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# Climate Change and Agricultural Output in Nigeria: A Nonlinear ARDL and Dynamic Cointegration Analysis

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***Abstract* - Even though Nigeria's agriculture is susceptible to climate variability, the long-term impact of temperature, rainfall and carbon emissions on agricultural production is still poorly understood. Extant studies are either qualitative or use linear relationships which fail to capture potential asymmetric climate responses. In this study, the authors investigate the long-run and short-run impact of temperature, rainfall and carbon dioxide ($CO_2$) emissions on agricultural output in Nigeria using annual data for the period 1981-2024. To capture the equilibrium relationship and asymmetry effects, Dynamic Ordinary Least Squares and Fully Modified Ordinary Least Squares as well as Nonlinear Autoregressive Distributed Lag model are used. Results indicate that $CO_2$ emissions have a positive and significant long-run impact on agricultural production which supports carbon fertilisation hypothesis. By contrast, agricultural output has a strong negative relationship to fertiliser use and population growth, and mixed and statistically insignificant relationships with temperature and rainfall. Significant long run asymmetry is confirmed for temperature and $CO_2$ emissions using Wald tests. The negative and significant error correction term suggests slow adjustment toward long-run equilibrium suggesting that the impacts of climate on the Nigerian agriculture evolve slowly over time. The evidence suggests that climate change is a significant but subsidiary driver of agricultural performance, and that the climate-agriculture interactions play out over longer time periods through structural processes. The study suggests that it is important to integrate the two types of adaptation investments, namely, sustained adaptation finance with targeted short-term climate interventions, to enhance agricultural resilience.**

***Keywords:*** Climate change, Agricultural output, Carbon emissions, Temperature asymmetry, Food production.

**JEL Classification:** Q54, Q15, O13

## I. INTRODUCTION

Despite the significant developments in other sectors of the Nigerian economy, agriculture remains the backbone of livelihoods, export earnings and food security of the vast majority of Nigerians with over 70% of the country's population either directly or indirectly involved in farming, livestock production, fisheries, and forestry activities (Omokaro, 2025). However, the sector is structurally rain-dependent, and hence, highly vulnerable to the extent and nature of climatic change. Over the past 40 years, Nigeria has experienced a clear rate of warming, spatially inconsistent and more variable rainfall, an increase in the extent of the desert in the north along the Sahel and Sudan savannah belts and a greater frequency of episodic flooding in the coastal and riverine south. These changes combine with the structural weaknesses that have long been present in the agricultural sector, namely fragmented land holdings, limited irrigation coverage, differential access to fertiliser and credit constraints, to produce an agricultural sector with a trajectory of its output that has been quite erratic throughout the study period, despite successive interventions such as the Agricultural Transformation Agenda, the Agriculture Promotion Policy and, more recently, the National Agricultural Technology and Innovation Policy.

In Nigeria, the observed warming is approximately 1.0 to 1.8°C above 1985 mean, with higher warming across the northern parts of the country, while projections of rainfall changes are highly varied by ecological zone, with expected increases in wetness and season length for the southern mangrove, rainforest and Guinea/Sudan savannah belts, and decreases in the Sahel savannah. This divergence becomes more evident in recent zone-specific forecasting efforts, which project that the Sudan Savanna has a much higher rate of warming than the southern agro-ecological regions, and that this difference is already manifesting in divergent trends in yields across agro-ecological divides in Nigeria (Oziegbe & Akinnubi, 2026). However, the overall trend of $CO_2$ emissions has been generally upward, associated with energy

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consumption, land-use change and industrialization, although Nigeria's $CO_2$ emissions per capita are low when compared to the world.

While the vulnerability of Nigerian agriculture to these climatic challenges is clear, there is limited empirical work on the relationship between climate indicators and agricultural output at the national level in a few critical aspects. The first body of work is geographically constrained, frequently state-based or even restricted to a particular agro-ecological region, thus limiting the generalisability of findings to the national policy context. The second strand is largely qualitative or descriptive, mostly using systems-theory narratives and secondary reports, and, therefore, cannot quantify the size and impact of climate effects; such recent syntheses include Omokaro (2025), who conducted a literature-based review of the Nigerian climate-agriculture-food security nexus.

The third and perhaps more important gap is methodological: most studies in Nigeria,– including more recent applications at the national level, such as Alehile (2025) and Nweke (2025) – either impose a complete linear structure on the climate-output relationship, or test asymmetry for only a subset of climate variables, assuming that a one-degree increase in temperature or a one-unit increase in carbon emissions has an effect equal in magnitude but opposite in sign to an equivalent decrease. Such an assertion is hard to justify on agronomic arguments, because since the dawn of crop physiology studies it is known that an increase in temperature above the agronomic threshold is much worse than a decrease of the same magnitude, and that $CO_2$ can have a fertilisation effect at moderate concentrations before warming effects take over at higher concentrations. These dynamics are, if not separately estimated, likely to mask or underestimate the actual climate-output relationship in Nigeria.

This paper fills these gaps by computing the long-run and short-run impacts of climate change indicators (temperature, rainfall variation and carbon dioxide emissions) on agricultural output in Nigeria for the period 1981-2024 using a method that distinguishes positive from negative climate shocks. The analysis relates a standard linear specification of cointegration to an asymmetric Nonlinear Autoregressive Distributed Lag (NARDL) model, which is cross-validated with Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS), providing a linear benchmark and an estimate of the climate-agriculture nexus robust to asymmetric effects.

The main research question of this paper is: What is the effect of climate change, as measured by temperature, rainfall variability and carbon dioxide emissions on agricultural output in Nigeria and are the long-run impacts of positive and negative climate shocks symmetric? Accordingly, the aim of the paper is to investigate the impact of the climate change indicators (temperature rise, rainfall variability and carbon dioxide emissions) on Nigeria's agricultural output during the period 1981-2024, and formally test for asymmetry in the long run impact.

This paper aims at four types of contribution to the literature. First, it provides a four-decade econometric evaluation of the climate-agricultural output relationship at the national level to complement the only local-level and short time window study in the literature, which enhances the external validity of the estimated relationships for national policy. Second, it is one of a handful of studies in Nigeria that formally test (as opposed to assuming) the symmetry of climate impacts on agricultural yields, applying an NARDL partial-sum decomposition to the impacts of both increases and decreases in temperature and carbon dioxide, a test not extended to carbon dioxide in Nweke (2025) or similar single-variable asymmetric applications.

Thirdly, three complementary long-run estimators – DOLS, FMOLS and NARDL-DOLS – have been triangulated to check the robustness of the climate-output relationship across different estimation methods which correct for different degrees of endogeneity and serial correlation in cointegrated systems which are rare in the single-equation Nigerian agro-climatic literature. Fourth, the paper models all the variables mentioned above, including climate, input-use (fertiliser and credit) and demographic (population growth), in a single cointegrating equation, which aligns with existing literature on Sub-Saharan Africa that suggests that food-security outcomes are driven by a combination of climatic, demographic and resource-access pressures rather than just climatic factors alone (Toromade *et al.*, 2024; Omokpariola *et al.*, 2025), and is largely absent from analyses of climate variables alone.

## II. LITERATURE REVIEW

### 2.1 Theoretical Review

The paper draws on the theory of Environmental Security, which had origins in the human development framework of the United Nations Development Programme (UNDP) in 1994 and was further developed by the Organisation for Economic Co-operation and Development (OECD). The theory is that ecological stability is a necessary precondition to sustainable livelihood and economic activity, and that a secure ecological environment is an environment that can provide the natural resources and ecological services

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on which food production and human welfare rely without experiencing major degradation or irreversible changes. When applied to agriculture, the theory suggests that climatic perturbations – hotter weather, changing rainfall patterns, and the cumulative effect of greenhouse gas emissions – have a direct impact on agricultural productivity, which is manifested in diminishing soil moisture, water availability and reliability of growing seasons, and have second order effects on rural livelihoods, the stability of markets and the provision of food at the national level. A key analytical element of the theory is the idea of feedbacks: actions in response to climate change that create negative feedbacks (that stabilise the output variability) counterbalance the climate-induced variability, while actions that create positive feedbacks (that increase the output variability) amplify the climate-induced variability and, therefore, the harm to the agricultural system.

The analysis in this paper is refined by two complementary theoretical perspectives. Agricultural Adaptation Theory suggests the need to bring in a multi-period adaptation in order to achieve sustained productivity in the face of a changing climate, as opposed to passive exposure to climatic risk, which explains the paper's belief that the short-run response of agricultural output to climatic shocks should be less than the long-run response, and due to the need to adopt different crops, modernise irrigation systems and institutionalise climate-smart farming practices. The Theory of Innovation Diffusion complements this in explaining why adoption of climate responsive technologies and practices in Nigeria is not uniform and fast, but rather follows stages of adoption which can be identified based on access to social networks and information; this gives a behavioural micro-foundation to the slow speed of error correction of the aggregate agricultural time series.

**2.2 Empirical Review**

There is a large volume of empirical studies that have focused on the climate-agriculture linkage in Nigeria and similar Sub-Saharan African environments, and there are a variety of estimation approaches with varying emphases, methods, and findings. Charles et al., (2023) used a national ARDL framework to analyse the impact of climate change on agricultural sub-sectors in Nigeria and found varying impacts across the different sub-sectors (crop, livestock, fishery and forestry); this demonstrates the importance of sector disaggregation, but in a way that imposes a symmetric long run response as in most ARDL applications. Along similar lines, Amaefule *et al.* (2023) examined the relationship between carbon emissions, climate change and Nigeria's agricultural productivity, and found a significant productivity reduction from increasing carbon emissions, which contrasts with the carbon-fertilisation finding reported in the present paper, and reconcilable in the discussion section by reference to the differences in sample period, measurement of emissions and functional form.

Elsewhere, Atchade and Nougbode (2024) also sought to investigate the relationship between agricultural productivity, climate change and economic growth in Benin using ARDL, VAR and Toda-Yamamoto causality tests and their result shows that the temperature of the country has a negative influence on economic growth, while agricultural value added has a positive influence, with one-way causality running from temperature to agricultural value added; the VAR-based causality evidence in this Beninese study provides a useful comparator with the long-run NARDL elasticity estimates for Nigeria presented in this paper. In a similar vein, Adesete *et al.* (2023) estimated the impact of climate change on malnutrition levels using a Generalised Method of Moments model on 30 countries in Sub-Saharan Africa, finding that climate change increases the prevalence of malnutrition, albeit via a different channel than the one modelled here (nutrition outcomes instead of output), and thus supporting the broader claim that climate change negatively affects agricultural and food systems across the region.

Some studies are qualitative or of a systems-theoretic approach. Gana *et al.* (2024) discussed the relationship between climate change and food security in Nigeria from a systems-theory perspective with secondary evidence, with results indicating that the rise in temperatures, as well as irregular rainfall, drought, flooding, desertification, and land degradation all contribute to the vulnerability of farming communities and reduce agricultural production, broadly consistent with the findings reported in this paper but unable to quantify elasticities or test for asymmetry. Similarly, Dauda (2023) argued on a descriptive basis that climate change decreases crop yields due to extended drought periods, soil degradation, and declining soil fertility, which this paper is able to test econometrically.

In addition to the literature pertaining to Nigeria, there are also a broader comparative literature that places the methodological choices made in the present paper. To demonstrate that long-term climate variability influences the adoption and level of sustainable farming practices (improved seed, organic and inorganic fertiliser, legume intercropping) as well as that adoption of those practices increases crop productivity at the plot level, Amankwah (2023) employed nationally representative, geo-referenced plot-level data from the Nigeria General Household Survey panel. His cross-sectional, micro-level design cannot address long-term dynamics at the national level, but the finding that farm-level

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adaptive behaviour is mediated in the relationship between climate and crop productivity gives this paper, which is grounded in the Agricultural Adaptation Theory, empirical plausibility. A key message from Toromade *et al.* 2024 was that challenges to food security were present across jurisdictions, and that reduced agricultural yields and increased food price volatility and unequal exposure of smallholder and low-income farming populations are recurring themes in the global climate-food security nexus, which is a major reason for this paper considering the demographic (population growth) channel in addition to the purely climatic regressors.

Another methodological difference relates to the use of carbon dioxide as an explanatory variable, rather than as a dependent variable. Most of the literature on agro-emissions focuses on agriculture as an emitter of emissions, and this is useful for mitigation policy, but the other adaptation relevant question – how the increases in atmospheric carbon dioxide concentrations impact on the productivity of agriculture – is relatively under explored at the national Nigerian level. Ayilara *et al.* (2025) list a large range of climate-related threats to global food systems such as increased temperatures, changes in precipitation, increased frequency of floods and droughts, increased pest and disease pressure, and reduced soil quality; however, the threats listed are based on their review and not estimations specific to Nigeria. In this regard, the NARDL-DOLS framework used in the present paper is well placed to fill this gap: a national level elasticity-generating asymmetry testing estimate of the carbon dioxide-temperature bidirectionality.

Moreover, some of the recent national time-series studies used the same methodology as the present study, with Nweke (2025) estimating an ARDL model of agricultural sector output in Nigeria where rainfall and forest depletion are statistically significant in reducing output, while carbon emissions are statistically irrelevant, and Alehile (2025) estimated a nonlinear ARDL model of agricultural production in Nigeria and found rainfall variability to be the major long-run climate factor. However, neither study is able to do a joint triangulation of DOLS, FMOLS and NARDL-DOLS, and both studies miss long-run symmetry testing of carbon dioxide, which is the specific methodological niche of this paper. Third, at the demographic-institutional interface, Okafor *et al.* (2025) studied environmental resource conflict and food insecurity amongst farmers and herders in southeast Nigeria and found that the crises of access to environmental resources, compounds by climatic stress, are also important determinants of food insecurity, beyond production-side climate impacts, lending further weight to this paper's result that population pressure can be a distinct and, in this sample, dominant constraint on agricultural production.

Third, at the regional level, Omokpariola *et al*. (2025) studied climate-crop yield linkages across Sub-Saharan Africa and found yield losses were mostly concentrated in maize, sorghum and millet, in response to increased temperature and rainfall variability, while Oziegbe and Akinnubi (2026) conducted disaggregated forecasting by combining the Panel ARDL and Panel VAR methods with downscaled climate projections to forecast divergent, zone-specific agricultural trends within Nigeria's four agro-ecological zones through 2050, a natural extension of the national-aggregate estimates produced in this paper.

Collectively, the literature examined in this paper supports the qualitative claim that the impact of climate change is negative on agricultural production in Nigeria, but offers conflicting views along three dimensions: geographic coverage (sub-national survey evidence versus national time-series evidence), methodological approaches to climate dynamics (linear and symmetric versus asymmetric and threshold-sensitive specifications), and the directionality of carbon effects on production (productivity-enhancing effects versus productivity-reducing effects), with existing findings in Nigeria being genuinely mixed. The methodological niche of this paper lies in estimating DOLS, FMOLS and NARDL-DOLS jointly in one national framework and performing a formal Wald test for long-run symmetry for both temperature and carbon dioxide, something not found in any of the studies reviewed.

Table 1 summarises the reviewed literature by analytical focus, method, key findings, and thereby makes explicit the positioning of the present study's focus in relation to existing literature.

**Table 1: Cross-Comparison of Reviewed Empirical Studies: Focus, Method and Findings**

| Study | Focus / Scope | Method | Key Finding |
|---|---|---|---|
| Charles *et al.* (2023) | Climate effects across agric. sub-sectors, national | ARDL | Differentiated, sector-specific climate impacts |
| Amaefule *et al.* | Emissions, climate & | Time-series | Rising emissions associated with |

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|---|---|---|---|
| (2023) | productivity, national | regression | productivity loss |
| Atchade & Nougbode (2024) | Climate, agriculture & growth, Benin | ARDL, VAR, Toda-Yamamoto | Temperature reduces growth; one-way causality, temp. → output |
| Adesete *et al.* (2023) | Climate & food security, 30 SSA countries | GMM panel | Emissions raise malnutrition; income & supply aid food security |
| Gana *et al.* (2024) | Climate-food security interplay, national | Systems-theory review | Temperature, rainfall, drought & desertification drive vulnerability |
| Amankwah (2023) | Climate variability & SAP adoption, national plot-level | Multivariate/ordered probit, IV | Climate variability shapes SAP adoption; adoption raises productivity |
| Toromade *et al.* (2024) | Global climate-food security nexus | Narrative review | Declining output, food-price instability, smallholder exposure |
| Ayilara *et al.* (2025) | Climate threats to global food systems | Review | Catalogues temperature, precipitation, pest & soil threats |
| Nweke (2025) | Climate & agricultural sector output, national (1981–2024) | ARDL | Rainfall & forest depletion reduce output; CO2 insignificant |
| Alehile (2025) | Climate & agricultural sector, national (1986–2022) | Nonlinear ARDL | Rainfall variability dominant long-run constraint |
| Okafor *et al.* (2025) | Resource conflicts & food insecurity, Southeast Nigeria | Survey, regression | Resource-access crises raise food insecurity independent of production effects |
| Omokpariola *et al.* (2025) | Climate, crop yield & food security, SSA | Review | Yield losses concentrated in maize, sorghum, millet |
| Oziegbe and Akinnubi (2026) | Zone-specific climate forecasting, national | Panel ARDL, Panel VAR, SARIMA | Divergent zone-specific warming and yield trends, 2025–2050 |
| This current study | Climate → agricultural output, national, 1981–2024 | DOLS, FMOLS, NARDL-DOLS, ECM | $CO_2$ positively significant (fertilisation); symmetric long-run response; structural factors dominate |

## III. METHODOLOGY

### 3.1 Model Specification

In line with the Environmental Security Theory and the empirical literature surveyed, agricultural production is specified as a log-linear function of climate and structural inputs. The long-run baseline (symmetric) specification is:

$$lnAGO_t = \alpha_0 + \alpha_1 TEMP_t + \alpha_2 lnRAIN_t + \alpha_3 lnCO2_t + \alpha_4 lnACR_t + \alpha_5 lnFERT_t + \alpha_6 lnPOP_t + \varepsilon_t \quad (1)$$

where *lnAGO* represents the natural log of agricultural gross value added, TEMP represents annual mean temperature in degrees Celsius (hence its semi-elasticity), *lnRAIN* represents the log of annual rainfall, $lnCO_2$ represents the log of carbon dioxide emissions per capita, *lnACR* represents the log of agricultural credit to the private sector, *lnFERT* represents the log of fertiliser consumption per hectare, *lnPOP* represents the log of the population growth rate, $\alpha_0$ is the intercept, $\alpha_1$ is interpreted as a semi-elasticity since TEMP is retained in levels, and $\alpha_2$- $\alpha_6$ are long-run elasticities, while $\varepsilon_t$ is a white-noise disturbance.

As increases and decreases in climate variables can have different impacts on agriculture, Equation (1) is expanded using the nonlinear partial-sum decomposition of Shin et al. (2014):

 

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$$lnAGO_t = \alpha_0 + \alpha_1 CO2_t^+ + \alpha_2 CO2_t^- + \alpha_3 TEMP_t^+ + \alpha_4 TEMP_t^- + \alpha_5 lnRAIN_t + \alpha_6 lnACR_t + \alpha_7 lnFERT_t + \alpha_8 lnPOP_t + \varepsilon_t \quad (2)$$

The positive and negative partial sums of CO2 emissions are defined as $CO2_t^+ = \Sigma_{s=1}{}^t\, max(\Delta lnCO2_s, 0)$ and $CO2_t^- = \Sigma_{s=1}{}^t\, min(\Delta lnCO2_s, 0)$, with $TEMP_t^+$ and $TEMP_t^-$ defined analogously for temperature. coefficients $\alpha_1$ and $\alpha_2$ represent the asymmetric LR effect of an increase and decrease in carbon emissions, respectively, and $\alpha_3$ and $\alpha_4$ represent the asymmetric LR effects of an increase and decrease in temperature, respectively. Formal testing of the null hypothesis of long-run symmetry ($H_0$: $\alpha_1 = \alpha_2$ and $H_0$: $\alpha_3 = \alpha_4$) is done via a Wald statistic distributed as $\chi^2(1)$.

### 3.2 Estimation Technique

Estimation proceeds sequentially. To stabilize variance and provide directly interpretable elasticities, all variables are transformed to natural logarithms, except TEMP, with a seven per cent coefficient of variation, which is not numerically stable. The order of integration of each series is determined using a triangulated battery of Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, as no single test is uniformly powerful against all alternative data-generating processes. Cointegration is, then, tested in two alternative ways: the ARDL bounds testing procedure developed by Pesaran (2001) which is suitable when the integration orders of regressors are mixed and the maximum-likelihood procedure of Johansen (1988, 1991) applied to the full variable system as a corroborating multivariate check.

If evidence of cointegration is found, the long-run parameters of Equation (1) are estimated by Dynamic Ordinary Least Squares (DOLS), following Stock and Watson (1993), who add leads and lags of the regressors in the first difference to remove the asymptotic bias caused by regressor endogeneity and serial correlation; Newey-West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors are used for inference. For a robustness check, Fully Modified OLS (FMOLS) as proposed by Phillips and Hansen (1990) is also estimated, with a semi-parametric kernel estimation of the long-run covariance matrix applied to the OLS estimator. The endogeneity of the contemporaneous construction of the partial sums is addressed by an NARDL-DOLS hybrid for the asymmetric specification in Equation (2).

To trace the short run dynamics and the speed of the adjustment towards the long run equilibrium an Engle-Granger Error Correction Model (ECM) has been used:

$$\Delta lnAGO_t = c + \rho ECT_{t-1} + \Sigma_i\, \varphi_i \Delta lnAGO_{t-i} + \Sigma_k\, \Sigma_j\, \psi_{kj} \Delta Z_{kt-j} + \varepsilon_t \quad (3)$$

where $ECT_{t-1}$ is the lagged residual from the long-run DOLS equation, $\rho$ is the speed-of-adjustment coefficient (expected negative, and significant for a stable equilibrium), and $\Delta Z_{kt-j}$ are first-differenced regressors. Robust (MacKinnon-White, 1985) standard errors are used throughout the ECM.

### 3.3 Pre- and Post-Estimation Diagnostics

The pre-estimation diagnostics include descriptive statistics with Jarque-Bera normality tests, a Spearman rank-order correlation matrix to screen for multicollinearity, the ADF/KPSS unit-root battery and the lag-order selections (Akaike, Schwarz Bayesian and Hannan-Quinn information criteria). The Breusch-Godfrey Lagrange Multiplier test for serial correlation (with 2 lags), White's test for heteroskedasticity, Jarque-Bera test for residual normality, Ramsey RESET test for functional-form misspecification, and the Durbin-Watson statistic are applied to the ECM.

### 3.4 Measurement of Variables and Data Sources

Table 2 succinctly captures the variables cum data sources utilised in the study. The data span 1981 to 2024. The a-priori expectations are as well contained in Table 3.

**Table 2: Variable Description, Measurement, Transformation and Data Sources**

| Code | Variable | Definition / Unit | Transformation | Source |
|---|---|---|---|---|
| AGO | Agricultural Output | Gross value added in agriculture (crops, livestock, forestry, fishing), current US$ | lnAGO | World Bank WDI |

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|---|---|---|---|---|
| TEMP | Temperature | Annual mean temperature (°C), population-weighted across states | Level | World Bank CCKP; NOAA |
| RAIN | Rainfall Variability | Annual average precipitation (mm) | lnRAIN | FAO AQUASTAT |
| $CO_2$ | Carbon Dioxide Emissions | $CO_2$ from fossil fuel combustion and industry (metric tonnes per capita) | ln$CO_2$ | Global Carbon Project |
| ACR | Agricultural Credit | Commercial bank credit to agriculture (% of total domestic credit) | lnACR | CBN Statistical Bulletin |
| FERT | Fertiliser Consumption | Nutrient use intensity (kg per hectare of arable land) | lnFERT | IFA |
| POP | Population Growth Rate | Annual population growth rate (%) | lnPOP | World Bank WDI |

**Table 3: A-priori Expectations of Variables**

| Variable | Expected Sign | Theoretical Rationale |
|---|---|---|
| TEMP (level) | + / − | Ambiguous: warming may extend growing seasons in the north (positive) but heat stress beyond agronomic thresholds reduces yield (negative); NARDL resolves the ambiguity |
| lnRAIN | + | Rainfall is the principal moisture source for rain-fed agriculture, which covers over 90% of Nigeria's cropped area |
| ln$CO_2$ | ± (level); $CO_2$+ −, $CO_2$− + | Carbon fertilisation at moderate concentrations is positive; warming externality dominates at higher concentrations |
| lnACR | + | Credit relaxes financing constraints on inputs, mechanisation and irrigation |
| lnFERT | + | Fertiliser replenishes soil nutrients, the primary input-intensity channel for smallholder yields |
| lnPOP | ± | Raises labour supply (positive) but intensifies demand pressure on land and food resources (negative, Malthusian channel) |

## IV. RESULTS AND DISCUSSION

### 4.1 Pre-Estimation Results

#### *4.1.1 Descriptive Statistics*

Descriptive statistics for the variables in the agricultural output model are presented for the period 1981-2024 in Table 4. Agricultural production averaged about US$58.4 billion, ranging from US$652 million to US$131 billion in current US dollars, with a standard deviation of US$43.4 billion, indicating a high level of variation linked to the process of structural change, exchange-rate pass-through and inflation over the sample. The mean annual temperature was 1,160.73 (index units consistent with the underlying aggregation) with a standard deviation of 83.29, while mean annual rainfall was 117.55, with a standard deviation of 8.34. The range for carbon dioxide emissions per capita was 0.18-33.22 tonnes, with the average of 7.76 tonnes showing a positive skew with larger emissions readings more commonly found in the later part of the sample. The Jarque-Bera statistics suggest that temperature, rainfall and carbon dioxide and fertiliser consumption are far from normal, which generally occurs in climatic or structural economic series where there are regime shifts and external shocks, whereas agricultural output is not significantly different from normal.

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**Table 4: Descriptive Statistics of Variables**

| Variable | Mean | Std. Dev. | Min | Max | Skewness | JB Prob. |
|---|---|---|---|---|---|---|
| AGO | 5.84e+10 | 4.34e+10 | 6.52e+09 | 1.31e+11 | 0.24 | 0.080 |
| TEMP | 1160.73 | 83.29 | 887.82 | 1296.63 | -0.53 | 0.038** |
| RAIN | 117.55 | 8.34 | 90.20 | 131.10 | -0.53 | 0.043** |
| $CO_2$ | 7.76 | 8.85 | 0.18 | 33.22 | 0.94 | 0.000*** |
| ACR | 16.81 | 6.35 | 3.02 | 26.56 | 0.07 | 0.313 |
| FERT | 9.53 | 4.85 | 4.15 | 22.56 | 1.37 | 0.025** |
| POP | 2.61 | 0.24 | 2.08 | 3.01 | -0.77 | 0.027** |

### *4.1.2 Correlation Analysis*

Before estimating the model, a Spearman rank-order correlation matrix was computed among the seven variables of the model to check the existence of multicollinearity among the regressors. Agricultural output is found to be positively associated with both carbon dioxide emissions and, albeit with a weak correlation, agricultural credit, reflecting a similar positive structural trend across the sample period, but shows no pairwise correlation with any of the other explanatory variables that is close to the usual 0.80 multicollinearity threshold. The negative relationship between the use of fertiliser and agricultural credit ($\rho = -0.518$, $p < 0.001$) indicates a credit-input substitution pattern, rather than complementarity, during the sample period, as discussed below in the context of the long-run estimates. The lack of significant pairwise collinearity allows the inclusion of all of the climate, credit, input and demographic regressors in a single cointegrating equation.

### *4.1.3 Unit Root Tests*

The results of the unit-root tests (ADF and KPSS) are presented in Table 5. Stationary properties of the variables through level are as follows: TEMP and lnRAIN are stationary; lnAGO and lnCO2 are stationary after 1 difference; lnACR, lnFERT and lnPOP are stationary after 1 difference, but the KPSS test results indicate that these variables are not stationary after 1 difference; thus, their interpretation in model selection is based on the Johansen procedure, which is robust to I(2) contamination of 1 series when cointegrating rank is interpreted cautiously, as well as on the DOLS/FMOLS. The results from the ADF and KPSS tests are largely consistent and suggest the applicability of cointegration-based estimators that are able to accommodate mixed orders of integration.

**Table 5: Summary of Unit Root Test Results (ADF and KPSS)**

| Variable | ADF Level (p) | ADF Δ (p) | KPSS Decision | Order of Integration |
|---|---|---|---|---|
| lnAGO | 0.588 | 0.530 | I(2) | I(2) |
| TEMP | 0.000*** | - | I(0) | I(0) |
| lnRAIN | 0.050** | - | I(0) | I(0) |
| lnCO2 | 0.205 | 0.000*** | I(1) | I(1) |
| lnACR | 0.759 | 0.000*** | I(1) | I(1) |
| lnFERT | 0.461 | 0.000*** | I(1) | I(1) |
| lnPOP | 0.231 | 0.000*** | I(1) | I(1) |

*Note: ADF includes intercept and trend; lag length by AIC. ***, **, * significant at 1%, 5%, 10%.*

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### *4.1.4 Lag Length Selection and Cointegration Tests*

The VAR lag order selection criteria shows that lag 4 is optimal on both the AIC and HQIC criteria (Table 6), suggesting a multi-season and multi-cycle agronomic adaption trend: current agricultural output depends on climatic and structural conditions up to 4 years prior. The ARDL bounds test reported in Table 7 gives a computed F-statistic value of 0.016 that is below the lower critical bound for cointegration at the 5 % level (2.62); thus, it cannot substantiate cointegration using the bounds-testing criterion. The Johansen procedure (Table 8), on the other hand, renders a very different verdict: the trace statistic rejects the null of no cointegration at r = 0 (187.65 against a critical value of 125.62) and keeps on rejecting up to r ≤ 3, whereas the maximum-eigenvalue statistic confirms one cointegrating vector at the 5 percent level. But with corroborating multivariate evidence of a stable long-run relationship, the study moves forward to examine the long-run climate-output relationship using DOLS, FMOLS and NARDL-DOLS estimation.

**Table 6: VAR Lag Order Selection Criteria**

| Lag | AIC | BIC | HQIC |
|---|---|---|---|
| 1 | -13.5853 | -11.2684 | -12.7361 |
| 2 | -14.6361 | -10.2477 | -13.0381 |
| 3 | -17.8725 | -11.3703 | -15.5215 |
| 4* | -22.4827* | -13.8237 | -19.3759* |

*Note: * denotes lag selected by the respective criterion*

**Table 7: ARDL Bounds Test for Cointegration**

| Significance | Lower Bound I(0) | Upper Bound I(1) | Computed F-Statistic | Decision |
|---|---|---|---|---|
| 10% | 2.26 | 3.35 | 0.0162 | No cointegration |
| 5% | 2.62 | 3.79 | | |
| 1% | 3.41 | 4.68 | | |

*Note: k = 6 regressors.*

**Table 8: Johansen Cointegration Test Results**

| H0 | Eigenvalue | Trace Stat. | Crit. Value (5%) | Max-Eigen Stat. | Crit. Value (5%) | Decision |
|---|---|---|---|---|---|---|
| r = 0 | 0.825 | 187.646 | 125.615 | 73.269 | 46.231 | Reject H0 |
| r ≤ 1 | 0.563 | 114.377 | 95.754 | 34.765 | 40.078 | Fail to reject |
| r ≤ 2 | 0.528 | 79.612 | 69.819 | 31.567 | 33.877 | Fail to reject |
| r ≤ 3 | 0.426 | 48.046 | 47.856 | 23.278 | 27.584 | Marginal |

*Note: Trace test indicates 4 cointegrating equations; max-eigenvalue test indicates 1.*

## 4.2 Post-Estimation Results

### *4.2.1 Long-Run Estimates: DOLS and FMOLS*

The estimates for Equation (1) made by DOLS are shown in Table 9. The coefficient on temperature is negative but not yet statistically significant (-0.109, p = 0.175), as expected from the theory that heat stress reduces output. The sign of rainfall is

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positive (126.764), but is also small and statistically insignificant, implying that the sheer amount of rainfall is insufficient alone to explain agricultural performance, perhaps because the timing and distribution of precipitation is more important for agricultural performance. The long-run impact of emissions on agricultural output is found to be positive and significant at the 10 percent level (0.375, p = 0.095), suggesting that carbon-fertilisation is working at Nigeria's current moderate level of per-capita emissions. Two variables have negative and statistically significant coefficients: fertiliser consumption (-1.151, p = 0.005) and population growth (-10.980, p = 0.002): the two jointly suggest that it is structural rather than climatic constraints to Nigeria's agriculture performance that are more binding on output over this sample.

**Table 9: DOLS Long-Run Estimates: Climate Change and Agricultural Output**

| Variable | Coefficient | Std. Error | t-Stat | Prob. |
|---|---|---|---|---|
| Constant | -440.168 | 357.258 | -1.232 | 0.218 |
| TEMP | -0.109 | 0.081 | -1.357 | 0.175 |
| lnRAIN | 126.764 | 94.099 | 1.347 | 0.178 |
| $\ln CO_2$ | 0.375 | 0.225 | 1.668 | 0.095* |
| lnACR | -0.211 | 0.628 | -0.336 | 0.737 |
| lnFERT | -1.151 | 0.413 | -2.787 | 0.005*** |
| lnPOP | -10.980 | 3.622 | -3.031 | 0.002*** |

*Note: ***, **, * significant at 1%, 5%, 10%. DOLS $R^2$ = 0.695.*

The estimate for the FMOLS presented in Table 10 is generally supportive. Temperature is essentially flat (0.003, insignificant), supporting the notion that a clearly discernible linear output penalty has yet to be observed even with the mean warming alone, likely because of some farmer adaptation to the slow warming. The carbon-fertilisation result is corroborated by the fact that carbon dioxide remains significant and positive at the 10 per cent level (0.202, p = 0.100). As is the case for fertiliser, agricultural credit also has a negative sign (-0.332) but becomes statistically insignificant when the DOLS semi-parametric correction is applied, thus implying that the semi-parametric correction in FMOLS is slightly more lenient than DOLS on the credit-output relationship.

**Table 10: FMOLS Long-Run Estimates: Climate Change and Agricultural Output**

| Variable | Coefficient | Std. Error | t-Stat | Prob. |
|---|---|---|---|---|
| Constant | 46.330 | 104.994 | 0.441 | 0.659 |
| TEMP | 0.003 | 0.025 | 0.115 | 0.908 |
| lnRAIN | -4.579 | 28.616 | -0.160 | 0.873 |
| $\ln CO_2$ | 0.202 | 0.123 | 1.645 | 0.100* |
| lnACR | 0.332 | 0.604 | 0.549 | 0.583 |
| lnFERT | -0.356 | 0.513 | -0.693 | 0.488 |
| lnPOP | -4.178 | 3.023 | -1.382 | 0.167 |

*Note: ***, **, * significant at 1%, 5%, 10%.*

#### *4.2.2 NARDL-DOLS Asymmetric Estimates and Symmetry Tests*

The NARDL-DOLS estimates of Equation (2) are presented in Table 11. The positive carbon emission increments ($CO2+$) have a significant positive coefficient (0.421, p = 0.011), while the negative ones ($CO2-$) are positive but insignificant (0.145, p = 0.366), showing that higher carbon emissions are associated with somewhat larger output over the estimation window, and the

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opposite is true for negative carbon emission changes. Relative to linear DOLS specification, rainfall becomes negative and weakly significant (-165.29, p = 0.085) in the asymmetric model, suggesting that, in addition to being beneficial to crops, excess rainfall is bad for them because of waterlogging, erosion and flooding. Consumption of fertiliser continues to be negative and significant (-0.771, p = 0.040), further supporting the structural-constraint story found with the linear specification.

The Wald formal tests for long run symmetry are presented in Table 12. The Wald statistic for carbon dioxide is 1.424 (p = 0.233) which is less than the critical value of $\chi^2(1) = 3.84$, and so the null hypothesis of symmetry ($\beta+ = \beta-$) cannot be rejected. Similarly, the Wald statistic of 0.001 (p = 0.977) does not reject symmetry for temperature. These findings suggest that, despite the moderate emission levels where the carbon-fertilisation channel has been identified, the agricultural output of Nigeria is not yet statistically different when it comes to temperature and carbon dioxide increases versus decreases – a result that is contrary to some agronomic priors, but is reasonable given that the climatic deviations for Nigeria are still moderate when compared to economies where threshold effects have become more sharply binding.

**Table 11: NARDL-DOLS Long-Run Estimates with Asymmetric Climate Effects**

| Variable | Coefficient | Std. Error | t-Stat | Prob. |
|---|---|---|---|---|
| Constant | 801.374 | 448.560 | 1.787 | 0.074* |
| lnCO2+ | 0.421 | 0.165 | 2.543 | 0.011** |
| lnCO2− | 0.145 | 0.161 | 0.904 | 0.366 |
| TEMP+ | 0.139 | 0.082 | 1.695 | 0.090* |
| TEMP− | 0.143 | 0.082 | 1.736 | 0.083* |
| lnRAIN | -165.292 | 95.852 | -1.724 | 0.085* |
| lnACR | -0.242 | 0.311 | -0.778 | 0.437 |
| lnFERT | -0.771 | 0.375 | -2.057 | 0.040** |
| lnPOP | -3.870 | 3.167 | -1.222 | 0.222 |

*Note: ***, **, * significant at 1%, 5%, 10%.*

**Table 12: Wald Test for Long-Run Asymmetry: $CO_2$ and Temperature**

| Test | $\beta^+$ | $\beta^-$ | Wald Statistic | p-value | Decision |
|---|---|---|---|---|---|
| $CO_2$ Asymmetry | 0.421 | 0.145 | 1.424 | 0.233 | Symmetric |
| TEMP Asymmetry | 0.139 | 0.143 | 0.001 | 0.977 | Symmetric |

*Note: Wald statistic ~ $\chi^2(1)$. H0: $\beta^+ = \beta^-$.*

### 4.2.3 Short-Run Dynamics

The Error Correction Model is shown in Table 13. The sign of the error correction term is right (-0.078), but it is not statistically significant (p = 0.351), indicating that an adjustment toward the long-run equilibrium takes place in the span of a year, but it is weak and poorly estimated. None of the short-run climate or input coefficients is statistically significant, which means that climate and input shocks do not have an immediate, statistically discernible impact on agricultural output in the same year, but rather the impact identified in the long-run equations is gradual, as is emphasised in the Agricultural Adaptation Theory on the multi-period structural adjustment.

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**Table 13: Short-Run Error Correction Model: Agricultural Output**

| Variable | Coefficient | Std. Error | t-Stat | Prob. |
|---|---|---|---|---|
| ECT(-1) | -0.078 | 0.083 | -0.940 | 0.351 |
| ΔlnCO2 | 0.056 | 0.071 | 0.789 | 0.433 |
| ΔTEMP | -0.012 | 0.028 | -0.429 | 0.670 |
| ΔlnRAIN | 18.442 | 31.006 | 0.595 | 0.554 |
| ΔlnACR | 0.016 | 0.153 | 0.103 | 0.918 |
| ΔlnFERT | -0.001 | 0.166 | -0.003 | 0.997 |
| ΔlnPOP | 2.558 | 2.521 | 1.015 | 0.310 |

*Note: ***, **, * significant at 1%, 5%, 10%.*

### 4.2.4 Diagnostic and Stability Tests

Diagnostics from the ECM are reported in Table 14. The model accounts for only a small proportion of variation ($R^2 = 0.176$) in the annual outputs of agriculture, and the F-statistic is also statistically insignificant, indicating that the group of explanatory variables does not explain much in terms of the short-run variation in agricultural output, which is not surprising given the long run, slow adjustment nature of the relationships. The Breusch-Godfrey and White tests do not reveal any evidence of significant serial correlation ($p = 0.245$) or heteroskedasticity ($p = 0.266$), while the Jarque-Bera test and the Ramsey RESET test reject normality and possible functional-form misspecification, respectively, suggesting that caution should be exercised when extrapolating the short-run coefficients, but the long-run cointegrating relationship is comparatively well supported by the DOLS/FMOLS/NARDL-DOLS triangulation.

**Table 14: Post-Estimation Diagnostic Tests (ECM)**

| Diagnostic Test | Statistic | p-value | Conclusion |
|---|---|---|---|
| R-squared | 0.176 | - | Moderate fit |
| F-statistic | 0.664 | 0.701 | Insignificant |
| Durbin-Watson | 1.581 | - | No serial correlation |
| Breusch-Godfrey LM (2 lags) | 2.815 | 0.245 | No serial correlation |
| White Heteroskedasticity | 39.757 | 0.266 | Homoskedastic |
| Jarque-Bera Normality | 151.214 | 0.000 | Non-normal |
| Ramsey RESET | 52.205 | 0.000 | Possible misspecification |

*Note: n = 40 (post-differencing observations).*

### 4.3 Discussion of Findings

The results suggest that, in 1981-2024, Nigerian agricultural output is determined less by the direct effects of climate shocks than by structural and demographic conditions – although this does not detract from the overall climate-vulnerability story that is more widely heard in the Nigerian literature. The substantial and positive finding of the carbon dioxide effect in both DOLS and FMOLS specifications is consistent with a carbon-fertilisation mechanism occurring at still moderate levels of Nigeria's per-capita emissions, which qualified a largely negative emissions-productivity relationship by Amaefule *et al.* (2023), and suggests a threshold effect – positive at low emission levels followed by negative at higher emission levels; this interpretation is not confirmed nor decisively ruled out by the statistically insignificant symmetry tests, especially in view of the moderate sample size. This positive carbon coefficient also contrasts somewhat with Nweke's (2025) bounds testing ARDL result for the country which covers the same period 1981-2024 but employed forest depletion and poverty as structural controls instead of fertiliser and agricultural credit.

The high and significant negative fertiliser coefficients, along with the high and significant negative population coefficient, mirror what Bello et al. (2024) report for Nigeria

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in their discussion of the poor performance of the agricultural sector and, in addition, demonstrate econometrically that the impact of input-management inefficiency on output is quantitatively more important than the impact of the climate factors studied in this paper. The weak and insignificant dynamics on shorter horizons, and the modest speed of error-correction, indicate that climate sensitivity is a long-horizon phenomenon: the present national time-series evidence suggests that whatever climate sensitivity there is at the farm level takes years, rather than a single season, to become apparent in aggregate output, in line with the Agricultural Adaptation Theory's premise of resilience through structural change. This reading is supported by Amankwah (2023) who provide plot-level evidence on Nigeria that it is not climate exposure per se, but rather the adoption of sustainable farming practices that drives the crop productivity.

Also, in a shorter sample of 1986-2022 for Nigeria, Alehile (2025) find a nonlinear ARDL result where rainfall variability is the more binding long-run climate constraint, consistent with the weakly significant negative rainfall coefficient from this paper under the asymmetric specification. The lack of evidence for long-run symmetry for both carbon dioxide and temperature does not negate the alarmist description of some qualitative studies such as Gana *et al.* (2024), who conclude that the climate change is a structural shock to Nigerian food systems; instead, it implies that so far, the average changes in climatic variables in Nigeria have not yet been sufficient to trigger a nonlinear risk threshold on the food output side.

This positive carbon dioxide coefficient in this paper, contrasted with the negative productivity finding of Amaefule *et al. (*2023), requires further investigation. There are three arguments that would make for a plausible explanation of the divergence. First, sample composition: Amaefule et al. (2023) focus on a smaller measure of productivity over a different estimation period, while the current study uses gross value added in agriculture over a longer time horizon from 1981–2024 that includes more decades of lower emissions per capita in Nigeria and thus a more prominent fertilisation effect relative to warming externalities. Second, choice of estimator: DOLS and FMOLS account for endogeneity and serial correlation problems, which can lead to a significant difference in the sign and magnitude of an estimated coefficient in small samples when compared to simple time-series regressions. Third, omitted-variable risk: the current specification controls for both fertiliser use and agricultural credit, as well as population growth, and so removes some of the structural variation that would otherwise be picked up by the emissions coefficient in a less dense specification. These reconciling thoughts point to a possible conditional nature of the carbon-fertilisation effect reported here: a feature of the climate-output relationship, this effect should be interpreted as conditioned by Nigeria's historical emissions path.

The results also shed light on the overall policy discussion on emphasis on mitigation (emissions reduction) or adaptation (resilience building) instruments for Nigerian climate-agriculture interventions. Although mitigation also has its own independent justification on the ground of global commons, the immediate policy priority may be towards adaptation and structural change, as the paper is unable to find a statistically significant asymmetric output penalty from increased temperature and carbon dioxide over the historical sample period, and the major, robustly significant constraints are of input-management and demographic nature, confirmed by Okafor *et al.* (2025) that the food insecurity of farming communities in southeast Nigeria is driven by the pressure of resources-access as opposed to only production-side climate shocks.

This is consistent with the Environmental Security Theory's feedback-loop logic: negative (stabilising) feedback investments – irrigation, drought-resistant cultivars, soil and fertiliser management – directly affect the channels identified as statistically dominant in the estimates in this paper, while the relatively weak and symmetric climate coefficients indicate that Nigeria still has a meaningful adaptation window before climatic constraints become the limiting factor of agricultural output. The zone-specific projections by Oziegbe and Akinnubi (2026) suggest a rapid intensification of warming and a divergence of yield trends in Nigeria's agro-ecological belts until 2050, implying that this window is not perpetual, and the national-aggregate picture portrayed in this study will require periodic re-evaluation as the climatic deviations grow more severe at the zone level.

## V. CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The objective of this paper was to assess the impact of climate change on Nigeria agricultural production during 1981-2424, with a particular emphasis on the possibility of asymmetric long-term effects of an increase and a decrease in climate pressures. There is no evidence that the impact of climate change in Nigeria is straightforward: a uniform reduction in agricultural output, but rather that the impact is more complex with carbon dioxide ($CO_2$) emissions having a positive long-run association with output in line with the carbon fertilisation effect, temperature and rainfall effects being of ambiguous sign and statistically weak over the

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sample period. Meanwhile, the direct impacts of climate change on Nigerian agriculture are statistically small and secondary in magnitude compared to the impacts of the three other variables: fertiliser mismanagement, population pressure and the expanded cultivation of marginal lands. Yet, despite the fact that qualitative literature and agronomic theory would suggest that it should, the long-run response of agricultural output to climate change at the national level and over the time span of this study has not yet reached statistically significant asymmetry levels, according to formal Wald tests.

The overall conclusion is that climate change and agricultural output in Nigeria are related through a slow moving, structurally mediated relationship, rather than an already crystallised climate emergency. The nonlinear, multi-estimator approach used here reveals that, even with a linear (DOLS, FMOLS) or explicitly asymmetric climate-output relationship (NARDL-DOLS), adaptation capacity, input-use efficiency and demographic pressure currently influence agricultural outcomes as much as the climate signal alone. In this way, the paper does not reject the claim of the climate-agriculture nexus in Nigeria but rather calls for a redirection of the urgency in order to better appreciate the fact that climate change is a very real and growing background risk for the production of Nigeria's agriculture but, on the available evidence, not the most pressing risk for policy attention in relation to input management and demographic planning.

### 5.2 Recommendations

The paper thus makes the following recommendations, based on the above findings. First, in the face of the predominance of structural over purely climatic constraints, government should focus on programmes to enhance the efficiency of fertiliser use (fertiliser-use testing services, blended and site-specific fertiliser recommendations and better extension monitoring) rather than on expanding generic inputs subsidies, with the evidence pointing to the fact that increased fertiliser use has failed to yield increased output. Second, agricultural planning that considers population levels, such as the policy of providing land-use consolidation incentives and productivity-enhancing mechanisation support, should be pursued to offset the demographic drag on output identified in this paper, and which, from the complementary evidence, is an independent driver of food insecurity in farming communities. Third, the carbon-fertilisation effect found here will only hold until Nigeria's emissions level reaches moderate levels; climate policy should, therefore, be designed to account for the potential at which warming externalities may exceed any remaining fertilisation benefits, but not be based on a permanently beneficial or permanently harmful emissions-output relationship. Fourth, in the absence of short-run climate impacts, and the slow speed of error correction, investment in agricultural resilience (such as irrigation, drought-tolerant seed varieties, and climate information services) should be designed as long-horizon capital projects rather than as short-term emergency responses. Fifth, national climate-agriculture planning should be supported by agro-ecological-zone-level monitoring and response, not just national aggregates that may hide the higher risk and warming zones, e.g., the Sudan Savanna. Finally, the next round of national data collection should focus on more disaggregated spatial and temporal climate and output data, so that threshold and asymmetric effects can be better identified than is possible in this paper using annual national aggregates.

## REFERENCES


[1] Adesete, A. A., Olanubi, O. E., & Dauda, R. O. (2023). Climate change and food security in selected Sub-Saharan African Countries: AA Adesete et al. *Environment, Development and Sustainability*, 25(12), 14623-14641.

[2] Alehile, K. S. (2025). Modelling the impact of climate change on Nigeria’s agricultural sector: A nonlinear modelling approach. *International Journal of Advanced Economics*, 7(4), 106-119.

[3] Amaefule, C., Shoaga, A., Ebelebe, L. O., & Adeola, A. S. (2023). Carbon emissions, climate change, and Nigeria’s agricultural productivity. *European Journal of Sustainable Development Research*, 7(1), 1-36.

[4] Amankwah, A. (2023). Climate variability, agricultural technologies adoption, and productivity in rural Nigeria: A plot-level analysis. *Agriculture & Food Security*, 12(1), 1-16.

[5] Atchadé, M. N., &Nougbodé, H. (2024). Statistical investigation on the relationship between climate change, food availability, agricultural productivity, and economic expansion. *Heliyon*, 10(12), 1-13.

[6] Ayilara, M. S., Fasusi, S. A., Ajakwe, S. O., Akinola, S. A., Ayilara-Adewale, O. A., Ajakaye, A. E., ... & Babalola, O. O. (2025). Impact of Climate Change on Agricultural Ecosystem. In Climate Change, Food Security, and Land Management: Strategies for a Sustainable Future (pp. 1-24*). Cham: Springer Nature Switzerland*.

[7] Bello, M. M., Yahaya, J. U., &Adamu, I. (2024). An analysis of sustainable agricultural productivity and food security in Nigeria. *Journal of Political Discourse*, 2(1), 45-60.

[8] Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical*

International Current Journal of Engineering and Science (ICJES)
Volume 5, Issue 7, pp 17-32, July-2026
ISSN (Online): 2583-7257
Article DOI: https://doi.org/10.47001/ICJES/2026.507003

*Society Series B: Statistical Methodology*, 37(2), 149-163.

[9] Charles, A. O., Anetor, F. O., & Akpabio, E. S. (2023). The effect of climate change on the agricultural sub-sectors in Nigeria: An autoregressive distributed lag (Ardl) approach., 57(2), 17-29.

[10] Dauda, H. N. (2023). Nigeria's food security policies: Focus on challenges and prospects of achieving food security in Nigeria. *World Climate Research Programme*, pp. 371-388. *The Journal of Developing Areas*

[11] Dell, M., Jones, B. F., &Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics*, 4(3), 66-95.

[12] Gana, I. M., Sadiq, K. H. A. D. I. J. A. T., Adamu, O. T., & Aliyu, M. O. H. A. M. M. E. D. (2024). The interplay between climate change and food security in Nigeria: challenges and opportunities. *Journal of Political Development*, 2(2), 154-164.

[13] Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: journal of the Econometric Society*, 59(6), 1551-1580.

[14] MacKinnon, J. G., & White, H. (1985). Some heteroskedasticity-consistent covariance matrix estimators with improved finite sample properties. *Journal of econometrics*, 29(3), 305-325.

[15] Nweke, O. (2025). Climate change and agricultural sector output in Nigeria. *American Journal of Social and Humanitarian Research*, 6(10), 2415–2425.

[16] Okafor, S., Ogbochie, A., Ugwu, C., Oranu, C., Amadi, G., Ugwuanyi, C., & Modesta, O. (2025). Environmental Resource Conflicts and Food Insecurity in Rural Southeast Nigeria: Implications for Humanitarian and Sustainable Development Policies. *Journal of Agriculture and Environment for International Development (JAEID)*, 119(1), 183-208.

[17] Omokaro, G. O. (2025). Multi-impacts of climate change and mitigation strategies in Nigeria: Agricultural production and food security. *Science in One Health*, 4, 1-12.

[18] Omokpariola, D. O., Agbanu-Kumordzi, C., Samuel, T., Kiswii, L., Moses, G. S., &Adelegan, A. M. (2025). Climate change, crop yield, and food security in Sub-Saharan Africa. *Discover Sustainability*, 6(1), 1-21.

[19] Oziegbe, T. R., &Akinnubi, R. T. (2026). Development of an Integrated Econometric-Atmospheric Model for Forecasting Climate Impacts on Nigerian Agriculture and Food Security: Divergent Zone-Specific Trends and Yield Declines. *Nigerian Journal of Physics*, 35(3), 91-118.

[20] Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, 16(3), 289-326.

[21] Phillips, P. C., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I (1) processes. *The review of economic studies*, 57(1), 99-125.

[22] Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of sciences*, 106(37), 15594-15598.

[23] Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. *In Festschrift in honor of Peter Schmidt: Econometric methods and applications* (pp. 281-314). New York, NY: Springer.

[24] Stock, J. H., & Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica: journal of the Econometric Society*, 61(4), 783-820.

[25] Toromade, A. S., Soyombo, D. A., Kupa, E., &Ijomah, T. I. (2024). Reviewing the impact of climate change on global food security: Challenges and solutions. *International journal of applied research in social sciences*, 6(7), 1403-1416.

[26] United Nations Development Programme. (1994). Human development report 1994: New dimensions of human security. *Oxford University Press.*

[27] World Bank. (2024). World development indicators. *World Bank Group*.

 

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