Effect of Climate Change on Rice Productivity in Nigeria

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ABSTRACT

This study analyzed the effects of climate change on Rice productivity in Nigeria from 1991 to 2022. It assessed how climate variables such as rainfall, temperature, sunshine duration, carbon dioxide emissions, and relative humidity influenced rice productivity. The research utilized secondary data analyzed through econometric models, including the Autoregressive Distributed Lag (ARDL) model, and the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The findings revealed that in the long run, annual rainfall and lagged temperature, carbon dioxide emissions, and relative humidity were significant at 5% determinants of rice productivity, while in the short run, current temperature and lagged climate factors played a crucial role. The study concluded that climate change significantly impacted rice productivity in Nigeria during the study period. It recommends the adoption of climate-resilient crop varieties, improved irrigation infrastructure, and enhanced agricultural extension services to mitigate the adverse effects of climate change on rice productivity in Nigeria.

INTRODUCTION

Climate change refers to long-term changes in temperature, precipitation patterns, and the frequency and intensity of extreme weather events. These changes are driven by increased greenhouse gas emissions, particularly carbon dioxide (CO_2), which contribute to global warming and disrupt established climatic patterns (IPCC, 2021). Nigeria, like many other African countries, is highly vulnerable to these climatic changes due to its heavy reliance on rain-fed agriculture and limited adaptive capacity (Ikuemonisan *et al.*, 2022). Agricultural Productivity refers to the efficiency with which agricultural inputs-such as land, labour, capital, and materials are converted into outputs, including crops, livestock, and other agricultural products. It is a critical indicator of a nation's agricultural efficiency and economic viability, reflecting the capacity to produce sufficient food and raw materials for both domestic consumption and export.

MATERIALS AND METHOD

The Study Area

This study was carried out in Nigeria, the most populous African country south of the Sahara (Durodola, 2019). It is a geopolitical and sovereign entity composed of 36 states and the Federal Capital Territory (FCT) Abuja. Nigeria is situated along the coast of West Africa between latitudes 4°S and 14°N and longitudes 3°W and 15°E. It shares common boundaries with Niger Republic to the west, Cameroon Republic to the east, and the Gulf of Guinea to the south.

Model Specification

According to Pesaran *et al*. (2001), the dependent variable must be I(1), while the exogenous variables can be either I(1) or I(0). Based on empirical literature, theories of interest, and diagnostic tests, the long run relationship between climate change and Rice productivity is given as:

$$InAPR_t = \lambda_0 + \lambda_1 InARF_t + \lambda_2 InATEMP_t + \lambda_3 InARELH_t + \lambda_4 InACDE_t + \lambda_5 InASUN_t + \lambda_7 InAFDI_{t-1} + \lambda_8 InDIA_t + \lambda_9 InGCEA_t + \lambda_{10} InINFR_t + \lambda_{11} InRER_t + \varepsilon_t \text{ …... (1)}$$

Where,

λ's = Long run coefficients

In= Stands for Natural Logarithm,

APR_{it} = Value of Rice productivity in period t

ARF_t = Average annual rainfall (millimetres) in period t

$ATEMP_t$= Average annual temperature (ºC) in period t

$ARELH_t$ = Average annual relative humidity (%) in period t

$ACDE_t$ = Average annual carbon dioxide (CO_2) emissions (Metric tons per year) in period t

$ASUN_t$= Average annual sunshine (hours) in period t

$AFDI_t$ = Agricultural foreign direct investment in period t

DIA_t = Total domestic private investment in agriculture (₦'Billion) in period t,

$GCEA_t$ = Government capital expenditure on agriculture (₦' Billion) in period t,

$INFR_t$ = Inflation rate (%) in period t,

RER_t = Real exchange rate (₦/$) in period t,

ε_t = Stochastic disturbance term.

3. RESULTS AND DISCUSSION

Diagnostic Tests: Stationary Properties of the Variable used in the Analysis

The estimation of the economic model in equations (1) was preceded by testing the statistical properties of the series, focusing on their stationarity. Table 1 presents the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests for the logged variables used in the analysis. Variables stationary at I(1) were differenced before subsequent analyses to avoid biases from non-stationary data. Bounds testing, as recommended by Pesaran *et al*. (2001), was employed to explore co-integration relationships within the ARDL framework, capturing both short- and long-term dynamics between the variables. This approach ensured robust estimation of the relationships, with the PP test reinforcing the validity of the results and supporting the use of the ARDL method.

The effect of climate change on Rice productivity in Nigeria from 1991 to 2022 was analyzed considering both long-run and short-run effects. This comprehensive assessment examined how climate variables have shaped Rice production over time, with selected macroeconomic variables included in the model as controls. A bounds test was also performed to investigate the presence of a co-integration relationship, ensuring that the analysis captures the dynamic interplay between these variables across different time frames.

Table 1: Result of unit root test of logged variables used in the analysis

Variable	Augmented Dickey-Fuller Test			Phillips-Perron Test		
	Level	**1st Difference**	**IO**	**Level**	**1st Difference**	**IO**
Average annual CO_2 emission ($ACDE_t$)	-1.599	-4.349 **	I(1)	-1.348	-4.431**	I(1)
Agricultural foreign direct investment ($AFDI_t$)	-1.516	-6.197**	I(1)	-1.339	-6.835**	I(1)
Area of land harvested of rice ($ALUCR_t$)	-1.902	-6.379**	I(1)	-1.832	-7.955**	I(1)
Value of rice productivity ($APFCR_t$)	-2.028	-5.214**	I(1)	-2.103	-5.214**	I(1)
Average annual relative humidity ($ARELH_t$)	-2.770	-6.373**	I(1)	-2.667	-8.511**	I(1)
Average annual rainfall (ARF_t)	- 10.122**	-	I(0)	- 6.228**	-	I(0)
Average annual sunshine hours ($ASUN_t$)	-5.042**	-	I(0)	- 8.195**	-	I(0)
Average annual temperature ($ATEMP_t$)	-4.331*	-	I(0)	-1.909	-4.411**	I(1)
Total domestic investment in agriculture (DIA_t)	-4.588**	-	I(0)	- 4.526**	-	I(0)
Food security index (FSI_t)	-2.847	-7.439**	I(1)	-2.847	-10.953**	I(1)
Govt. capital expenditure on agric. ($GCEA_t$)	-2.130	-6.816**	I(1)	-1.893	-9.373**	I(1)
Average annual inflation rate ($INFR_t$)	-2.667	-5.335**	I(1)	-2.882	-8.421**	I(1)
Average annual real exchange rate (RER_t)	-0.308	-4.251*	I(1)	-0.444	-4.131*	I(1)

Note: For ADF test at level, critical value at 1% = - -4.297, and at 5% = -3.568; at first difference, critical value at 1% = -4.297, and at 5% = -3.568. For PP test at level, critical value at 1% = -4.285, and at 5% = -3.563; at first difference, critical value at 1% = -4.297, and at 5% = -3.568. Asterisks * and ** represent 5% and 1% significance levels, respectively. These tests were performed by including a constant and trend in the regressions. IO = integration order.

Table 2: Bounds test result of the presence of a co-integration relationship between climate change indicators, as well as macroeconomic indicators and Rice productivity in Nigeria

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
F-statistic	10.04172	10%	2.07	3.16
k	11	5%	2.33	3.46
		2.5%	2.56	3.76
		1%	2.84	4.10

Source(s): Author Construction from EViews 13 computation, 2024

The bounds test results revealed that the F-statistic of 10.04172 is significantly higher than the upper bounds critical values across all significance levels, including the 1% level (4.1) and the 5% level (3.46). This indicates that the test statistic exceeds the critical values for each of these significance levels, thereby allowing us to reject the null hypothesis of no co-integration at the 1% level. Such strong evidence suggests the existence of a long-run co-integration relationship among the variables under consideration.

ARDL Long-run Coefficients

Table 3: presents the ARDL long-run coefficients, detailing the effect of climate change on Rice productivity in Nigeria from 1991 to 2022.

In Table 3, the R^2 value of 0.995004, accompanied by an adjusted R^2 of 0.979302, indicates that the independent variables collectively account for 99.5% of the variation in Nigeria's rice productivity within the period under study. This high explanatory power demonstrates that the model effectively captures the dynamics of rice productivity in Nigeria. The null hypothesis of no model significance is unequivocally rejected, as evidenced by the F-statistic of 63.36910, which is highly significant at the 1% level, given the p-value of 0.000005, well below the 0.05 threshold. Additionally, the Durbin-Watson statistic of 2.018192 falls within the acceptable range, suggesting the absence of serial autocorrelation and further validating the robustness of the model.

Table 3: Results of the ARDL Long-Run Coefficients for the Effect of Climate Change on Rice Productivity in Nigeria (1991–2022), with Control for selected Macroeconomic Variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LN(APFC_RICE(-1))	-0.294053	0.176702	-1.664118	0.1400
LN(ARF)	-2.320258	0.722736	-3.210380**	0.0149
LN(ARF(-1))	-3.024334	0.496539	-6.090825***	0.0005
LN(ATEMP(-1))	59.33089	9.060794	6.548090***	0.0003
LN(ATEMP(-2))	-44.57111	10.51688	-4.238055***	0.0038
LN(ACDE(-1))	1.116954	0.863307	1.293808	0.2368
LN(ACDE(-2))	-1.547178	0.708570	-2.183522*	0.0653
LN(ARELH(-1))	-2.660371	0.449204	-5.922411***	0.0006
LN(ARELH(-2))	-0.494527	0.409916	-1.206410	0.2668
LN(ASUN)	2.098203	0.597490	3.511694***	0.0098
LN(ALUC_RICE(-1))	0.962863	0.283827	3.392429**	0.0116
LN(ALUC_RICE(-2))	0.824166	0.301619	2.732474**	0.0292
LN(AFDI(-1))	0.050747	0.035071	1.446958	0.1912
LN(DIA)	-0.187659	0.092670	-2.025029*	0.0825
LN(DIA(-1))	0.722541	0.223022	3.239776**	0.0143
LN(GCEA(-1))	-0.687164	0.230477	-2.981486**	0.0205
LN(GCEA(-2))	-0.087767	0.054984	-1.596230	0.1545
LN(INFR(-1))	0.089013	0.050184	1.773728	0.1194
LN(INFR(-2))	0.162038	0.051094	3.171355**	0.0157
LN(RER(-1))	-0.221291	0.206579	-1.071216	0.3196
LN(RER(-2))	-0.367614	0.170640	-2.154317*	0.0682
C	-15.71065	20.03102	-0.784316	0.4586
@TREND	0.111925	0.030842	3.629025***	0.0084

R-squared	0.995004	Mean dependent var	4.035539
Adjusted R-squared	0.979302	S.D. dependent var	0.468267
S.E. of regression	0.067368	Akaike info criterion	-2.479241
Sum squared resid	0.031769	Schwarz criterion	-1.404989
Log likelihood	60.18861	Hannan-Quinn criter.	-2.135578
F-statistic	63.36910***	Durbin-Watson stat	2.018192
Prob(F-statistic)	0.000005		

Source(s): Author Construction from EViews 13 computation, 2024. (***), (**) and (*) denote 1%, 5% and 10% significance level

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Dependent Variable: LN(APFC_RICE)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (1 lag, automatic): LN(ARF) LN(ATEMP(-1)) LN(ACDE(-1)) LN(ARELH(-1)) LN(ASUN) LN(ALUC_RICE(-1)) LN(AFDI(-1)) LN(DIA) LN(GCEA(-1)) LN(INFR(-1)) LN(RER(-1))
Fixed regressors: C @TREND
Selected Model: ARDL(1, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1)

The lag value of rice productivity is integrated into the model to capture the effects from previous years. The result shows that LN(APFC_RICE(-1)) is not significant (P>0.1), suggesting very weak persistence in rice productivity from the previous period and the trend variable (@TREND) were the significant variables that influenced rice productivity in Nigeria within the period under study.

The coefficients for Average Annual Rainfall (LN(ARF)) and its one-period lag (LN(ARF(-1))) are both statistically significant, with LN(ARF) showing a coefficient of -2.320258 (p = 0.0149) and LN(ARF(-1)) having a coefficient of -3.024334 (p = 0.0005). These negative coefficients indicate that increases in rainfall, both current and lagged, have a detrimental effect on rice productivity. The negative relationship suggests that excessive rainfall can adversely affect rice production. High rainfall levels often lead to waterlogging, which can suffocate rice plants, hinder root development, and increase the risk of fungal diseases. Additionally, excessive rainfall can disrupt the timing of planting and harvesting, further compromising yield. This finding aligns with the work of Folorunsho & Ajiwoju (2024), who found that higher rainfall intensity negatively affects rice yields in East Africa due to increased water stress and disease prevalence. Similarly, *Mba et al*., (2022) observed that excessive rainfall during the growing season significantly reduced rice productivity in Southeast Asia by causing waterlogging and nutrient leaching.

This finding is consistent with the study by *Maina et al*., (2023), which reported that optimal temperature ranges can enhance rice growth, but extreme temperatures can lead to reduced yields. Similarly, *Adeleke et al*., (2023) highlighted that temperature variability has both positive and negative effects on rice productivity, emphasizing the importance of temperature management in rice cultivation.

Similarly, Ogbanje & Okpe (2024) found that elevated CO_2 levels, combined with other climatic factors, significantly reduced rice productivity over time.

The coefficient for average annual sunshine duration (LN(ASUN)) is positive (2.098203, p = 0.0098), indicating a beneficial effect on rice productivity. This suggests that increased sunshine duration enhances rice growth and productivity. Adequate sunlight is crucial for photosynthesis, which drives plant growth and yield. Longer sunshine hours can improve photosynthetic efficiency, resulting in higher biomass and better grain development. This result aligns with the findings of *Gbenga et al*., (2021), who demonstrated that increased sunlight positively impacts rice yield by enhancing photosynthesis and overall plant health

The trend variable (@TREND) is statistically significant with a coefficient of 0.111925 (p = 0.0084). This indicates a positive long-term trend in rice productivity over the study period, suggesting that productivity has generally increased over time, potentially due to advancements in agricultural practices and technology (*Ikuemonisan et al*., 2023).

The coefficients for Domestic Investment in Agriculture (LN(DIA)) and its one-period lag (LN(DIA(-1))) are significant, with LN(DIA) having a coefficient of -0.187659 (p = 0.0825) and LN(DIA(-1)) having a coefficient of 0.722541 (p = 0.0143). The positive coefficient for LN(DIA(-1)) indicates that domestic investment in agriculture from the previous period positively impacts rice productivity. In contrast, the negative coefficient for LN(DIA) suggests a detrimental effect from current domestic investment. The positive effect of past domestic investment could reflect the benefits of previous investments that enhance productivity through improved infrastructure, technology, or inputs. However, the negative effect of current investment might indicate that the investment is not effectively translating into immediate productivity gains, possibly due to inefficiencies or misallocation of resources. This observation aligns with studies like *Pickson et al*., (2024), which found that past investments often yield benefits over time, whereas current investments might face implementation challenges. Similarly, Essien et al., (2021) highlighted that domestic investment's effect on productivity can vary depending on how effectively the funds are utilized and the immediate challenges faced by the sector.

The coefficient for government capital expenditure in agriculture (LN(GCEA(-1))) is negative (-0.687164, p = 0.0205), indicating a detrimental effect on rice productivity. This suggests that increased government spending on agricultural capital might not always translate into improved rice yields. The negative effect might be due to inefficiencies or misallocation of funds within the agricultural sector. Government investments in capital infrastructure might not always directly benefit rice cultivation if the funds are not effectively utilized or if they do not address the specific needs of rice farmers. This result is supported by the findings of *Christopher et al*., (2023), who noted that inefficiencies in government spending can lead to sub-optimal outcomes in agricultural productivity. Similarly, Abubakar (2023) found that government capital expenditure often fails to improve productivity when not aligned with the needs of the agricultural sector.

The coefficient for the two-period lagged inflation rate (LN(INFR(-2))) is positive (0.162038, p = 0.0157), suggesting that inflation rates from two periods ago positively affect rice productivity. The positive relationship might be due to the fact that inflationary pressures, when not extreme, can lead to increased spending and investment in agriculture as prices rise, potentially improving productivity. This effect may also be linked to adjustments in input costs and market dynamics over time. The finding is consistent with research by Daniel & Rita (2022), which noted that moderate inflation could stimulate agricultural investment and productivity. Similarly, *Isaac et al*.,(2024) observed that inflation has a nuanced effect on agriculture, with past inflation sometimes encouraging investments in productivity-enhancing technologies.

ARDL Error Correction Regression Estimated Short-run Coefficients

Table 4 presents the result of the ARDL error correction regression estimated short-run coefficients for effect of climate change on Rice productivity within the study period, with selected macroeconomic controls.

Table 4: Results of the ARDL Error Correction Regression Estimated Short-run Coefficients for the Effect of Climate Change on Rice Productivity in Nigeria (1991–2022), with Control for selected Macroeconomic Variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	15.71065	0.893765	17.57807***	0.0000
@TREND	0.111925	0.006507	17.20093***	0.0000
DLN(ARF)	-2.320258	0.169706	-13.67220***	0.0000
DLN(ATEMP(-1))	59.33089	3.736914	15.87698***	0.0000
DLN(ACDE(-1))	-1.116954	0.328648	-3.398637**	0.0115
DLN(ARELH(-1))	-2.660371	0.191936	-13.86071***	0.0000
DLN(ALUC_RICE(-1))	0.962863	0.100533	9.577629***	0.0000
DLN(DIA)	-0.187659	0.014908	-12.58756***	0.0000
DLN(GCEA(-1))	-0.687164	0.043859	-15.66765***	0.0000
DLN(INFR(-1))	0.089013	0.020551	4.331370***	0.0034
DLN(RER(-1))	-0.221291	0.038532	-5.743073***	0.0007
ECM(-1)	-0.694053	0.039429	-17.60280***	0.0000
R-squared	0.954971	Mean dependent var		0.031963
Adjusted R-squared	0.927453	S.D. dependent var		0.155976
F-statistic	34.70381	Durbin-Watson stat		2.018192
Prob(F-statistic)	0.000000			

Diagnostic test

Test statistics	***F-statistic***	***P-value***	***Interpretation***
Heteroskedasticity test: Breusch-Pagan-Godfrey	0.853246	0.6420^{ns}	No heteroskedasticity
Breusch-Godfrey Serial Correlation LM Test	1.192667	0.5641^{ns}	No Serial Correlation
Ramsey RESET stability	2.003471	0.1846^{ns}	Model correctly specified
Jacque-Bera test	1.483633	0.4762^{ns}	Normal distribution

Source(s): Author Construction from EViews 13 computation, 2024. (***), and (**)denote 1%, and 5% significance level. (^{ns}) denote not significant.

ARDL Error Correction Regression

Dependent Variable: DLN(APFC_RICE)

Selected Model: ARDL(1, 1, 1, 1, 1, 0, 1, 0, 1, 1, 1, 1)
Case 5: Unrestricted Constant and Unrestricted Trend

The Error Correction Model results of the short run indicate that not all climate change indicators and macroeconomic determinants have a significant effect on rice productivity in the short run. In the short run, the immediate effects of certain climatic variables, such as average rainfall (DLN(ARF)) and average annual temperature (DLN(ATEMP(-1))), show a significant effect at a 1% significance level. Specifically, the coefficient for rainfall is highly negative, indicating that lower rainfall in the short run can significantly reduce rice productivity, highlighting the crop's dependency on adequate water supply. Conversely, temperature has a strong positive impact, suggesting that higher temperatures can boost productivity, potentially by accelerating the growth cycle of rice under favourable conditions. Relative humidity (DLN(ARELH(-1))) also negatively affects productivity at a 1% significance level, indicating that excessive humidity may be detrimental, possibly due to increased risk of diseases or waterlogging. Additionally, annual carbon dioxide emissions (DLN(ACDE(-1))) exhibit a negative and significant effect at a 5% significance level, suggesting that higher CO_2 levels reduce rice productivity.

The area of land under rice cultivation (DLN(ALUC_RICE(-1))) has a positive and significant effect at a 1% significance level, indicating that increasing the cultivated area can lead to greater productivity in the short run. However, this effect must be managed carefully to avoid diminishing returns.

Regarding macroeconomic variables, private domestic investment in agriculture (DLN(DIA)) has a negative and significant effect at a 1% significance level, suggesting that short-term investments may not immediately translate into productivity gains. Government capital expenditure on agriculture (DLN(GCEA(-1))) also shows a significant negative effect at a 1% level, indicating inefficiencies or delays in the productive use of these funds. Inflation rate (DLN(INFR(-1))) shows a positive and significant effect at a 1% significance level, which may reflect an environment where rising prices could lead to higher revenue for producers in the short run, potentially boosting productivity. The real exchange rate (DLN(RER(-1))) similarly has a negative and significant effect at a 1% significance level, reflecting how exchange rate fluctuations can increase the cost of imported inputs, thereby reducing productivity.

The adjustment speed to equilibrium, as indicated by the Error Correction Model (ECM), is negative and significant at the 1% level, confirming the model's long-term stability. The ECM coefficient of -0.694053, which is negative and lies between zero and one, indicates that approximately 69.4% of any short-term deviation from the long-run equilibrium is corrected annually. This result implies that the model's errors can be corrected over time, with the adjustment to equilibrium occurring at a rate of 69.4% per year.

CONCLUSION AND RECOMMENDATIONS

This study analyzed the effects of climate change on rice productivity in Nigeria. The findings show that in the long run, annual rainfall, lagged values of temperature, carbon dioxide emissions, relative humidity, agricultural foreign direct investment, private domestic investment, inflation rate, real exchange rate, food security index, and the trend variable significantly influenced rice productivity. The findings revealed that in the long run, annual rainfall and lagged temperature, carbon dioxide emissions, and relative humidity were significant determinants of rice productivity, while in the short run, current temperature and lagged climate factors played a crucial role. The study concluded that climate change significantly impacted rice productivity in Nigeria during the study period (1991-2022). It recommends the adoption of climate-resilient crop varieties, improved irrigation infrastructure, and enhanced agricultural extension services to mitigate the adverse effects of climate change on rice productivity in Nigeria.

REFERENCES

Abubakar, S. (2023). Effect of Government Expenditure on Agricultural Productivity in Nigeria. *Gusau Journal of Economics and Development Studies*, *3*(1), 15–15. https://doi.org/10.57233/gujeds.v3i1.16

Adeleke, O. A., Adeleke, H. M., Fajobi, D. T., Akintola, R. O., Olawuyi, E. O., Ayantola, M. I., Binuomote, S. O., and Odugbemi, A. J. (2023). An Empirical Analysis of Climate Change Effects on Selected Cereals Acreage in Nigeria: A Ricardian Approach. *European Journal of Theoretical and Applied Sciences*, *1*(4), 1314–1321. https://doi.org/10.59324/ejtas.2023.1(4).122

Christopher, N., Abdu, S., and Batiyak, U. (2023). EFFECT OF GOVERNMENT SPENDING ON AGRICULTURAL OUTPUT IN NIGERIA: (1990-2022). *International Journal of Advanced Research in Accounting, Economics and Business Perspective*, *7*(2), 14–25. https://doi.org/10.48028/iiprds/ijaraebp.v7.i2.02

Daniel, O., Chukwujioke, and Rita, O., Onyinye. (2022). Investigating the Effect of Macroeconomic Variables on Agricultural Output in Nigeria. *Asian Journal of Research in Agriculture and Forestry*, 41–48. https://doi.org/10.9734/ajraf/2022/v8i230153

Durodola, O.S. (2019) the Impact of Climate Change Induced Extreme Events on Agriculture and Food Security: A Review on Nigeria. Agricultural Sciences, 10, 487-498.

Folorunsho, J. O., and Ajiwoju, M. (2024). Analysis of Perceived Effects of Rainfall Variability on Rice Yield in Lokoja, Kogi State, Nigeria. *ABUAD Journal of Social and Management Sciences*, *5*(1), 136–151. https://doi.org/10.53982/ajsms.2024.0501.07-j

Gbenga, O., Ibrahim, O. H., and Ayodele, O. J. (2021). Analysis of the Effect of Climate Change on Rice Production in Nigeria. *International Journal of Agriculture System*, *8*(2), 119–129. https://doi.org/10.20956/ijas.v8i2.2476

Ikuemonisan, E. S. (2022). Cassava Production in Nigeria: Trends, Instability and Decomposition Analysis. *Developing Country Studies*, *12*(3). https://doi.org/10.7176/dcs/12-3-04

Ikuemonisan, E. S., Olaoba, S. A., and Akinbola, A. E. (2023). Growth, Instability and Trend Analysis of Rice Production Indicators in Nigeria. *Qeios*. https://doi.org/10.32388/euanpe

Intergovernmental Panel on Climate Change. (2021). Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri RK, Meyer LA (eds.)]. IPCC, Geneva, Switzerland, p. 151, 2014.

Isaac, S. E., Okon, J. I., Arinze, N. P., and Odii, N. M. (2024). Exchange Rate Depreciation and the Nigeria's Agricultural and Industrial Sectors. *Asian Journal of Economics Business and Accounting*, *24*(7), 393–406. https://doi.org/10.9734/ajeba/2024/v24i71418

Mba, C., Ezeh, C., Madu, I. A., and Emeribe, C. (2022). Assessment of climate variability and the determinants of rice productivity in Southeastern Nigeria. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi*, 805–824. https://doi.org/10.29133/yyutbd.1132709

Maina, M. M., Shanono, N. J., Bello, M. M., Nasidi, N. M., and Abdullahi, M. (2023). Simulation of Climate Change Effect on Rice (Oryza Sativa L.) Production in Kano River Irrigation Scheme (Kris) Using Apsim Model. *Fudma Journal of Sciences*, *7*(3), 21–27. https://doi.org/10.33003/fjs-2023-0703-1845

Oyeranti, O. A. (2024). Effect of Carbon Footprint on Agricultural Productivity in Nigeria: An Empirical Analysis. *International Journal of Social Science and Economic Research*, *09*(05), 1518–1535. https://doi.org/10.46609/ijsser.2024.v09i05.013

Pickson, R. B., Gui, P., Jian, L., & Boateng, E. (2024). The role of private sector investment in agriculture: A catalyst for sustainable development in Asia. *Sustainable Development*. https://doi.org/10.1002/sd.3105

Pesaran U.,and Boserup, E. (2001). *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure.* Chicago: Aldine