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Sowing the Seeds of Sustainability: Climate Change and Agriculture in a Resource-Rich Country

Seyi Saint Akadiri¹, Jeremiah Tule², Peter Offum³, Ifeanyi Ogbekene⁴¹ Advanced Research Center, University of Lefke, Mersin, Turkey, ² Department of Economics, Bingham University, Karu, Nigeria, ³ Research Department, Central Bank of Nigeria, Abuja, Nigeria, ⁴ Clemson University, Policy Studies Department, United States.

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This study examines how manufacturing emissions, urbanization, and globalization impact Nigeria's crop production (1981–2023) using the ARDL approach. Results show emissions harm agriculture, while urbanization and globalization boost it via demand, infrastructure, and technology. The structural breaks highlights political and economic shifts for the sampled country. Thus, stricter environmental regulations, strategic urban planning, and leveraging globalization for technology transfer and investment are essential to balancing industrial growth, sustainability, and agricultural productivity.

I. Introduction

Climate change poses severe and urgent risks to both developed and developing economies, disrupting agricultural productivity through extreme weather events, declining soil quality, and shifting rainfall patterns (Hirwa et al., 2022). These challenges disproportionately impact vulnerable populations, escalating food scarcity, price volatility (Olasehinde-Williams & Akadiri, 2024), and nutritional deficiencies. Additionally, climate vulnerability has intensified the debt burden in 50 nations, limiting their adaptive capacity.

Climate change places significant risks for agriculture in resource-rich countries, often exacerbating existing disparities. However, studies indicate that the wealth of resources can create a paradox in which these nations are less sensitive to the impact of climate change due to their dependence on fossil fuels (Tadadjeu et al., 2023). On the contrary, effective resource management can favor sustainable agricultural practices, offering a beacon of hope in the face of climate change (Adekoya et al., 2022). Innovations in agricultural methods can integrate the abundance of natural resources with climatic resilience strategies, thus promoting long-term environmental health (Ren et al., 2023). In addition, the improvement of resource efficiency is crucial for sustainable development in these regions (Feng et al., 2023).

Manufacturing remains the primary source of greenhouse gas (GHG) emissions, with large corporations accounting for nearly half (Davda, 2024). In response, global initiatives such as the UN's Net-Zero Expert Group and the

World Bank's financial instruments aim to mitigate emissions, with a target of carbon neutrality by 2050. Meanwhile, the private sector and central banks are urged to integrate environmental governance into their frameworks.

The EKC theory explains the link between climate change and economic output. Initially, rising economic activity leads to environmental degradation through increased carbon emissions. However, as nations reach higher income levels, they invest in cleaner technologies and policies, reducing pollution and promoting sustainability (Stern, 2004). The Green Solow Model suggests that while industrial activities contribute to pollution, technological innovation can offset emissions while maintaining productivity (Brock & Taylor, 2010).

Nigeria faces acute climate risks, including extreme temperatures, erratic rainfall, erosion, and flooding. Deforestation and desertification, compounded by climate-induced migration, have fueled conflicts over arable land (Nwankpa, 2022). In the manufacturing sector, energy intensity and reliance on equity-funded companies are key contributors to climate change, with studies advocating for carbon pricing as a viable emissions reduction strategy (Inah et al., 2022).

Globalization has facilitated agricultural growth through enhanced trade, technology transfer, and financial flows, reducing production costs and increasing efficiency (Barrett et al., 2023). However, climate change is reshaping agricultural structures, requiring the adoption of resilient technologies to sustain output under growing demographic pressures. Structural shifts, including policy reforms and economic disruptions, also influence productivity. For instance, Nigeria's agricultural sector began recovering in

1993 following the Structural Adjustment Programme, a set of economic policies implemented by the Nigerian government and the International Monetary Fund. However, political instability—marked by the annulment of the June 12 election, military coups, and oil price volatility—impeded globalization and exacerbated manufacturing emissions. Subsequent shocks, such as the 2002 oil boom and the 2008 financial crisis, further disrupted economic activity and emissions trends.

Urbanization is another key driver of agricultural transformation. As cities expand, fewer individuals engage in farming, leading to supply shocks and rising food prices. This demographic shift also increases industrial emissions due to unsustainable manufacturing practices (Komarek & Msangi, 2019). Additionally, infrastructure deficits and inconsistent policies have weakened Nigeria's agricultural sector since the 1960s oil boom, diverting labor from farming and increasing dependence on imports (Deininger et al., 2022).

Sustainable agricultural strategies are not just a choice, but a necessity for economic resilience, food security, and global competitiveness. While extensive research links climate change to agricultural productivity, limited attention has been given to the impact of climate change and sectoral emissions. This study addresses this gap by examining the impact of manufacturing emissions, structural breaks, globalization, and urbanization on agricultural productivity in Sub-Saharan Africa. These insights are vital for formulating policies that balance industrial growth with environmental sustainability, a balance that we must strive to achieve without delay.

II. Data and Methodology

A. Data

This study investigates the relationship between environmental degradation and crop production in Nigeria from 1981 to 2023. Where crop output (CROP) is quantified in billions of naira, while emissions from the manufacturing sector (MAN) serve as an indicator of environmental degradation. The analysis includes globalization (KOF) and population (POP) as control variables. Data for this research is sourced from the Central Bank of Nigeria (CBN) and the International Monetary Fund (IMF) Climate Dashboard.

B. Methodology

The empirical model includes factors like environmental degradation, population, and globalization. The model is specified in Equation (1):

$$CROP_t = f(MAN_t, KOF_t, POP_t) \quad (1)$$

We rewrite Equation (1) in its econometric linear form as follows:

$$CROP_t = \beta_0 + \beta_1 MAN_t + \beta_2 KOF_t + \beta_3 POP_t + \varepsilon_t \quad (2)$$

where β_0 to β_3 are the parameters to be estimated, while ε_t is the error term. We begin with the generalized specification for an ARDL model as follows:

$$Z_t = \alpha + \sum_{k=1}^p \delta Z_{t-k} + \sum_{j=0}^q \gamma D_{t-j} + \mu_t \quad (3)$$

where Z_t is the dependent variable, D_t is the vector of regressors, α , δ and γ are the model parameters, and μ_t is the stochastic error term.

We perform a logarithmic transformation of *CROP*, *MAN*, and *KOF* to align them with POP in percentage terms. Subsequently, we rewrite Equation (3) to incorporate the specific variables under study, resulting in an ARDL model version presented below. We conduct multiple structural break tests with unknown dates based on Bai and Perron (1998). The identified break dates are 1993, 2002, and 2008. However, the only statistically significant break date is 1993. Consequently, we create a dummy variable set to zero for the years 1981 to 1992 and one for the years 1993 to 2023.

$$\begin{aligned} \Delta LCROP_t = & \alpha_0 + \sum_{k=1}^p \alpha_{1k} \Delta LCROP_{t-k} \\ & + \sum_{j=0}^{q1} \alpha_{2j} \Delta LMAN_{t-j} \\ & + \sum_{j=0}^{q2} \alpha_{3j} \Delta LKOF_{t-j} \\ & + \sum_{j=0}^{q3} \alpha_{4j} \Delta POP_{t-j} \\ & + \sum_{k=1}^3 \delta_k Dummy_{tk} \\ & + \gamma_1 LCROP_{t-1} + \gamma_2 LMAN_{t-1} \\ & + \gamma_3 LKOF_{t-1} + \gamma_4 POP_{t-1} + \varepsilon_t. \end{aligned} \quad (4)$$

where α_0 denotes the intercept parameter. α_1 to α_5 indicate the short-run parameters, while γ_1 to γ_5 represent the long-run parameters. The optimum lags are p , $q1$, $q2$, and $q3$. ε_t denotes the stochastic disturbance term.

We assess the cointegration relationship among the variables in Equation (4) using the bounds test approach, where we compare the calculated F-statistics with the asymmetric upper and lower bounds critical values. If the computed F-statistic exceeds the upper bound critical values, a long-run relationship is confirmed, allowing us to proceed with estimating the long-run parameters. Subsequently, the study estimates short-run parameters along with the speed of adjustment in Equation (5).

$$\begin{aligned} \Delta LCROP_t = & \alpha_0 + \sum_{k=1}^p \alpha_{1k} \Delta LCROP_{t-k} \\ & + \sum_{j=0}^{q1} \alpha_{2j} \Delta LMAN_{t-j} \\ & + \sum_{j=0}^{q2} \alpha_{3j} \Delta LKOF_{t-j} \\ & + \sum_{j=0}^{q3} \alpha_{4j} \Delta POP_{t-j} \\ & + \sum_{k=1}^3 \delta_k Dummy_{tk} \\ & + \lambda ECT_{t-1} + \varepsilon_t \end{aligned} \quad (5)$$

where ECT represents the error correction term, and λ indicates the coefficient of the speed of adjustment, which measures the speed of reversion from short-run deviations

Table 1. Bai-Perron test results (L+1 vs. L sequentially determined breaks)

Sequential F-statistic determined breaks: 3			
Break Test	F-statistic	Scaled F-statistic	Critical Value**
0 vs. 1 *	46.01601	184.0640	16.19
1 vs. 2 *	9.331480	37.32592	18.11
2 vs. 3 *	6.520009	26.08004	18.93
3 vs. 4	0.392738	1.570953	19.64
Break dates:			
	Sequential	Repartition	
1	2002	1993	
2	1993	2002	
3	2008	2008	

Note: * denotes statistical significance at 5% level. ** indicates Bai and Perron (2003) critical values.

Table 2. Bounds test result

	Lower bound, I(0)	Upper bound, I(1)
10%	2.592	3.454
5%	3.100	4.088
1%	4.310	5.544
F-statistic	14.574*	

Note: * indicates statistical significance at 1% level.

to long-run equilibrium. Finally, the study conducts post-estimation diagnostic tests to ensure that the estimated model conforms with the basic assumptions of the OLS estimation technique.

III. Results

We commence our analysis by investigating multiple structural breaks with undetermined dates, as outlined by Bai and Perron (1998). The corresponding results are presented in [Table 1](#).

The cointegrating ARDL bounds testing result is vital as it offers a robust framework for examining the existence of a long-term equilibrium relationship between partially integrated variables. [Table 2](#) presents the cointegrating ARDL bounds testing results. The estimated F-statistic coefficient (14.574) exceeds both the lower and upper confidence intervals; therefore, we conclude that a long-run cointegrating relationship exists among the variables in the model.

Having established the cointegrating relationship among the series, we estimate the ARDL bounds testing model, as reported in [Table 3](#). The empirical findings reveal a dynamic between manufacturing emissions and crop production, where emissions exert a significant long-run negative impact ($-0.187, p < 0.003$) at the 1% significance level; this suggests that rising industrial emissions contribute to environmental degradation, adversely affecting agricultural productivity over time, potentially through soil contamination, acid rain effects, or disruptions in climatic conditions.

Conversely, urban population growth and globalization demonstrate a positive and negative impact on crop pro-

duction. In the short run, urban population ($0.694, p < 0.000$) and globalization ($-1.261, p < 0.007$) significantly impact agricultural output at the 1% significance level; this is to increase food demand, stimulating production, technological diffusion, and improved market access. In the long run, these variables maintained their influence—manufacturing emission ($-0.907, p < 0.000$), urbanization ($1.085, p < 0.000$) and globalization ($-2.071, p < 0.000$) at the 1% level—highlighting the harmful impact of manufacturing emissions and globalization, and demographic expansion in driving agricultural resilience and productivity.

A critical aspect of the model is the error correction term ($-0.375, p < 0.000$), which is harmful and statistically significant, confirming the presence of a long-run equilibrium relationship; this indicates that any deviations in manufacturing emissions, urban population, or globalization from their long-term trajectory prompt an automatic adjustment in crop production, ensuring stability over time (Olasehinde-Williams & Akadiri, 2024). The significance of the 1993 and 2002 break dates dummy at the 1% level also suggests a structural shift in agricultural productivity patterns, possibly reflecting policy changes, technological advancements, or macroeconomic shocks that altered the relationship among these variables.

The model was subjected to several diagnostic tests to ensure our results' robustness. The non-significance of diagnostic checks confirms the absence of serial correlation, heteroscedasticity, and non-normality, reinforcing the reliability of the estimated coefficients. Moreover, the stability test, depicted in [Figure 1](#), affirms the structural soundness of the model, demonstrating that the estimated relationships remain consistent over time. These findings collectively enhance the empirical credibility of the study, reinforcing the critical role of environmental, demographic, and economic factors in shaping agricultural outcomes.

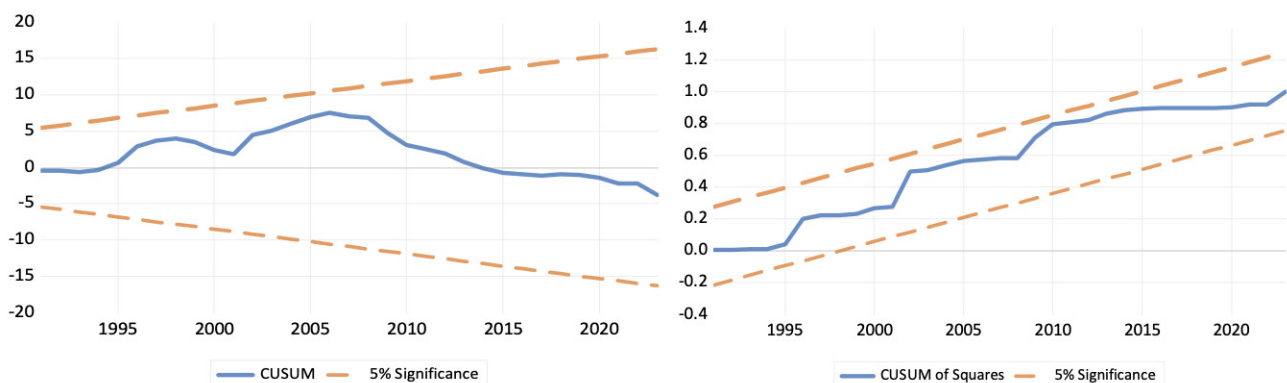
IV. Conclusion

This study highlights significant structural breaks that coincide with Nigeria's political and economic instability. The findings underscore the enduring influence of historical and policy shifts on the interplay between manufac-

Table 3. ARDL model estimation

Dependent Variable: $\Delta LCROP_t$	Coefficient	p-values
Short-run parameters (A)		
$\Delta LCROP_{t-1}$	-0.327***	0.000
$\Delta LKOF$	-1.261***	0.007
$\Delta LPOP$	0.694***	0.000
$Dummy_{1993}$	0.429***	0.000
$Dummy_{2002}$	0.436***	0.000
$Dummy_{2008}$	0.011	0.249
ECT_{t-1}	-0.375***	0.000
Long-run parameters (B)		
$LMAN_t$	-0.907***	0.000
POP_t	1.085***	0.000
$LKOF_{t-1}$	-2.071***	0.000
Diagnostic tests (C)		
R^2	0.746	
Adjusted R-squared	0.672	
LM- stat (BG-test), F (2,30)	0.070	0.791
Heteroscedasticity (ARCH-test), F (1, 38)	0.181	0.672
Ramsey RESET (F-test), F (1, 31)	0.051	0.822

Note: BG denotes Breusch-Godfrey. * and *** indicate statistical significance at 10% and 1% levels, respectively.

**Figure 1. Graphical plot of the CUSUM & CUSUM of squares test for stability test.**

turing emissions, urbanization, globalization, and agricultural productivity. These insights emphasize the necessity for targeted, evidence-based policy interventions to mitigate environmental risks while fostering agricultural resilience.

One of the most pressing concerns identified is the detrimental impact of manufacturing emissions on agricultural productivity. To address this, the government should implement stringent emissions control policies, including carbon pricing mechanisms and sector-specific caps, to curb industrial pollution. Additionally, incentives such as tax credits and subsidies should be introduced to encourage manufacturers to adopt cleaner technologies. Enforcing compliance with international environmental standards through regular audits and penalties will ensure that industries operate within sustainable limits.

Urbanization presents both challenges and opportunities for agricultural productivity. While rapid urban expansion can result in the loss of arable land, strategic urban planning can optimize the benefits of urbanization for the agricultural sector. The government should develop innovative urban planning frameworks integrating green spaces, water conservation systems, and sustainable land use policies. Investing in rural-urban connectivity through improved transport and logistics infrastructure will help reduce post-harvest losses and enhance agricultural supply chain efficiency. Promoting agritech hubs and innovation centres in urban areas can also modernize farming practices and attract youth participation in agriculture.

Globalization has adversely affected Nigeria's crop production, posing challenges to agricultural competitiveness. To mitigate these negative impacts, the government should

prioritize policies that protect local farmers from unfair competition while promoting sustainable agricultural practices. Limiting the influx of low-cost imported crops that undermine domestic production and investing in home-grown technological innovations can enhance productivity and resilience. Additionally, strengthening trade policies to safeguard local farmers and ensuring strategic foreign direct investment in climate-smart agriculture and agro-industrial value chains will be crucial for fostering long-term sustainability and food security.

This study provides actionable insights into the intricate interactions between manufacturing emissions, urbanization, and globalization in Nigeria's agricultural sector. A re-

sults-driven policy approach—balancing industrial growth with environmental sustainability, strategic urban development, and global integration—will be instrumental in securing Nigeria's long-term food security and agricultural productivity. Implementing these policies will mitigate the adverse effects of industrialization on agriculture and position Nigeria's agricultural sector for sustained economic growth in an increasingly globalized world.

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