EFFECT OF CLIMATE CHANGE ON AGRICULTURAL SECTOR: EVIDENCE FROM NIGERIA

IME OKON UTUK (PH.D)
DEPARTMENT OF ECONOMICS, AKWA IBOM STATE UNIVERSITY,
utuk_ime2003@yahoo.com

ANIEFIOK BENEDICT UDO (PHD)
DEPARTMENT OF ECONOMICS, TOPFAITH UNIVERSITY, MKPATAK,
aniefiok.benedict@gmail.com

BONIFACE LINUS AKPAN (PH.D)
DEPARTMENT OF ECONOMICS, AKWA IBOM STATE UNIVERSITY,
bornifaceakpan@gmail.com

EDUNO, EDEDET BASSEY
DEPARTMENT OF ECONOMICS, AKWA IBOM STATE UNIVERSITY, eduno.wisdom5@gmail.com;
ededeteduno@aksu.edu.ng

INIGBEHE MICHAEL OKON
DEPARTMENT OF ECONOMICS, AKWA IBOM STATE UNIVERSITY,
mikeokon72@yahho.com

KEYWORDS
climate change, agriculture, Cobb-Douglas production function, Nigeria, fully modified ordinary least squares (FMOLS)

ABSTRACT
This study conducts an empirical investigation of the effects of climate change on agriculture production in Nigeria from 2000-2022. The fully modified ordinary least squares (FMOLS) estimator was employed for estimation of the specified model. The result shows that among the climate change variables, temperature (LNTEMP) has a significant positive impact on agriculture sector while rainfall has a negative and significant effect on agricultural sector. More so, methane emissions (LNMETH) exhibited an inverse relationship with agriculture sector. Carbon dioxide emission (LNCO2) shows a positive but insignificant relationship with agriculture sector. In that regard, the Federal government needs to invest in agricultural science research so that scientists can produce crops that are resistant to the harsh climatic conditions. At the same time, climate-smart agricultural innovations to conserve water such as solar-powered drip irrigation and rainwater harvesting should be concentrated on to help farmers cope with droughts. Also, farmers can cut emissions by improving fertilizer use.

Introduction

Nigeria's agriculture contribution to GDP makes it the largest sector in the country. Crop production accounts for a huge chunk of activities in the sector representing 88% of total industry size with livestock, forestry and fishing accounting for the balance of 12%. The sector achieved GDP of US$113.64 billion in 2014, the highest in the last five years (2013 – 2017) (pwc.com, 2022). Agriculture contribution to Nigeria's GDP dropped by 31% from US$113.64 billion in 2013 to US$78.45 billion in 2017(pwc.com, 2022). Since 2014 when agriculture sector achieved GDP ofUS$113.64 billion, the sector's contribution has been declining due to low agriculture yields, conflicts such as terrorism and the herdsmen crisis, as well as the impact of climate change. The focus of this study is on climate change which reflects the variations in the average daily weather conditions such as temperature, humidity, rainfall, and sunshine of a location over an extended period. In recent times, it has been aggravated by human activities above other natural shifts or variations(Firstbanknigeria.com, 2023).

Nigeria's climate has been changing, evident in: increases in temperature; variable rainfall; rise in sea level and flooding; drought and desertification; land degradation; more frequent extreme weather events; affected fresh water resources and loss of biodiversity. The durations and intensities of rainfall have increased, producing large runoffs and flooding in many places in Nigeria (Haider, 2022).

Rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands. Droughts have also become a constant in Nigeria, and are expected to continue in Northern Nigeria, arising from a decline in precipitation and rise in temperature. Lake Chad and other lakes in the country are drying up and at risk of disappearing. Temperature has risen significantly since the 1980s. Climate projections for the coming decades reveal a significant increase in temperature over all the ecological zones (Haider, 2022). It is on this premise that this study attempts to empirically examine the effect of climate change on agriculture production.

Past studies that have examined the impact of climate change on food production at the country, regional, or global scale (Parry et al. 1999; Lobell and Burke, 2008 and Deressa and Hassan, 2010; McCarthy et al. 2001). However, the literature that provides evidence of climate change impacts on agricultural sector in Nigeria include: Apata (2022); Ani, Anyika and Mutambara (2022); Uwazie (2020); Ayo et al. (2014); Fasona and Omojola (2005); Idumah et al. (2016); Ikem, 2018; Ogbo et al. (2019); Oyinloye et al. (2018); Ayinde et al., 2020). Nevertheless, there is need for more evidence in order to ensure greater implementation of mitigation and adaption measures in Nigeria so that more food can be produced to feed the growing population all year round.

The study is organized as follows: in section 2, **climate and climate change experience in Nigeria** is discussed. Section 3 contains an explanation of the methodology in terms of the specification of model, technique of analysis as well as data source used in the study. Section 4 provides the results and analysis. Finally, section 5 gives the summary, conclusion and recommendations.

Overview of Climate and Climate Change Experience in Nigeria

Nigeria has a tropical climate with 2 distinct seasons: wet and dry seasons. These seasons have varying lengths of rainy and dry seasons depending on the geographical location. For example, the southern part of Nigeria has a longer period of rainy season (March to November) than the Northern part (May to September). Dry season is prevalent in the north coupled with high temperatures that may reach an average monthly value of 38 degrees celsius, while the mean temperature in southern Nigeria hovers around 32-33 degrees Celsius (Future Learn, 2021). In the north, the harmattan wind, which is a dry and hot wind, blows longer than it does in southern Nigeria.

Nigeria like other countries of the world has its own experience of climate change disasters like the one that struck 25 years ago in the north-eastern region presently comprising Borno and Yobe states, the southern part of Lake Chad, the section of it that lies inside Nigerian territory dried up. About four decades ago, the Lake covered an area of over 40,000 square

kilometers, whereas it now encompasses a mere 1,300 square kilometers (Beyioku, 2016). While the negative trend continues unabated and as land is laid to waste by the rising temperature leading to the rapid southward expansion of the Sahara Desert, Farmlands and surrounding villages became barren and were swallowed up by advancing desertification, which led to massive migration of people in search of more fertile terrain from the north east towards the greener plateau and middle belt regions. More so, growing desertification forced thousands of Fulani herdsmen to move to the south and middle belt leading to clashes with crop farmers culminating in death of hundreds according to the reports of residents and activists.

Nigeria's Guinea Savannah region is not spared either. Logging and over dependence on firewood for cooking have stripped a greater part of this area of its vegetation cover. The situation is similarly replicated in the south, where the forest around Oyo has long been reduced to grassland. The south – eastern part of the country has been struck by a different ill. There, gulley-erosion has devastated many settlement areas and farmlands, leading to poverty among local populations.

Just as desertification is devastating vast areas of the north, rising sea levels are threatening Nigeria's coastal regions. Although a source of oil wealth, the Niger Delta's low-lying terrain and criss-cross of waterways make it extremely vulnerable to flooding, apart from being at the risk of rising sea level, it has fallen victim of extreme oil pollution. Moreover, in the southern Nigeria, climate change is also reflected in the massive flood experienced in 2012, houses, farms, farm products, properties and even human beings were swept away. Also the statistics released by the southwest zonal office of the National Emergency Management Agency (NEMA) about 2 years ago show that no fewer than 5000 persons were affected and 60 houses destroyed in a windstorm which occurred in four states in the south -west region (Beyioku, 2016).Negligence and a failure to tackle the issue of climate change by successive governments have also contributed to the rise of insurgency groups across the country.

Methodology

3.1 Specification of Model

The framework of this study is hinged on the neo-classical model based on the Cobb-Douglas production function which describes the relationship between the quantity of output and two factors of production, physical capital and labor, as follows:

$$Q = AK^{\alpha} L^{\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where: $\alpha + \beta = 1$. The capital, K, represents the monetary value of physical assets necessary for production, such as buildings, machinery, and equipment. The labor, L, represents the productive effort of the workforce, measured in person-hours. The exponent α is a value between 0 and 1 that measures the responsiveness or elasticity of output with respect to capital. A is a constant known as the total-factor productivity (TFP). The value of A is a ratio of output to total input, and reflects the overall quality or efficiency of the production process. As technology improves, and the skill and education of the workforce increase, enterprises will convert labor and capital to output products more efficiently, meaning the total-factor productivity should rise over time.

The Cobb-Douglas formula can be easily generalized to include more than two factors of production. As such, equation (1) was augmented to capture the effect of climate change variables on agriculture sector in Nigeria as follows:

$$LNAGO_t = Ə_0 + Ə_1 LNGCF_t + Ə_2 LNLAB_t + Ə_3 LNRAIN_t + Ə_4 LNTEMP_t + Ə_5 LNCO2_t + Ə_6 LNMETH_t + Ə_7 LNFDI_t + \tilde{ω}_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where: AGO is the volume of agricultural output (tones) (proxy for agriculture sector); LAB is labour force (Million); GFC is gross capital formation (₦Billion) used as a proxy for capital; Rainfall (mm per year) (RAIN); Temperature (0 C) (Celsius) (TEMP); Carbon Dioxide Emission (kiloton (kt)) (CO_2). Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring: Methane emissions (kt of CO2 equivalent) (METH). Methane emissions are those stemming from human activities such as agriculture and from industrial methane production. The greenhouse gases, mainly carbon dioxide and methane are mostly generated in Nigeria from oil and gas production,

land-use change, forestry, agriculture and fugitive emissions; foreign direct investment (FDI) (proxy for technology);LN is the natural log, t is time period, ω= error terms or stochastic variables; $\ddot{e}_0$= constant term; and $\ddot{e}_1$ - $\ddot{e}_7$ = parameters estimates.

3.2 Data Source

The data were obtained from World Development Indicators, theglobaleconomy.com, indexmundi.com, Climateknowledgeportal.worldbank.org; tradingeconomics.com, countryeconomy.com, worlddata.info, and Statistical Bulletin and Annual Report and Statement of Accounts published by the Central Bank of Nigeria (CBN). The data span the period 2000 to 2022.The logical basis for choosing these periods is owing to data availability and accessibility.

3.3 Method of Data Analysis

Augmented Dickey-Fuller (ADF) unit root test was deployed to ascertain whether the variables have unit roots. Thereafter, this study used autoregressive distributed lag (ARDL) bounds test to check the long-run relationships among the variables. The ARDL bounds testing method consents to the study of long-run relationships between variables, irrespective of whether they are stationary at levels (I(0)), first difference (I(1)) or fractionally integrated. This helps to circumvent some of the common problems encountered in time series empirical research, such as the absence of unit root tests power and confusion about the stationarity properties of the study variables. Finally, the FMOLS estimator was deployed for estimation of the specified models. It is required that the variables of a model are co-integrated for the FMOLS technique to be applied. This is to say that a long run relationship between the variables of the model must be established to proceed with the model estimation. This method is also applicable in cases of estimation of model involving small dataset, particularly where it is quarterly time series data for robust parameter estimates.

4. Results and Discussion

4.1 Unit Root Test

Table 1 reports the results of ADF tests. The unit root test reveals that the variables are integrated in a mixed order of I(0) and I(1). This combination of integration gives the foundation for the use of Auto-regressive Distributed Lag (ARDL) bounds test to check for evidence of a long-run relationship among the variable.

Table 1: Augmented Dickey Fuller (ADF) Unit Root Results

Variable	ADF test				Order of Integration
	Levels		1st difference		
	Intercept	Trend & Intercept	Intercept	Trend & Intercept	
LNAGO	-1.533607	-3.831620**	---	---	I(0)
LNLAB	3.457457	-1.247874	-4.457404*	---	I(1)
LNRAIN	-2.101127	-2.042642	-12.99423*	---	I(1)
LNTEMP	-3.886835*	---	---	---	I(0)
LNCO2	-2.089835	-2.637268	-5.099276*	---	I(1)
LNMETH	-2.005797	-1.683836	-2.021038	-3.261452***	I(1)
LNFDI	-3.121809**	---	---	---	I(0)

Note: ADF test was performed using Schwarz information criterion and the automatic lag selection set as 4 lags. Also, *, ** and *** imply statistical significance at 1%, 5% and 10% levels respectively.

***Source**: Author's computation using Eviews 10*

4.2 ARDL Bound Test

The autoregressive distributed lag (ARDL) bounds testing approach to co-integration was applied. The used of this technique has numerous advantages over other techniques of estimation like Engle and Granger (1987) and Johansen (1991). One of the major advantage of this technique is that it can be applied in respective of the order of co-integration of the independent variables (either I(1) or I(0) or both). More so, ARDL model is statistically a significant tool of econometric analysis and has advantageous over other techniques of analysis because it can accommodate small sample size. The rule of ARDL bounds testing is that if the computed F-statistic falls below the lower bound we would conclude that the variables are I(0), so no cointegration is possible, by definition. If the F-statistic exceeds the upper bound, we conclude that we have cointegration. Finally, if the F-statistic falls between the bounds, the test is inconclusive.

ARDL bounds test is estimated and the result is shown in Table 2. The is specified in its original form where LNAGO is the dependent variable and LNGCF, LNLAB, LNRAIN, LNTEMP, LNCO2, LNMETH, and LNFDI are independent variables. Due to the sample size, the study chose a maximum lag length of 1 for the dependent variable and independent variables. In addition, the specification was with Restricted Constant and No Trend, and the model selection criteria wasAkaike information criterion. The result in Table 2 revealed that the null hypothesis of no long run relationship exist is rejected since the F-statistic value 6.646879 is greater than the upper bound I(1) which has a value of 3.9 at 1% level of significance.

Table 2: F-Bounds Test Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	6.646879	10%	1.92	2.89
k	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

Source: Author's computation using Eviews 10

4.3 Long-Run FMOLS Estimates

The long run results are estimated based on fully modified OLS (FMOLS) technique. It is relevant for understanding the perpetual relationships among the variables which could be useful for long term policy evaluations. The result shows that among the climate change variables, temperature (LNTEMP) has a significant positive impact on agriculture sector while rainfall has a negative and significant effect on agricultural sector. Moreso, methane emissions (LNMETH) exhibited an inverse relationship with agriculture sector. Specifically, a percent increase in methane emissions may result into a reduction on agriculture output by 3.206971% in Nigeria. According to Branscombe (2016) models showed that approximately 93% of crop losses over the rest of the century could be caused by non–carbon dioxide emissions, the most damaging of these being methane.

Methane emissions are very harmful to plants because the gas increases surface ozone that causes harmful chlorosis, or a yellowing of the leaves.

The effects of carbon dioxide are more complicated. Carbon dioxide fertilizes plants, which means as the amount of the gas in the atmosphere increases, crop yields initially increase as well. But as carbon emissions continue to contribute to climate warming, the overall impact becomes negative and will outweigh the benefits of fertilization after only 10 years (Branscombe, 2016). Carbon dioxide emission (LNCO2) shows a positive but insignificant relationship with agriculture sector. This shows that carbon dioxide emission effect on agriculture output in Nigeria does not really matter. For instance, In the year 2018, Nigeria's total greenhouse gas emissions was 336 million metric tons of carbon dioxide equivalent (MtCO2e), which is less than 1 percent of global emissions (UNFCCC.int, 2021). This means that emissions per person per year is less than 2 tons, compared to the global average of over 6 tons (Ritchie and Roser, 2020; Ge et al., 2020).

From Table 3, agriculture output decreases by 0.8754485 for every 1% increase in rainfall (LNRAIN). The coefficient of rainfall is statistically significant at 10% significance level. as observed by climatechange.gov.ng (2021), the mean annual variability and trend of rainfall over Nigeria in the last few decades depict the existence of a number of inter-annual fluctuations that have been responsible for dry and wet years or extreme climate events such as droughts and floods in many parts of the country and at different times. Crop production in Nigeria depends on location and climatic conditions. Crops that need rainfall to grow are abundant in the south, while those that do not need rainfall grow more in the north. Excess rain and drought associated with climate change affects this natural distribution of crops in Nigeria and reduces their production in large quantities to meet the population's demand (Future Learn, 2021). The 2022 floods described by experts as the worst Nigeria has experienced since 2012, destroyed crops in over 500,000 hectares of farmlands belonging to thousands of smallholder and commercial farmers across the country (Dailytrust.com, 2022). The total value of destroyed physical and durable assets caused by the 2012 floods, was estimated to be 1.48 trillion (US$9.5 billion), or about 2% of the rebased GDP of US$510 billion (Mbanyeude, 2022).

The result shows that a percent increase in temperature (LNTEMP) will increase agriculture output by 9.742603% which shows a very huge effect. This relationship is statistically significant at 1% significance level. However, according to climatechange.gov.ng (2021), various studies show that annual and seasonal timescales indicate a significant positive increase in temperatures in Nigeria. They show that mean temperatures have been consistently increasing throughout the country in the last five decades and have been rising significantly since the 1980s, with a change of 1.01°C (0.52 to 1.5°C) in the linear warming for the period 1951 - 2005. The linear warming for the same period for 30-year averages on a decadal slice further revealed positive changes in temperature by an average of 0.2°C/decade.

A percent increase in foreign direct investment (LNFDI) (proxy for technology) will, however, increase agriculture out by 0.65%. This shows the relevance of foreign direct investment in Nigeria. This result aligns with Edewor et al (2017) that found a positive significant relationship between FDI and agriculture output in Nigeria.

The regression estimate in Table 3 reveals that agriculture output response to labour force (LNLAB) is positive. The result indicates that the established influence is however not significant at any conventional statistical significance level even though it shows that agriculture output grows by 1.433462% for every 1% increase in labour force. Finally, it can be observed that when capital (LNGCF) increases by 1%, agriculture output decreases by 0.048959%. Nevertheless, this negative effect is insignificant.

Table 3: FMOLS Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGCF	-0.048959	0.333768	-0.146685	0.8855
LNLAB	1.433462	1.077304	1.330601	0.2046
LNRAIN	-0.875448	0.421688	-2.076058	0.0568**
LNTEMP	9.742603	5.497922	1.772052	0.0981***
LNCO2	0.170407	0.524011	0.325197	0.7498
LNMETH	-3.206971	1.413787	-2.268354	0.0397**
LNFDI	0.217950	0.068671	3.173842	0.0068*
C	-16.60671	16.17147	-1.026914	0.3219

R-squared	0.576166	Mean dependent var	5.126299
Adjusted R-squared	0.364249	S.D. dependent var	0.288638
S.E. of regression	0.230143	Sum squared resid	0.741521
Long-run variance	0.022270		

Note: *, ** and *** imply statistical significance at 1%, 5% and 10% levels respectively.

***Source**: Author's computation using Eviews 10*

4.4 Post-Estimation Tests

The validity and the robustness of the model is revealed by the diagnostic tests applied on the residuals. Specifically, in Table 4, the Correlograms Q-Statistics was deployed to conduct the residual test for serial correlation. The result in Table 4 shows that the Q-statistics are insignificant at all lags as depicted by their probability value, indicating there isno presence of serial correlation. The normality test was equally used to determine if the residuals are normally distributed at 5 percent level. The Jarque-Bera statistic formed the basis for rejecting or accepting the null hypothesis of normal distribution at 5 per cent level. The Jarque-Bera test statistic (0.082470) in Figure 1 indicates that the residual of the model is normally distributed since the p-value of 0.959603is greater than the significance level of 5% i.e., 0.959603>0.05.

Table 4: Correlograms Q-Statistics

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
. *| . |	. *| . |	1	-0.165	-0.165	0.6881	0.407
. | . |	. | . |	2	0.030	0.002	0.7113	0.701
. |* . |	. |* . |	3	0.085	0.093	0.9143	0.822

.**| . |	.**| . |	4	-0.259	-0.239	2.8892	0.577
. | . |	. | . |	5	0.036	-0.049	2.9284	0.711
.**| . |	***| . |	6	-0.338	-0.365	6.6907	0.350
. | . |	. | . |	7	0.029	-0.056	6.7208	0.459
. *| . |	. *| . |	8	-0.088	-0.202	7.0143	0.535
. *| . |	.**| . |	9	-0.183	-0.260	8.3717	0.497
. |**. |	. | . |	10	0.234	-0.065	10.782	0.375
. | . |	. *| . |	11	-0.018	-0.067	10.797	0.460
. | . |	. *| . |	12	0.061	-0.177	10.992	0.530

Source: Author's computation using Eviews 10

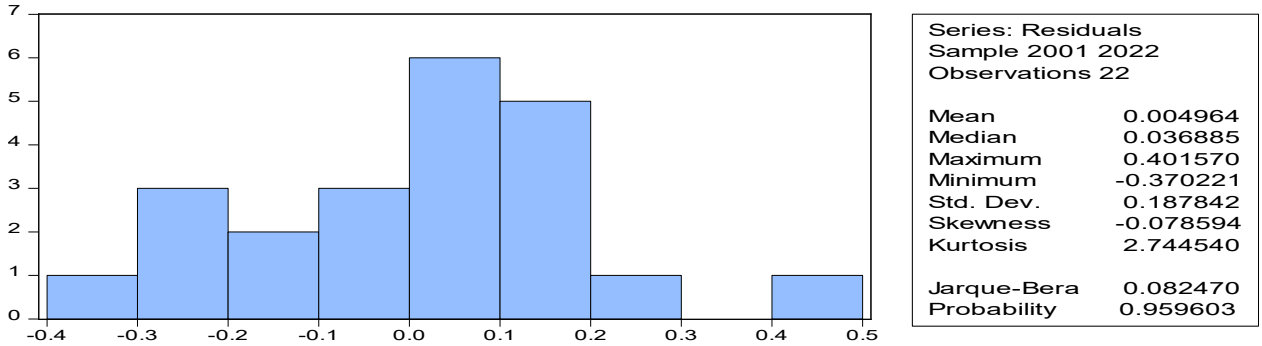


Figure 1: Normality Test

Source: Extracted fromEviews 10

5. Summary, Conclusion and Recommendations

This study conducts an empirical investigation of the effects of climate change on agriculture production in Nigeria from 2000-2022. This study used secondary data spanning from obtained from World Development Indicators, indexmundi.com, and Climateknowledgeportal.worldbank.org. The fully modified ordinary least squares (FMOLS) estimator was employed for estimation of the specified model. The result shows that among the climate change variables, temperature (LNTEMP) has a significant positive impact on agriculture sector while rainfall has a negative and significant effect on agricultural sector. Moreso, methane emissions (LNMETH) exhibited an inverse relationship with agriculture sector. Specifically, a percent increase in methane emissions may result into a reduction on agriculture output by 3.206971% in Nigeria. Carbon dioxide emission (LNCO2) shows a positive but insignificant relationship with agriculture sector. Agriculture output decreases by 0.8754485 for every 1% increase in rainfall (LNRAIN). The result shows that a percent increase in temperature(LNTEMP) will increase agriculture output by 9.742603% which shows a very huge effect. This relationship is statistically significant at 1% significance level. A percent increase in foreign direct investment (LNFDI) (proxy for technology) will, however, increase agriculture out by 0.65%. The regression estimate reveals that agriculture output response to labour force (LNLAB) is positive but insignificant. Lastly, was observed that when

capital (LNGCF) increases by 1%, agriculture output decreases by 0.048959%. Nevertheless, this negative effect is insignificant.

Conclusively, climate change is one of the most serious environmental threats facing mankind worldwide. It affects agriculture in several ways, including its direct impact on food production in Nigeria has shown in this study. As such, Nigeria has to adapt to the effects of climate change and mitigate the negative impact of climate change on agriculture at the national and individual levels. In that regard, the Federal government needs to invest in agricultural science research so that scientists can produce crops that are resistant to the harsh climatic conditions. At the same time, climate-smart agricultural innovations to conserve water such as solar-powered drip irrigation and rainwater harvesting should be concentrated on to help farmers cope with droughts.

In the effort to reduce greenhouse gas emissions, farmers should increase fertilizer usage since the bulk of greenhouse gas emissions from arable farming systems come from the use of inorganic fertilizers.

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