activities since the mid-1800s and hence, the burning of fossil fuels (including coal, gas, and oil) that constitute the principal source of greenhouse gases [1]. The impacts the ramifications of climate change are extensive and profound. ranging from sea-level rise, fierce weather, occurrences of storms, floods, hurricanes, droughts and increased frequency of fires among many more. The outcomes of climatic change are also observable in poverty, malnutrition, and various other health and socio-economic repercussions [2], [3].

The influence of climate change on agriculture is paramount., a critical sector which directly employs around 35% of the total national workforce in Nigeria as of 2020 (FAO). Agriculture is more sensitive and liable to climate change than any other sector. The inter-annual rainfall amount in Northern Nigeria usually leads to climate hazards, especially the droughts which has drastic consequences on the food production process is an observed reality [1]. Climate change may lead to variations of rainfall and temperature that will shape crop growing seasons and affect the yield of rain-fed crops [4]. Since agriculture in Nigeria predominantly relies on rainfall, making it susceptible to climate change affects crop development, soil moisture availability, soil erosion, pest and disease prevalence, sea level rise, and soil fertility [4].

In spite of the widespread research which provides a basis for assessing the effects of climate change on agricultural productivity in Nigeria, the nation is experiencing major setbacks particularly for the agricultural output owing to the repercussions of recent climatic catastrophes, it is paramount that the issue needs further investigation with a real possibility of reversing the harm and that way enabling recovery and effective policymaking. This study is carried out at a time when the country is still recovering from recent climate disasters that have significantly impacted agricultural output.

Specifically, the objectives are to analyse the specific climate-related risks and challenges faced by the agricultural sector in Nigeria, assess the correlation between climatic change and agricultural output, and assess the degree the impact of climate change on agricultural productivity in Nigeria.

The outcomes of this research will be vital for the institutions of government that are responsible for environmental and climate regulations as they will help shape commendable polices. Therefore, this paper seeks to assess the significant effects of climate change on agricultural productivity in Nigeria. Section two of the paper reviews literature and theories, section three encompasses the technique. Section four delineates the analysis of the study. and interpretation of data as well as discuses results, and finally, section five round the research work with summa and policy recommendations.

2. LITERATURE REVIEW

The agricultural industry is considered the primary foundation of the Nigerian economy, involving a substantial part of the population either in a direct or indirect manner in its production line [5]. However, although it is vital, Nigerian agriculture faces a lot of constraints that reduce productivity, like slow technology adoption, insufficient irrigation systems, bad land tenure systems, high production costs, effects of climate change, land degradation and large post-harvest losses.

The impacts of climate change are already apparent in the Nigerian context which are extremely dangerous for different sectors, especially for agriculture. These impacts include the rising average temperatures, irregular rainfall patterns, the sea-level rising every now, the frequently flooded surfaces, drought and deserts, land degradation, more severe weather conditions, freshwater depleting, the biodiversity diminishing [6], [7] .

Nigeria has a tropical climate characterized by three distinct zones: a rain-forest monsoon climate in the short, a savannah in the greater part of the centre, and a Sahelian hot and semiarid in the north (World Bank, n.d). The country experiences two main seasons – wet (rainy) and dry.

The South African Confederation of Agriculture Union states that the principal greenhouse gases are carbon dioxide, methane, and nitrous oxide., which comprise 80%, 14%, and 6% of total greenhouse gas emissions, respectively [8]. Greenhouse gases are effective absorbers of heat radiation emitted from the Earth's surface, functioning as a thermal blanket over the atmosphere, so maintaining a higher temperature than would otherwise prevail. If anthropogenic greenhouse gas emissions persist at current patterns until 2030, the Earth is projected to undergo a mean temperature rise ranging from 1.5°C to 4.5°C [9]. Developed nations are mostly responsible for climate change, whereas emerging nations disproportionately suffer due to poverty and limited technical advancement [10].

The effects of climate change present severe threats to agricultural productivity in Nigeria. Although in some regions with elongated growing season some advantages might be revealed, the overall consequences of this issue are probably negative. Rise in disease vector abundance, crop diseases, pest attack and weed increase could be among the factors contributing to lesser production [8], [9] . The change in the rainfall patterns could mean drought or flood, which could affect the production and food security. Species of ecosystems needing stable environments are more likely to fail in the face of fast changes, while the alien plants and animals will thrive in the disturbed habitats [11]. Nigeria is most vulnerable with water resources, agriculture, health, ecosystems, forestry and food security and weather change with long-term impact declining yields, food insecurity and malnutrition [8], [9].

A multitude of research have investigated the impacts of climate change on agricultural output in sub-Saharan Africa, accompanied by many findings pointing to detrimental effects:

Findings revealed that the productivity depends on the rains (positively), but not on the temperatures (negatively) [12], [13], [14], [15]. However, [16] reported contradictory results of positive climate change impacts. Studies also highlighted threats to food security, yields and the resource base [7], [17]. Recent work using advanced techniques like NARDL corroborates mixed effects of rainfall and temperature changes [18].

[19] analysed the the correlation between climate and agricultural productivity Sub-Saharan Africa from 1961-2008. Employing a panel production function approach, they found that higher temperatures above 30°C had severe negative impacts on yields of staple crops like millet, sorghum and maize.

On the other hand, [20] used integrated assessment models and found some potential for agricultural benefits from modest warming and rainfall increases in certain arid regions of Africa, although protective adaptation would be required.

[18] Examined the effects of climate change on particular food crop yields in South-east Nigeria. The research employed descriptive statistics, cointegration analysis, and an error correction model. The analysis indicated that the climatic patterns were unstable, exhibiting peak points throughout the examined time. The coefficients of the ECM (-1), which denote the speed of adjustment of crop outputs to equilibrium following a disturbance, were found to be -0.365 ($p<0.01$), -0.211 ($p<0.05$), and -0.599 ($p<0.001$) for the yam, maize, and cassava output models, respectively. It was subsequently determined that all variables, with the exception of lagged yam output and temperature, exhibit a positive correlation with yam output. Conversely, lagged maize production, precipitation days, and temperature have an inverse correlation. Conversely, precipitation amount, humidity, and sunlight are positively associated with maize yield. Finally, the amount of rainfall, number of rainy days, sunshine duration, and delayed cassava yield are positively associated with cassava output, while temperature and humidity show a negative correlation. The research suggests that climate change adversely affects the production of the chosen food crop.

However, studies often project negative the effects of climate change in Africa magnitudes can vary based on factors like geographic scope, time periods, crops analysed, and modelling approaches used [21]. The empirical review puts together prior researches that demonstrates that climate change adversely affects Nigerian agriculture, though with some mixed findings. In total this highlights the importance of conducting updated, region-specific assessments like this study aims to do for Nigeria by adopting a holistic nationwide approach.

3. THEORETICAL FRAMEWORK AND METHODOLOGY

The empirical model is framed about product aggregation levels and functional form frameworks utilising the sustainable living theory approach into account. This theory connects sustainable farming production with the access to the production factors that are defined as the capability to deal with pressures and shocks without compromising on resource base [22]. The sustainable livelihood approach is commonly applied to analyse the livelihoods of rural communities that depend heavily on natural resource-based activities like farming, fishing, or forestry [23]. It provides a framework for assessing livelihood vulnerability, identifying constraints, and developing asset-building strategies. Based on this, an expanded production function delineates agricultural output as a function of environmental conditions and supplementary input factors.

3.1 *Source of Data*

This work will make use of annual data set to investigate the correlation between climate change and agricultural productivity in Nigeria over the period of 1991 to 2022. The data set are derived from the Central Bank of Nigeria Statistical Bulletin 2022, World Bank Data Bank, Nigerian Meteorological Agency.

3.2 *Model Specification*

The fundamental production function can be estimated using econometric methods at different levels of aggregation. The aggregate production function represents the most general, accounting for aggregated, multi-output production at the macroeconomic level (e.g., sector, country). Moreover, it denotes that the extent of a particular input's effect on the output cannot be determined [24]. This study employs both aggregate and disaggregate analyses due to the asymmetry in agricultural outputs' responses to input changes and adapt [18] estimation technique. Several functional forms exist, including the continuous elasticity of substitution (CES) function, along with specific instances such as Leontief and Cobb-Douglas functions. The CES function as delineated by [10] defines production as:

$$\boldsymbol{Q = A(\gamma K^{-p} + (1-\gamma)L^{-p})^{(-\frac{1}{p})}}$$

Where Q is output, K is capital, L is labour, A is efficiency, γ is a share parameter, and ϱ is the substitution parameter. Although capturing varying elasticities of substitution, the CES is rarely used in agriculture [16]. This study adopts the Cobb-Douglas functional form.

The general production function is specified as:

$$AGDPt = f(Tempt, Raint, CoEt)$$

Where $AGDPt$ is agricultural output measured as Agricultural GDP, $Raint$ is rainfall (cm), $Tempt$ is temperature (degrees), and $CoEt$ is carbon emission.

Econometrically:

$$AGDPt = \beta 1 + \beta 2Tempt + \beta 3Raint + \beta 4CoEt + ut$$

Taking the log-linear form:

$$LogAGDPt = \beta 1 + \beta 2Tempt + \beta 3Raint + \beta 4CoEt + ut$$

4. RESULT PRESENTATION AND DISCUSSION

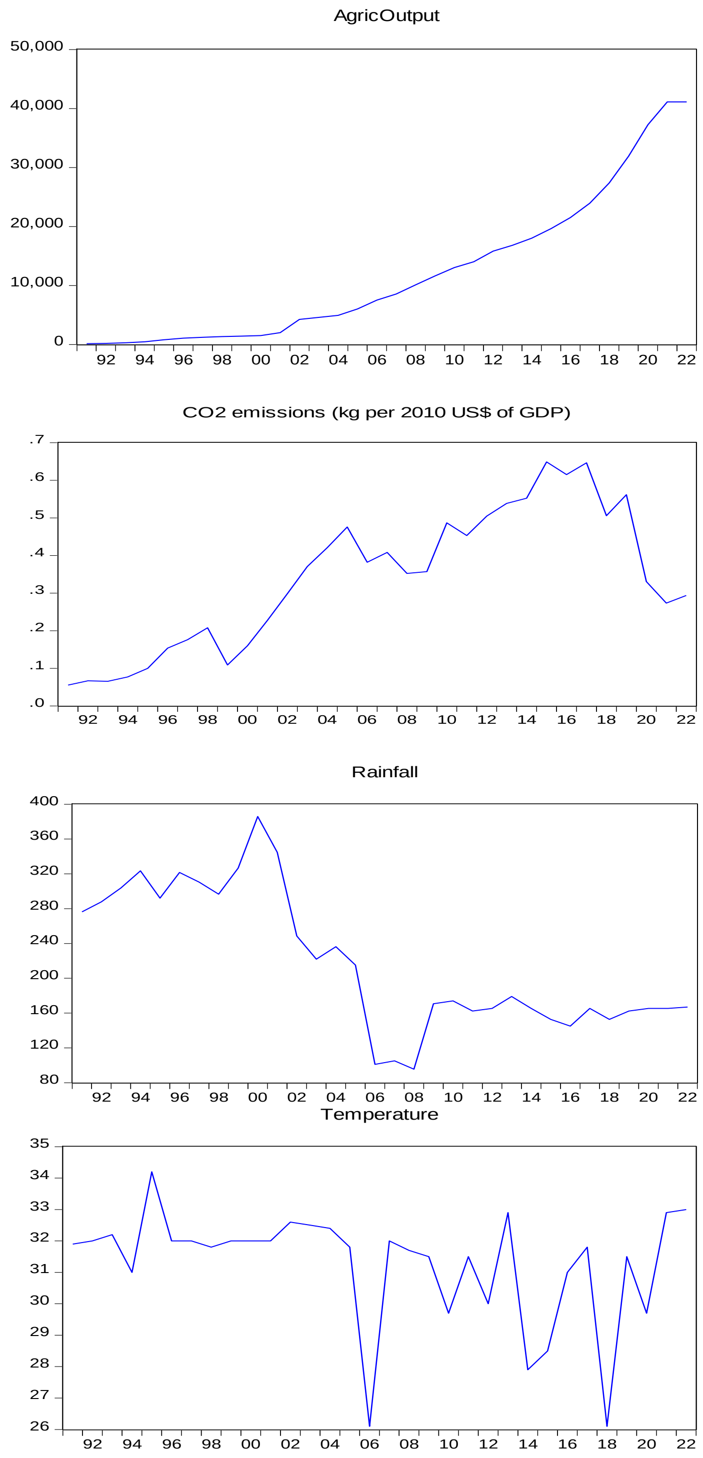

Figure 1. Trend Analysis on the Pattern and Behaviour of the Variables
Source: Author's Computation 2023

a. Trend of Agricultural Output, Temperature, Rainfall, Carbon Emissions

Agricultural productivity was proxied by the annual agricultural GDP in Nigeria for the period of 1991-2022. The graph shows that agricultural productivity has been on a rise continuously since the 90's up till 2022 where the figure remains unchanged from the 2021 figures. The rise in production levels is due to good weather patterns, use of mechanized farming, amongst other efficient agricultural practices.

The graph also illustrates the trend of temperature spanning the period of 1991-2022. Here the temperature in Nigeria during this period has been rather stable, averaging out around 33°C or perhaps a little lower.

Rainfall in Nigeria for the period of 1991-2022 illustration by graph indicates the continuous change of Nigeria's rainfall fluctuation with the highest rainfall occurred in 2000 (386mm) while in 2008 the lowest rainfall (96mm) was experienced.

And finally, carbon emission (proxied by the annual carbon dioxide emission in kg) within this period have been showing a rising trend from the 90’s till 2020 were Nigeria witnessed a drop in that particular rate of emissions.

b. Descriptive Analysis of the data

Table 1. Descriptive Statistics

	Agricultural Output	Rainfall	Temperature	Carbon Emissions
Mean	12175.88	218.3206	30.25625	0.339779
Median	8032.640	176.5000	31.8000	0.354713
Maximum	41126.06	385.9000	34.20000	0.648901
Minimum	123.2356	95.58000	0.000000	0.055476
Std.Dev	12598.69	80.04997	5.823198	0.185276
Skewness	1.004189	0.368226	-4.588108	-0.022703
Kurtosis	2.942240	1.921439	24.30360	1.820704
Jarque-Bera	5.382557	2.274208	717.3953	1.857068
Probability	0.067794	0.320747	0.000000	0.395133
Observations	32	32	32	32

Source: Author’ findings
Note: **significant at 5%

Table 1, presents summary statistics for Agricultural Output, Rainfall, Temperature, and Carbon Emissions from 1991-2022. The mean and median values situated between the maximum and minimum suggest a normal distribution for each series. The statistics of the skewness show that the Agricultural Output and Rainfall are positive, while Temperature and Carbon Emissions are negative. Kurtosis provides measures of the peakedness (kurtosis) of the distribution, with values more than 3 representing leptokurtic and less than 3 platykurtic (flatness). Temperature has leptokurtic effect, while the rest of the variables are platykurtic types relative to the normal. In conclusion, the p-values found from the Jarque-Bera statistic indicates that the sample series are regularly distributed.

Table 2. Result of the Unit Root Test

Augmented Dickey-Fuller Test (ADF)							
	LEVEL			AT FIRST DIFFERENCE			I (d)
	constant	trend and intercept	none	constant	trend and intercept	none	
Carbon Emissions	-1.652049	-0.735571	-0.253586	-5.822330**			I(1)
Temperature	-5.925412**						I(0)
Rainfall	-1.265721	-1.954088	0.94494	-4.786529**			I(1)

Augmented Dickey-Fuller Test (ADF)							
	LEVEL			AT FIRST DIFFERENCE			I (d)
	constant	trend and intercept	none	constant	trend and intercept	none	
Log Agric Output	-4.408054**						I(0)

Source: *Author's computation 2023*
Note: **significance at 5%

c. Result of the Bounds Test

The time-series data have been validated as stationary at both the level and first difference., based on the evidence from the ADF unit root test (see to table 2). It is essential to examine the co-integration, namely the enduring correlation between the variables. The ARDL bounds test methodology is utilised due to the time series. characteristics of the data. The outcome of the boundaries test is displayed in Table 3. The F-statistic is compared against the critical boundaries at a 0.05 significance level. The findings indicate a lower bound of 2.79 and an upper bound of 3.67, with an F-statistic of 4.242183. The above result indicates that the F-statistic exceeds both the lower and upper bound values, signifying the presence of a long-term link. Co-integration exists among Agricultural Output, Rainfall, Temperature and Carbon Emissions in Nigeria.

Table 3. Results from the Bounds test

F-statistics	Value	K
	4.242183	3
Critical Value		
Significance	I0	I1
10%	2.37	3.2
5%	2.79	3.67
2.5%	3.15	4.08
1%	3.65	4.66

Source: *Author's computation 2023*
Note: **significance at 5%

d. Result of Model Estimation

Tables 4 and 5 report the immediate and enduring effects of climate change on agriculture productivity in Nigeria.

Table 4. Error Correction Model Result (Short Run Test)

Variable	Co efficient	Prob. Value
D (LOG Agric Output (-1))	0.323106	0.0017
D(Rainfall)	-0.000427	0.0169
D (Rainfall (-1))	0.000723	0.0009
D(Temperature)	-0.001508	0.1437
ECT (-1)	-0.082660	0.0000
R^2	0.848375	
Adjusted R^2	0.816786	
F-Stat	26.85701	0.000000

Source: *Author's computation 2023*
Note: **significant at 5%

Table 5. Long Run Test

Variables	Co-efficient	P-Value
Carbon Emissions	-0.527508	0.5264
Temperature	-0.116253	0.0050
Rainfall	-0.005785	0.0020

Source: *Author's computation 2023*
Note: **significant at 5%

The results indicate that rainfall in the short term, it is associated with a negative and considerable impact on agricultural productivity. (-0.00047), which implies that one percent fall in rainfall results in a decrease in agricultural output. Aggregate output declines by 0.0427 % in the short run, while in the lag year rainfall exerts a beneficial influence on agricultural productivity of 0. 000723 percent [21]. However, in the long run, the coefficient (-0.005785) shows that a one percent change in rainfall reduces the agricultural output by 0.005785 percent. Hence, the rainfall can be seen as a positive factor in agricultural production when it happens in a normal amount, but otherwise, too much rain can cause flooding, potentially resulting in erosion and leaching that can lead to a decrease in nutrient availability and productivity. This was in tandem with [21].

Regarding temperature, the result disclosed that it exerts a detrimental and substantial impact on agricultural production over the long term (-0.116253 percent) though insignificant in the short run (-0.001508 percent). The fact that soil fertility decreases as a result of higher temperatures raises challenges for livestock and other agricultural production. Consequently, the result suggests that carbon emission has beneficial and substantial impact on agriculture produce. The coefficient value of 0.527508 signifies that a one percent increase in carbon emissions will lead to a 0.527508 percent decrease in agricultural production in the long run, aligning with [25] finding that carbon emissions impair agricultural productivity.

The error correction term (-0.082660) is negative and statistically significant.\ 5%, suggesting deviations from the adjustments transitioning from the short term to the long term are rectified by 0.08% annually. The R^2 of 84% indicates the independent variables account for 84% of the variance in the dependent variable. Also, the F-statistic (26.85701) confirms the overall model's statistical significance.

5. CONCLUSION AND POLICY RECOMMENDATION

This research work assessed the effects of climate change on agriculture productivity in Nigeria. The data indicate that temperature substantially adversely affects agricultural productivity in both the immediate and extended future in Nigeria. This was in range with [19] findings. Also, as [6], [26] postulated rainfall and carbon emission have a negative and substantial impact on agricultural productivity at both short-run and long-run in Nigeria. Based on these findings, we conclude climate change adversely impacts agriculture. productivity in Nigeria, this evidence supports the position of [18].

This study emphasises the need to invest in enhancing the adaptive capacity of farmers., especially small agricultural producers, who are significantly constrained by their dependence on natural climate variables and the absence of essential institutional support systems. Institutional support systems will aid farmers in comprehending projected climate changes and mitigate the effects of climate change. The suggestions are emphasised.

1. In the light of the empirical evidence regarassessing the detrimental effects of climate change on agricultural output necessitates an urgent effort to educate rural farmers regarding efficient management of weather and climate risks, together with the sustainable use of meteorological and climate data for agricultural output.
2. Policy makers are tasked with formulating measures that will assist local farmers in adapting farming practices to alleviate the effects of climate change.
3. Biotechnological advancement in the cultivation of crop seedlings that enables rapid growth, alongside the development of crops that thrive in elevated temperatures and exhibit resilience to carbon effects emissions. This can be achieved through efficient financing of research institutions and biotechnology centres in Nigeria.
4. Various regions in Nigeria encounter distinct climate-induced hazards. It is essential to thoroughly examine the optimal adaption approach necessary for each zone. The northern region frequently encounters drought, and the southern regions experience flooding. Adaptation programmes must to be grounded in the limitations and opportunities of each agro-ecological zone, instead of utilising a standardised approach to tackle the challenges.

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