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THE EFFECTS OF GREENHOUSE GAS EMISSIONS ON CEREAL CROP PRODUCTION IN NIGERIA

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ABSTRACT
The study analyzed the effects of greenhouse gas emissions on Cereal Crop production in Nigeria using secondary data from 1990 to 2023. The data were analyzed using Autoregressive Distributed Lag Model (ARDL). The study revealed that GHG emissions have significantly fluctuated, with carbon dioxide and methane emissions increasing substantially. Cereal crop production exhibited varying trends, with maize and rice showing growth, while wheat production remained inconsistent. The result showed that a long run relationship exists between cereal crop production, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) emissions. Further, the result revealed that in the short run, a unit increase in carbon dioxide, methane and nitrous oxide emissions decreased maize production by 6.6%, 13.5% and 3.7% respectively, wheat by 17.2%, 28.8% and 7.4% respectively while carbon dioxide and methane reduce rice by 9.6% and 15.1%. In the long run, a unit increase in carbon dioxide, methane and nitrous oxide emissions will decrease cereal production. Specifically, maize will fall by 6.6%, 13.2% and 3.7% respectively, rice by 1.4%, 6.7% and 2.8% respectively while only CO2 emission reduces wheat by 4.6% in the long run. In general, methane emissions had the largest detrimental short and long run effects on cereal crop production. The study recommends the need for government to encourage the adoption of environmentally friendly farming techniques that will reduce greenhouse gas emissions such as conservation tillage, crop rotation and agroforestry.

Keywords: Greenhouse Gas Emissions, Cereal Crop Production, Climate Change, Food Security, Agricultural Sustainability, Nigeria.

1. INTRODUCTION

Cereal grains, including wheat, maize, and paddy, are considered primary crops as they serve as staple foods for most of the global population. By 2050, an estimated 70–100% increase in cereal grain supply will be required to feed the predicted world population of 9.8 billion people (Godfray *et al*., 2010). While boosting production rates is widely accepted as a solution, historical trends indicate that current production levels are insufficient to meet future targets (Ray *et al*., 2013). Furthermore, this challenge is exacerbated by the ongoing reduction in fertile and arable land due to unsustainable agricultural practices (Hawkesford *et al*., 2013).

Global climate change poses an additional threat to cereal production. Researchers have established that rising greenhouse gas (GHG) emissions significantly impact crop yields (Tripathi *et al*., 2016; Howden *et al*., 2007). The Earth's surface temperature is projected to rise by approximately 0.2°C per decade over the next 30 years, with estimates suggesting a global

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temperature increase of 2.5 to 4.5°C by the end of the 21st century due to increasing atmospheric concentrations of greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) (Solomon, 2007; Bernstein *et al*., 2008). These climatic changes reduce net carbon gain by increasing plant respiration rates, leading to lower crop yields and increasing the prevalence of weeds, pests, and diseases (Asseng *et al*., 2011; Högy and Fangmeier, 2008). For instance, a 1°C rise in temperature could reduce wheat production yields by 3–10% (You *et al*., 2009). Given the rapid population growth and increasing food demand, the decline in agricultural yields of major cereal crops threatens global food security.

Food insecurity and climate change, both driven by rising GHG emissions, are among the most pressing challenges of the 21st century, often considered even more serious than global terrorism (APF, 2007; King, 2004; Ayinde *et al*., 2011). Between 1970 and 2004, global GHG emissions increased by approximately 70%, largely due to industrialization, deforestation, and agricultural activities (Omojolaibi, 2011). Agriculture itself is a major contributor to climate change, responsible for an estimated 8% increase in GHG emissions between 1990 and 2010, with projections suggesting a further rise to 15% by 2030, equating to about 7 billion tonnes annually (Matthew *et al*., 2018). The continuous rise in GHG concentrations contributes to global temperature increases, altered precipitation patterns, extreme weather events, and shifting seasons, all of which disrupt cereal crop productivity and food security worldwide (IPCC, 2019).

The environmental impacts of GHG emissions extend beyond agriculture, affecting biodiversity, resource depletion, and increasing contamination levels (Ali *et al*., 2023). To prevent catastrophic climate change effects, the global temperature increase must be limited to below 1.5°C. However, current trends suggest that this target remains unattainable (Liu *et al*., 2022). Increasing arid conditions resulting from climate change contribute to declining crop yields by immobilizing essential soil nutrients and promoting salinity, ultimately rendering farmland sterile (Arora, 2019). The situation worsens when increased CO_2 emissions occur without corresponding carbon fertilization (Ackerman and Munitz, 2016). Given agriculture's vital role in food production, it is imperative to achieve sustainable agricultural practices that ensure food security without compromising ecological integrity (Bennetzen *et al*., 2016).

In sub-Saharan Africa (SSA), agricultural emissions account for two-thirds of the rise in food demand projected for the first half of the 21st century (Matthew and Adegboye, 2010; Alege *et al*., 2017; Matthew *et al*., 2018). Although climate change is a global phenomenon, its adverse effects disproportionately affect developing nations, particularly SSA countries, due to factors such as weak institutional capacity, high poverty levels, reliance on rain-fed agriculture, and inadequate infrastructure (Watson, 1997; Imoh and Okechuku, 2015; Eboh, 2009). The impact of climate change in SSA manifests through shifts in land and water availability, increased droughts, flooding, soil degradation, and disease outbreaks affecting both crops and livestock (Eboh, 2009).

Nigeria, as Africa's largest GHG emitter, faces unique climate-related challenges. Apart from agricultural emissions, the country's Niger Delta region hosts over 123 gas flaring sites, contributing to roughly one-sixth of global gas flaring, with approximately 75% of the gas produced being flared (World Bank, 2008). Other major contributors to Nigeria's GHG emissions include rapid population growth, urbanization, industrialization, and deforestation, which further exacerbate climate change (Akinro *et al*., 2008). These emissions have severe implications for agriculture, as CO_2 accumulation can degrade soil fertility, harm livestock, and negatively impact aquatic life due to acid rain formation (Ayinde *et al*., 2011; Edoji *et al*., 2016).

Moreover, CO_2 emissions have been linked to health issues, including leukemia and birth defects (Edoji *et al*., 2016).

Agriculture remains the backbone of Nigeria's economy, contributing to food security, employment, foreign exchange earnings, and industrial raw materials. However, the sector's reliance on seasonal rain-fed farming makes it highly vulnerable to climate change. Any disruption in agricultural productivity due to climate-related factors poses severe challenges to poverty eradication, economic growth, and environmental sustainability. Ayinde *et al*. (2011) noted that climate change is placing Nigeria's agricultural system under severe stress, with extreme weather events such as droughts and floods becoming more frequent. The impact of climate change varies by region within Nigeria: The North-East zone is predominantly affected by drought, desertification and heat stress; South-South and South-West geo-political zones by sea level rise and deforestation-induced changes; the North-Central by changes due to de-vegetation and overgrazing and the South-East by erosion, flooding and land degradation (Ozor, 2009).

Despite the significant threats posed by climate change and GHG emissions on cereal crop production, there is a paucity of comprehensive research that directly examines the relationship between GHG emissions and cereal crop productivity in Nigeria. Existing studies have focused primarily on the general impact of climate change on agriculture but fail to explicitly address the role of GHG emissions—particularly CO_2, CH_4, and N_2O—in driving these changes. Many studies, such as Mathauda *et al*. (2000), have examined temperature variations but do not explicitly link them to specific GHG emissions, leaving a gap in understanding how these gases impact crop yield.

Furthermore, most existing research focuses on specific regions or single cereal crops like rice or maize, without offering a broader analysis of multiple cereal crops (e.g., rice, maize, sorghum, and millet) across Nigeria's diverse climatic conditions. Additionally, while studies such as Edoja *et al*. (2016), Aye and Edoja (2017), Opeyemi *et al*. (2022), and Amaefule *et al*. (2023) have examined CO_2 emissions, they largely neglect the influence of other potent GHGs such as methane (CH_4) and nitrous oxide (N_2O). This narrow focus limits a comprehensive assessment of the full environmental impact of agricultural practices on cereal crop production.

Addressing these research gaps is essential for developing effective adaptation and mitigation strategies to enhance the resilience of Nigeria's agricultural sector. Therefore, objective of this is to investigate the short and long run effects of GHG emissions on cereal crop production in Nigeria. Consequently, the following null hypothesis were tested: there is no long run relationship been greenhouse gas emissions and cereal crop production in Nigeria; there is no significant short run effects of GHGs emissions on cereal crop production in Nigeria and there is no significant long run effects of GHGs emissions on cereal crop production in Nigeria. Findings from this research will contribute valuable insights to policy formulation, helping to create sustainable agricultural practices that can mitigate the adverse effects of climate change on food security.

The paper is structured as follows: Introduction is presented in section 1 while literature review is presented in section 2. Section 2 is Methodology while section 4 is results. Section 5 concludes.

2. LITERATURE REVIEW

Several studies have been conducted on climate change in general and greenhouse gas (GHG) emissions in particular, examining their impacts on various sectors, including agriculture. This review focuses on the relationship between GHG emissions and cereal crop production. For instance, Chandio *et al*. (2021) conducted a study to investigate the long-run and short-run impacts of climate change on wheat and rice production in Turkey from 1980 to 2016. They utilized the ARDL model and Johansen and Juselius cointegration test to analyze the data. Their research revealed that CO_2 emissions and temperature had a negative impact on wheat production in both the short and long term, whereas precipitation had a positive effect. Non-climatic factors, such as the harvested area and domestic credit, also played a role, with the harvested area positively influencing wheat production and domestic credit having a significant but mixed effect. For rice production, CO_2 emissions negatively impacted output, while temperature and precipitation had a positive effect. Similar to wheat, the harvested area contributed positively to rice production, but the effect of domestic credit was mixed. The VECM Granger Causality test showed that both climatic and non-climatic factors significantly affect crop production. The study concluded that climate change adversely impacts both wheat and rice production and recommended developing temperature-resistant crop varieties and enhancing climate change information dissemination to farmers. This research differs from the topic "Effects of greenhouse gas emission on cereal crop production" primarily in its scope and methodology. Chandio *et al*., (2021) focus on a specific geographic region (Turkey) and used a combination of long-term and short-term analysis methods to understand the impacts of various climatic and non-climatic factors on specific crops (wheat and rice). In contrast, the broader research topic might encompass a more generalized view of the effects of GHG emissions on a range of cereal crops across different regions, potentially using different methods and focusing on a wider array of environmental and agricultural variables. The study's geographic specificity and the detailed analysis of non-climatic factors in addition to climatic ones highlight a focused examination of how climate and other factors interplay in crop production, which may not be as explicitly covered in broader or more generalized research on the topic.

Opeyemi *et al.*, (2022) investigated the relationship between carbon dioxide (CO_2) emissions and cereal yield in Nigeria, spanning from 1961 to 2018. The primary objective was to assess how CO_2 emissions affect cereal production and to contribute to the broader understanding of climate change impacts on agriculture. Utilizing secondary data from FAOSTAT, the researchers analyzed annual data on carbon emissions, cereal yield, and Gross Domestic Product (GDP) growth. To determine the stationarity of the variables, they employed Augmented Dickey-Fuller (ADF) tests. For examining both short-run and long-run effects, the Autoregressive Distributed Lag (ARDL) method was applied. Their findings revealed a statistically significant negative relationship between CO_2 emissions and cereal yield in the short run, with a coefficient of -0.216025, indicating that increased CO_2 emissions adversely impact cereal crop production in Nigeria. This research differs from the broader topic of "Effects of greenhouse gas emissions on cereal crop production" in several ways. While Opeyemi *et al*., specifically focused on carbon dioxide emissions alone and its impact on cereal yields, the broader research topic encompasses the effects of multiple greenhouse gases (GHGs) including methane (CH_4) and nitrous oxide (N_2O), which also contribute to climate change and affect agricultural productivity. Additionally, the study by Opeyemi *et al*., concentrated on historical data and the specific case of Nigeria, whereas the broader topic involved a wider range of the six agroecological locations in Nigeria, time periods, and GHGs, as well as considering various aspects of cereal crop production such as quality and overall agricultural productivity.

Mulusew and Hong investigated the dynamic linkage between greenhouse gas emissions and agricultural productivity in Ethiopia from 2019 to 2022 using the Vector Auto Regressive (VAR) Model. The key objective of their research was to understand how greenhouse gas emissions impact agricultural productivity over both the short and long term. They utilized the VAR Model to analyze the relationship and incorporated error correction estimates to assess how quickly productivity adjusts to equilibrium levels. Their findings revealed that the coefficient of the "speed of adjustment" term for the expected productivity equation was statistically significant and negative, with a coefficient value of −0.744. This result indicates that agricultural productivity adjusts by 74.4% each year towards its long-run equilibrium level, highlighting a significant short-term response to disruptions caused by greenhouse gas emissions. Consequently, the study suggests that mitigating measures are necessary to address these short-term productivity disruptions. This research differs from the topic "Effects of greenhouse gas emission on cereal crop production" in that it focuses specifically on agricultural productivity in Ethiopia as a whole, rather than on cereal crops specifically. Mulusew and Hong's study provides a broader view of agricultural productivity rather than narrowing in on the effects on specific crops like rice, maize, or sorghum.

Çakan and Tipi (2024) conducted a study to assess the impact of climate change on major food crops in Turkey over the period from 1980 to 2019. Their key objective was to explore how variables such as precipitation, temperature, cultivation area, fertilizer use, and gas-diesel consumption influenced crop production. To achieve this, they used time series data and employed analytical methods including the Toda–Yamamoto causality test and the ARDL (Autoregressive Distributed Lag) cointegration approach to investigate the relationships between these factors and crop production. The study found a cointegration relationship between crop production and the studied factors, with long-run estimations indicating that increases in precipitation, cropland, fertilizer use, and gas-diesel consumption led to higher crop production. Conversely, higher temperatures were found to reduce crop production. The authors highlighted the necessity for government intervention to address climate change, recommending adaptation strategies such as the use of drought-resistant crop varieties and the implementation of efficient irrigation systems. This research differs from the topic of "Effects of greenhouse gas emission on cereal crop production" in several ways. While Çakan and Tipi (2024) focused on a broader set of climate-related factors and their overall impact on crop production, including temperature and precipitation, they did not specifically isolate greenhouse gas emissions as primary variables of interest. Their study variables emphasized the influence of various environmental and agricultural factors on crop yields and includes policy recommendations based on these broader climate change effects. In contrast, research on greenhouse gas emissions specifically targets the direct impact of gases like CO_2, CH_4, and N_2O on cereal crop production, exploring how these emissions alone contribute to changes in crop yields and quality, potentially requiring more targeted mitigation and adaptation strategies.

Mulusew and Hong (2024) conducted a study to investigate the long-term effects of greenhouse gas emissions on agricultural productivity in Ethiopia, utilizing the Vector Auto

Regressive (VAR) Model to analyze their data. Their key objective was to understand how different factors, including greenhouse gas emissions and agricultural practices, impact overall agricultural yields. The study found that a 1% increase in fertilizer consumption, agricultural land, nitrous oxide (N_2O) emissions, rural population, and the area devoted to grain production resulted in long-run increases in agricultural yield of 0.28%, 2.09%, 15.92%, 5.33%, and 1.31%, respectively. On the other hand, rises in agricultural employment, methane (CH_4), and carbon dioxide (CO_2) emissions led to significant reductions in agricultural productivity by 5.82%, 17.11%, and 2.75%, respectively. These findings underscore the necessity for Ethiopia to shift from high-emission agricultural practices to improve long-term productivity and sustainability. In contrast, the research topic "Effects of greenhouse gas emission on cereal crop production" focuses specifically on how greenhouse gas emissions affect the production of cereal crops, rather than general agricultural productivity. While Mulusew and Hong's study provides a broader analysis of agricultural productivity and its relationship with various factors, including GHG emissions, the specific research on cereal crop production would delve deeper into how GHGs impact yields, quality, and overall performance of cereal crops like rice, maize, sorghum, and millet. This narrower focus aims to offer more targeted insights and recommendations for cereal crop management in the context of climate change and GHG emissions in Nigeria.

Gul *et al*., (2022) conducted a study to investigate the impact of climate change on major crop yields in Pakistan over the period from 1985 to 2016. The research aimed to understand how both climatic factors—such as temperature and rainfall—and non-climatic factors—including crop area, fertilizer use, and credit—affect crop yields. To achieve this, they employed unit root tests and an Autoregressive Distributed Lag (ARDL) model to analyze long-run relationships among these variables. The study found that temperature had a varied impact on crop yields, while factors such as crop area, rainfall, fertilizer use, and credit had a positive effect on yields. The Granger causality tests demonstrated significant and bidirectional causal relationships between temperature, fertilizer use, and credit. The researchers recommended implementing climate-adaptive policies for farmers and conducting further research on heat-tolerant crop varieties to promote sustainable agriculture. This research differs from the topic "Effects of greenhouse gas emission on cereal crop production" in several ways. While Gul *et al.*, focused on the impact of climate change on crop yields in general, particularly considering temperature and rainfall, the research topic on greenhouse gas emissions specifically examines how GHGs influence cereal crop production. The study by Gul *et al*., also included non-climatic factors such as fertilizer use and credit, which were not the central focus of the greenhouse gas emissions research.

Zhai *et al.*, (2017) evaluated the impacts of climate change and technical progress on wheat yield in Henan, China, spanning from 1970 to 2014. Utilizing an autoregressive distributed lag approach, their research aimed to understand the relationship between climate variables, technical advancements, and wheat yield. The study found a significant long-run relationship among these factors. Specifically, the use of agricultural machinery and fertilizer positively impacted wheat yield, with a 1% increase in fertilizer and machinery usage leading to yield increases of 0.19% and 0.21%, respectively. Conversely, precipitation during the wheat growth period negatively affected yield, while land size had a positive short-term effect. Temperature changes had no notable impact on yield. The study concluded that technical progress is vital for improving wheat yield and recommended that policies should address both

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climate change and technical advancements to mitigate climate-related impacts on agriculture. This research differs from the topic "Effects of greenhouse gas emission on cereal crop production" in several keyways. While Zhai *et al*., focused on the impact of climate change and technical progress on wheat yield, the research topic on greenhouse gas emissions specifically addresses how emissions directly influence cereal crop production. The study by *Zhai et al.*, examines broader climate factors, including precipitation and temperature, and their interactions with technological advancements, rather than focusing exclusively on the role of greenhouse gases. Additionally, the methodology and findings of Zhai *et al*., emphasize the importance of technical progress in mitigating yield impacts, whereas the greenhouse gas emissions research would concentrate more directly on how changes in gas concentrations affect crop growth and productivity.

Attiaoui and Boufateh (2019) conducted a study to examine the effects of climate change on cereal farming in Tunisia, utilizing a panel ARDL-PMG approach to analyze data spanning from 1975 to 2014. Their research aimed to understand how climate change impacts cereal production and involved investigating the relationship between climate variables and cereal outputs. The study found that while current temperatures still support crop growth, the primary negative effect on cereal output was due to rainfall shortages. Interestingly, a long-run relationship between cereal production and labour was observed, which an unexpected finding was. The authors highlighted the importance of continuous technological advancements and favourable climate conditions for maintaining cereal farming productivity. They recommended strategies including yield improvement, income stabilization for farmers, development of a regional specialization map, and anti-drought insurance to adapt to climate change and sustain agricultural practices in Tunisia. This research differs from the topic of "Effects of greenhouse gas emissions on cereal crop production in Nigeria" in several ways. Firstly, while Attiaoui and Boufateh focus on the impacts of general climate change, including temperature and rainfall changes, on cereal farming in Tunisia, the research topic specifically addresses the role of greenhouse gas emissions as a driver of climate change. The study does not isolate the effects of GHG emissions but instead looks at broader climate factors and their impacts on cereal production. Additionally, the emphasis on labour's long-run relationship with cereal production and the strategies recommended for adaptation are specific to the context of Tunisia and may not directly apply to the impacts of GHG emissions on cereal crop production in different regions, such as Nigeria.

3. METHODOLOGY

3.1 Data

This study employed a time series analysis design to comprehensively explore the impact of greenhouse gas (GHG) emissions on cereal crop production in Nigeria. Data for this study were obtained from secondary sources like FAOSTAT and World Development Indicators. The study covered a thirty three-year period from 1990 to 2023. Statistical properties such as the mean and standard deviation were calculated to summarize the central tendency and dispersion of the data. Additionally, Augmented Dickey-Fuller (ADF) test was conducted to determine the stationarity of the time series data, which was crucial for further time series analysis. The Autoregressive Distributed Lag (ARDL) model was used to assess both short-run and long-run effects of greenhouse gas emissions on cereal crop production. The ARDL model was

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particularly suitable for this analysis as it could handle different orders of integration of variables, making it robust in examining the dynamics between the variables over time.

The variables were measured as follows:

1. Maize production was measured as the total maize output in metric tonnes annually.
2. Rice production was measured as the total rice output in metric tonnes annually.
3. Wheat production was measured as the total wheat output in metric tonnes annually.
4. Total cereal production (TCP) was measured as the total cereal crops output in metric tonnes annually.
5. Total greenhouse gas (TGH) emission was measured as the total greenhouse gases emitted in kilotonnes annually.
6. Carbon dioxide emission (CO_2) was measured as the amount of carbon dioxide emitted in kilotonnes annually.
7. Nitrous oxide emission (N_2O) was measured as the amount of nitrous oxide (percentage of CO_2) emitted in kilotonnes annually.
8. Methane (CH_4) was measured as the amount of methane (percentage of CO_2) emitted in kilotonnes annually.

3.2 Empirical Models

Augmented Dickey-Fuller (ADF) Test

The ADF test was used to determine whether the time series data for the variables are stationary, which is essential for avoiding spurious regression results. Stationarity means that the statistical properties of a series, such as the mean and variance, remain constant over time. The ADF test checks for a unit root in the data, with the null hypothesis indicating the presence of a unit root (i.e., the series is non-stationary) and the alternative hypothesis indicating stationarity.

The ADF test model can be specified as:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_t + \epsilon_t \tag{1}$$

Where ΔY_t is the first difference of the variable Y_t, α is a constant, β is the coefficient on the time trend, γ is the coefficient of the lagged level Y_{t-1}. δ_i represents the coefficients of the lagged differences, p is the number of lags included, ϵ_t is the error term. (Dickey and Fuller, 1979: Enders 2014).

Autoregressive Distributed Lag (ARDL) Model

The ARDL model was employed to assess both short-run and long-run relationships between greenhouse gas emissions and cereal crop production. Unlike traditional cointegration models, the ARDL approach is flexible as it can be used regardless of whether the underlying variables are I(0), I(1), or a combination of both. This makes it particularly suitable for the study's mixed-order integration data.

The ARDL model can be specified as follows:

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-1} + \sum_{i=1}^{q} \beta_j \Delta X_{t-j} + \lambda_1 Y_{t-1} + \lambda_2 Y_{t-1} + \epsilon_t$$
(2)

Where ΔY_t is the dependent variable (e.g., cereal crop production) in first differences

ΔX_{t-j} represents the independent variables (CO_2, CH_4, N_2O emissions) in first differences,

α_0 is a constant term,

α_i and β_j are short-run dynamic coefficients,

λ_1 and λ_2 are long-run coefficients,

p and q represent the lag orders

ϵ_t is the error term. (Nkoro and Uko 2016).

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 1 provides descriptive statistics for greenhouse gas (GHG) emissions, including methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), and total greenhouse gas emissions (TGH), alongside cereal crop production (TCP) in Nigeria over 34 observations. The mean total cereal production (TCP) stands at approximately 24.4 million metric tons, with maize contributing the highest average production at 7.88 million metric tons, followed by rice at 5.05 million metric tons and wheat at 72,748.55 metric tons. The median values for all crops are slightly lower than their means, indicating the presence of some higher values that skew the distribution. On the emissions side, CH_4 has a mean of 144,397.6 metric tons, CO_2 averages 97,300.7 metric tons, and N_2O emissions stand at 30,717.55 metric tons, while total greenhouse gas emissions (TGH) average 278,819.2 metric tons.

Examining dispersion and volatility, total cereal production fluctuates significantly, ranging from a minimum of 17.68 million to a maximum of 30.65 million metric tons, suggesting notable variations over time. Maize production, in particular, exhibits high volatility, ranging between 4.11 million and 12.99 million metric tons, with a standard deviation of 2.75 million metric tons. Similarly, rice production also shows substantial variability, with a standard deviation of 2.65 million metric tons. On the emissions front, CH_4 and CO_2 display standard

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deviations of 8,703.5 and 12,495.1 metric tons, respectively, indicating notable fluctuations in annual emissions.

Analyzing the distribution shape, CH_4 and CO_2 emissions exhibit slight negative skewness, meaning that a few lower-than-average values dominate their distribution. Conversely, total cereal production, maize, N_2O, rice, TGH, and wheat are positively skewed, suggesting that some years experienced significantly higher production than the average. Wheat production, with a skewness of 1.07, and rice, with a skewness of 1.02, show the most asymmetric distributions. In terms of kurtosis, most variables hover around a value of 3, indicating approximately normal distributions. However, wheat, with a kurtosis of 4.65, is leptokurtic, suggesting the presence of extreme values that deviate significantly from the mean.

The Jarque-Bera test, which assesses normality, shows that TCP, CH_4, CO_2, maize, N_2O, and TGH are normally distributed at a 5% significance level, given their probability values above 0.05. However, rice and wheat deviate significantly from normality, with probability values of 0.048 and 0.006, respectively, indicating the influence of extreme values such as droughts or bumper harvests on their production trends.

The findings suggest that cereal crop production in Nigeria, particularly for maize and rice, is highly volatile, possibly due to climate variability, changes in agricultural policies, or external factors such as GHG emissions and rainfall patterns. The positive skewness in crop production data implies that in certain years, favorable weather conditions, improved agricultural techniques, or policy interventions have led to unusually high yields. Conversely, the negative skewness in CH_4 and CO_2 emissions suggests periods of lower emissions, possibly due to shifts in agricultural practices or reduced industrial activity. The non-normality observed in rice and wheat production suggests that extreme climatic events have had significant effects on these crops over time.

Overall, the analysis highlights the fluctuations in cereal crop production and GHG emissions in Nigeria, indicating that climate change and other environmental factors may be impacting agricultural productivity. The variability in production, especially for staple crops like maize and rice, underscores the need for adaptive strategies in the agricultural sector. Further research is required to establish the effects of specific GHGs and crop yields to develop climate-resilient agricultural policies that ensure food security and economic stability.

Table 1. Summary Statistics of the Variables

	TCP	CH_4	CO_2	Maize	N_2O	RICE	TGH	WHEAT
Mean	24396110	144397.6	97300.70	7878782.	30717.55	5049203.	278819.2	72748.55
Median	22624300	145013.8	97931.00	7015500.	30026.51	3556625.	270547.8	66000.00
Max	30645842	157860.8	119544.1	12988270	41216.29	10889549	332247.0	165000.0
Min	17678000	124198.2	72768.80	4107000.	20146.93	2427000.	233668.6	32600.00
Std. Dev.	4226316.	8703.512	12495.11	2754080.	7010.539	2653277.	27877.60	27768.91
Skewness	0.268390	-0.436225	-0.063505	0.622961	0.159451	1.018059	0.446920	1.066479
Kurtosis	1.587712	2.307808	1.979655	2.069362	1.748223	2.613811	1.939103	4.645482
Jarque-Bera	3.233808	1.757090	1.497750	3.426080	2.363914	6.084469	2.726309	10.28093
Prob.	0.198512	0.415387	0.472898	0.180317	0.306678	0.047728	0.255852	0.005855
Sum	8.29E+08	4909519.	3308224.	2.68E+08	1044397.	1.72E+08	9479852.	2473451.
Sum Sq. Dev.	5.89E+14	2.50E+09	5.15E+09	2.50E+14	1.62E+09	2.32E+14	2.56E+10	2.54E+10
Obs.	34	34	34	34	34	34	34	34

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.2 Unit Root Test

Preliminary investigations to ensure stability of time series data on greenhouse gas emissions and selected cereal crops production was carried out using Augmented Dickey Fuller (ADF) test to determine the presence of unit root, that is to ascertain if the variables are

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stationary (Table 2). ADF was preferred to test for unit root because it is the simplest approach and it is very suitable when dealing with a large and complex set of time series data. The result showed that all the variables are not stationary at level. This indicated that they have a random walk (unit root) meaning that their future values do not converge from their past values. A further test at first difference of the entire variables rejected the null hypothesis at 5% as the values of ADF t-statistic are greater in absolute term than the critical values. It is therefore concluded that the series are integrated of order I(1) meaning that the variables are stationary at first difference.

Table 2: Result of unit root test

	Level		First Difference		
Variable	**ADF**	**Prob.**	**ADF**	**Prob.**	**Inference**
CO_2	-2.202939	0.2091	-5.991055***	0.0000	I(1)
CH_4	-1.563096	0.4897	-4.688245***	0.0007	I(1)
N_2O	-0.336575	0.9086	-6.058791***	0.0000	I(1)
Maize	0.848886	0.9934	-7.794528***	0.0000	I(1)
Rice	-0.416803	0.8939	-4.419519***	0.0015	I(1)
Wheat	-2.495216	0.1257	-5.355828***	0.0001	I(1)
TGH	-1.237531	0.6461	-5.789470***	0.0000	I(1)
TCP	-1.814744	0.3667	-8.58577***	0.0001	I(1)

******* Significant at 1%

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.3 Bounds test for long run relationship between greenhouse gas emissions and cereal crop production

In the first step of the ARDL analysis, the presence of long-run relationships was tested. Bounds test was used to determine whether a linear combination of non-stationary variables is stationary. According to Kwiatkowski *et al.* (1992), regressing a non-stationary series on another non-stationary series yields spurious regression, but if a linear combination of the series is stationary, the variables are said to be cointegrated and the regression is no longer spurious. The result of the bounds test for maize production (Table 4) shows that the computed F-statistics 6.387112 is greater than the upper bound critical value, 4.01 at the 0.05 probability level. Therefore, cointegration exists among the variables. This implies that a long run relationship exists between maize production, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions.

Similarly, the result of the bounds test for rice production (Table 4) shows that the computed F-statistics 4.230147 is greater than the upper bound critical value, 4.01 at the 0.05 probability level. Therefore, cointegration exists among the variables. This implies that a long run relationship exists among rice production, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions.

The result of the Bounds test for wheat production (Table 4) shows that the computed F-statistics 5.588737 is greater than the upper bound critical value, 4.01 at the 0.05 probability level. Therefore, cointegration exists among the variables. This implies that a long run relationship exists among wheat production, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions.

Therefore, the null hypothesis one ($H0_1$) which stipulated that there is no long run relationship between greenhouse gas emissions and cereal crop production in Nigeria is hereby rejected, which implies that there exists a long run relationship between greenhouse gas emissions and cereal crop production in Nigeria. This is in line with the work of Çakan and Tipi (2024) found a cointegration relationship between crop production and the studied factors.

Table 4: Bounds test for co-integration between greenhouse gas emissions and cereal crop production

Crops	**Test statistics**	**Value**	**Significance (%)**	**1(0)**	**1(1)**
Maize	**F**	6.387112	10	2.45	3.52
	K	4	5	2.86	4.01
			2.5	3.25	4.49
			1	3.74	5.06
Rice	**F**	4.230147	10	2.45	3.52
	K	4	5	2.86	4.01
			2.5	3.25	4.49
			1	3.74	5.06

Wheat	**F**	5.588737	10	2.45	3.52
	K	4	5	2.86	4.01
			2.5	3.25	4.49
			1	3.74	5.06

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.4 Short Run Effects of Greenhouse gas emissions on Cereal Crop Production in Nigeria

4.4.1 Short Run Effects of Greenhouse gas emissions on Maize Production

The results of the ARDL as shown in Table 5 indicated that in the short run, the conditional error correction term or speed of adjustment, ECM (-1) is negative (-0.670918) and statistically significant. The result implies that 67% of the deviation from the long run equilibrium position is corrected within the year. This indicates a quick speed of adjustment (that is, the speed at which the deviation from long run equilibrium is adjusted quickly where -0.670918 of the disequilibrium is removed immediately in each period).

The result of the ARDL as shown in Table 5 indicated that in a short run, the coefficients of carbon emissions (-6.6059) was negative and statistically significant at the 10% probability level during the fourth lagged period. This implies that a unit increase in carbon emissions will decrease maize production by 6.605931 units *ceteris paribus*. This could be due to the immediate impacts of climate change induced by carbon emissions. Increased CO_2 leads to global warming, which can cause heat stress during the maize growing season, adversely affecting photosynthesis and grain formation. Over time, higher CO_2 emissions contribute to environmental changes that may reduce soil fertility, making it harder for crops to thrive. This finding is consistent with Opeyemi *et al.* (2022) who reported that there is a direct relationship between Carbon dioxide emission and cereal yields.

Furthermore, the coefficients of methane emissions (-13.2025) was negative and statistically significant at the 5% probability level during the fourth lagged period. This implies that a unit increase in methane emissions will decrease maize production by 13.20250 units *ceteris paribus*. Methane (CH_4) is a potent greenhouse gas, and its effects on climate change are more intense per unit than carbon dioxide, though it exists in lower concentrations. The significant reduction in maize production following an increase in methane emissions may stem from methane's role in accelerating global warming, which affects maize in several ways.

More also, the coefficients of nitrous oxide emissions (-3.736886) were negative and statistically significant at the 5% probability level during the fourth lagged period. This implies that a unit increase in nitrous oxide emissions will decrease maize production by 3.736886 units *ceteris paribus*. Nitrous oxide is a potent greenhouse gas, with a significant warming potential, often emitted from agricultural soils following the use of nitrogen-based fertilizers. This means that the use of synthetic fertilizers commonly associated with maize farming can lead to higher N_2O emissions.

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Table 5: Short run effects of greenhouse gas emissions on maize production

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNMAIZE(-1)	-0.407324	0.249084	-1.635285	0.1460
LNMAIZE(-2)	-0.263594	0.316588	-0.832607	0.4326
LNCO2	-2.395600	1.779979	-1.345858	0.2203
LNCO2(-1)	0.281943	2.135645	0.132018	0.8987
LNCO2(-2)	-0.546732	2.094397	-0.261045	0.8016
LNCO2(-3)	-1.650081	3.529255	-0.467544	0.6543
LNCO2(-4)	-6.605931	3.236230	-2.04124*	0.0806
LNCH4	-0.940885	3.118165	-0.301743	0.7716
LNCH4(-1)	3.905551	4.193483	0.931338	0.3827
LNCH4(-2)	-0.147227	3.553877	-0.041427	0.9681
LNCH4(-3)	-4.877682	5.685578	-0.857904	0.4193
LNCH4(-4)	-13.20250	5.217289	-2.530529**	0.0392
LNN20	-2.911291	1.472467	-1.977153*	0.0886
LNN20(-1)	3.037086	2.201117	1.379793	0.2101
LNN20(-2)	-0.805058	1.763243	-0.456578	0.6618
LNN20(-3)	0.912596	1.795296	0.508326	0.6268
LNN20(-4)	-3.736886	1.431363	-2.610718**	0.0349
LNTGH	6.700321	5.617020	1.192861	0.2718
LNTGH(-1)	-3.686125	7.034029	-0.524042	0.6164
LNTGH(-2)	2.453093	6.334968	0.387231	0.7101
LNTGH(-3)	6.418572	10.51651	0.610333	0.5609
LNTGH(-4)	-21.39023	9.409793	-2.273188**	0.0572

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CointEq(-1)	-0.670918	0.448818	-3.72293***	0.0074

Diagnostics Statistics			
R-squared	0.992084	Mean dependent var	15.85330
Adjusted R-squared	0.967204	S.D. dependent var	0.350338
S.E. of regression	0.063445	Akaike info criterion	-2.599255
Sum squared resid	0.028176	Schwarz criterion	-1.525003
Log likelihood	61.98882	Hannan-Quinn criter.	-2.255592
F-statistic	39.87576	Durbin-Watson stat	2.549141
Prob(F-statistic)	0.000023		

* significant at 10%, ** significant at 5%, *** significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.4.2 Short Run Effects of Greenhouse gas emissions on Rice Production

Table 6 indicates that in the short run, the conditional error correction term or speed of adjustment, ECM (-1) is negative (-0.298941) and statistically significant. The result implies that 29.8% of the deviation from the long run equilibrium position is corrected within the year. This indicates a slow speed of adjustment (that is, the speed at which the deviation from long run equilibrium is adjusted quickly where -0.298941 of the disequilibrium is removed immediately in each period).

The result of the ARDL as shown in Table 6 indicated that in a short run, the coefficients of carbon emissions (-9.628644) was negative and statistically significant at the 1% probability level during the first lagged period. This implies that a unit increase in carbon emissions will decrease rice production by 9.628644 units *ceteris paribus*. This indicates that rice, as a crop, might be more vulnerable to the environmental changes caused by carbon emissions compared to maize. This is likely due to the high-water requirement of rice and its sensitivity to both temperature and water availability. Carbon emissions contribute to climate variability, including unpredictable or insufficient rainfall. Rice, particularly in rain-fed systems, is highly dependent on stable water supply, and disruptions in rainfall can severely impact production.

Furthermore, the coefficients of methane emissions (-15.07452) were negative and statistically significant at the 5% probability level during the first lagged period. This implies that a unit increase in methane emissions will decrease rice production by 15.07452 units *ceteris paribus*. This suggesting that methane has a more severe short-term impact on rice production than carbon. This could be due to methane's higher heat-trapping potential, which accelerates climate changes that directly affect rice-growing conditions.

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More also, the coefficients of nitrous oxide emissions (-4.892906) were negative and statistically significant at the 10% probability level during the second lagged period. This implies that a unit increase in nitrous oxide emissions will decrease rice production by 4.892906 units *ceteris paribus*. The magnitude of the effect of nitrous oxide emissions (-4.892906) is smaller compared to the effects of carbon (-9.628644) and methane (-15.07452) on rice production. This suggests that while N_2O emissions negatively affect rice yields, the overall short-term impact is less severe than that of the other greenhouse gases. Nitrous oxide emissions from agricultural activities are closely tied to the use of synthetic fertilizers, which are often applied in excess to boost yields. However, over time, this practice can lead to soil nutrient depletion and nitrogen loss, which not only reduces the efficiency of fertilizer use but also harms crop production.

Table 6: Short Run Effects of Greenhouse gas emissions on Rice Production

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNRICE(-1)	-0.163992	0.313377	-0.523308	0.6169
LNRICE(-2)	0.092350	0.232158	0.397790	0.7026
LNRICE(-3)	-0.913319	0.233662	-3.908714***	0.0058
LNRICE(-4)	-0.313980	0.335869	-0.934829	0.3810
LNCO2	-4.349017	3.123019	-1.392568	0.2064
LNCO2(-1)	-9.628644	3.163604	-3.043568***	0.0188
LNCO2(-2)	-7.503844	4.441940	-1.689317	0.1350
LNCO2(-3)	-1.375700	3.206810	-0.428993	0.6808
LNCO2(-4)	6.791641	3.635747	1.868018	0.1040
LNCH4	-6.057558	5.135967	-1.179439	0.2768
LNCH4(-1)	-15.07452	5.499675	-2.740984**	0.0289
LNCH4(-2)	-10.26933	7.484472	-1.372085	0.2124
LNCH4(-3)	-3.692885	5.213759	-0.708296	0.5017
LNCH4(-4)	10.26774	5.811222	1.766881	0.1206
LNN20	1.077751	1.563615	0.689269	0.5128
LNN20(-1)	-1.289234	2.469365	-0.522091	0.6177

LNN20(-2)	-4.892906	2.369012	-2.065378*	0.0777
LNTGH	11.25550	9.119487	1.234225	0.2569
LNTGH(-1)	-27.34477	9.541525	-2.865870**	0.0241
LNTGH(-2)	21.44686	13.39806	1.600744	0.1535
LNTGH(-3)	5.413639	8.838741	0.612490	0.5596
LNTGH(-4)	-17.30250	9.970870	-1.735305	0.1263
CointEq(-1)	-0.298941	0.535513	-4.292971***	0.0036
Diagnostics Statistics				
R-squared	0.991598	Mean dependent var		15.37271
Adjusted R-squared	0.965191	S.D. dependent var		0.475142
S.E. of regression	0.088648	Akaike info criterion		-1.930245
Sum squared resid	0.055009	Schwarz criterion		-0.855993
Log likelihood	51.95367	Hannan-Quinn criter.		-1.586582
F-statistic	37.55108	Durbin-Watson stat		3.087020
Prob(F-statistic)	0.000028			

* significant at 10%, ** significant at 5%, *** significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.4.3 Short Run Effects of Greenhouse gas emissions on Wheat Production

Table 7 indicates that in the short run, the conditional error correction term or speed of adjustment, ECM (-1) is negative (-0.571226) and statistically significant. The result implies that 57.1% of the deviation from the long run equilibrium position is corrected within the year. This indicate a slow speed of adjustment (that is, the speed at which the deviation from long run equilibrium is adjusted quickly where -0.571226 of the disequilibrium is removed immediately in each period).

The result of the ARDL as shown in Table 7 indicated that in a short run, the coefficient of carbon emissions (-12.31831) was negative and statistically significant at the 1% probability level during the base period. This implies that a unit increase in carbon emission will decrease wheat production by 12.31831 units *ceteris paribus*. This signifies that carbon emissions have a significant and negative effect on wheat production, more substantial than the effects observed for other crops like maize and rice in the earlier findings. This indicates that wheat may be particularly vulnerable to the impacts of rising carbon emissions.

Furthermore, the coefficients of methane emissions (-17.42791) was negative and statistically significant at the 1% probability level during the base period. This implies that a unit increase in methane emission will decrease wheat production by 17.42791 units *ceteris paribus*. The substantial negative coefficient suggests that methane emissions have a severe short-term impact on wheat production. Methane is a potent greenhouse gas that contributes to global warming. Elevated temperatures can significantly affect wheat growth, especially during critical phases such as flowering and grain filling, leading to reduced yields. This suggests that wheat may be particularly sensitive to methane-induced climate changes.

More also, the coefficients of nitrous oxide emissions (-8.164997) were negative and statistically significant at the 1% probability level during the base year. This implies that a unit increase in nitrous oxide emissions will decrease wheat production by 8.164997 units *ceteris paribus*. This indicates that nitrous oxide emissions have a **substantial negative effect** on wheat production, although less severe than the impacts of methane (-17.42791) and carbon emissions (-12.31831). This suggests that while N_2O emissions are significant, they may not be as immediately damaging to wheat production as the other greenhouse gases.

Table 7: Short Run Effects of Greenhouse gas emissions on Wheat Production

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LNWHEAT(-1)	0.027278	0.193136	0.141236	0.8912
LNWHEAT(-2)	-0.598504	0.182336	-3.282425***	0.0111
LNCO2	-12.31831	2.848882	-4.323909***	0.0025
LNCO2(-1)	-1.487874	4.775263	-0.311580	0.7633
LNCO2(-2)	3.865386	4.367353	0.885064	0.4019
LNCO2(-3)	-17.24946	5.554661	-3.105403***	0.0145
LNCO2(-4)	-4.620712	1.221881	-3.781639***	0.0054
LNCH4	-17.42791	5.313313	-3.280046***	0.0112
LNCH4(-1)	-3.655036	8.521714	-0.428909	0.6793
LNCH4(-2)	9.752573	7.541110	1.293254	0.2320
LNCH4(-3)	-28.82516	8.523687	-3.381771***	0.0096
LNN20	-8.164997	2.540339	-3.214137***	0.0123
LNN20(-1)	5.320623	4.533262	1.173685	0.2743

LNN20(-2)	1.617009	3.760674	0.429979	0.6786
LNN20(-3)	-7.414188	3.262176	-2.272773**	0.0527
LNN20(-4)	-4.722270	2.298503	-2.054498**	0.0740
LNTGH	-35.90444	8.915917	-4.027005***	0.0038
LNTGH(-1)	3.737836	15.18969	0.246077	0.8118
LNTGH(-2)	-17.51126	13.48525	-1.298549	0.2303
LNTGH(-3)	49.85958	16.04700	3.107097***	0.0145
LNTGH(-4)	6.982786	2.634356	2.650661**	0.0292
CointEq(-1)	-0.571226	0.253177	-6.206031***	0.0003
R-squared	0.969036	Mean dependent var		11.18505
Adjusted R-squared	0.887757	S.D. dependent var		0.345758
S.E. of regression	0.115838	Akaike info criterion		-1.328335
Sum squared resid	0.107348	Schwarz criterion		-0.300791
Log likelihood	41.92503	Hannan-Quinn criter.		-0.999615
F-statistic	11.92231	Durbin-Watson stat		2.153708
Prob(F-statistic)	0.000616			

* significant at 10%, ** significant at 5%, *** significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.5 Long Run Effects of Greenhouse gas emissions on Cereal Crop Production in Nigeria

4.5.1 Long Run Effects of Greenhouse gas emissions on Maize Production

In the long run (Table 8), the coefficient of carbon emissions (-6.988246) was negative and statistically significant at the 1% probability level. This implies that a unit increase in carbon emissions will decrease maize production by -6.988246 units in the long run *ceteris paribus*. More so, the coefficient of methane emissions (-10.799130) was negative and statistically significant at the 1% probability level. This implies that a unit increase in methane emissions will decrease maize production by -10.799130 units in the long run *ceteris paribus*. Similarly, the coefficient of nitrous oxide emissions (-2.220322) was negative and statistically significant at the 1% probability level. This implies that a unit increase in nitrous oxide emissions will decrease maize production by -2.220322 units in the long run *ceteris paribus*. Therefore, the null hypothesis three ($H0_3$), which stipulated that there is no significant long run effects of GHGs emissions on cereal crop production in Nigeria is hereby rejected.

The findings indicate that all three greenhouse gases—carbon dioxide, methane, and nitrous oxide—have significant long-term negative impacts on maize production in Nigeria. The negative coefficients highlight a consistent trend where increased emissions correlate with decreased yields, which can lead to broader implications for food security and agricultural sustainability in the region. Among the three GHGs, methane emissions have the most substantial negative effect on maize production, followed by carbon emissions and then nitrous oxide. This ordering suggests that efforts to mitigate methane emissions could have a particularly pronounced benefit for maize yields. While the impact of nitrous oxide is less severe in comparison, its consistent negative effect indicates that all emissions should be addressed in agricultural policies. This finding is consistent with Mulusew and Hong (2024) who reported that methane (CH_4), and carbon dioxide (CO_2) emissions led to significant reductions in agricultural productivity in Ethiopia by 17.11%, and 2.75%, respectively.

Table 8: Long run effects of greenhouse gas emissions on maize production

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO2	-6.988246	1.332313	-5.245197***	0.0012
LNCH4	-10.799130	2.449609	-4.408512***	0.0031
LNN20	-2.220322	0.672932	-3.299477***	0.0131
LNTGH	-20.948023	3.677819	-5.695773***	0.0007
C	-15.985308	5.445252	-2.935641**	0.0218

* Significant at 10%, ** Significant at 5%, *** Significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023

4.5.2 Long Run Effects of Greenhouse gas emissions on Rice Production

Results in Table 9 showed that in the long run, the coefficient of carbon emissions (-1.373772) was negative and statistically significant at the 5% probability level. This implies that a unit increase in carbon emissions will decrease rice production by -1.373772 units in the long run *ceteris paribus*. More so, the coefficient of methane emissions (-6.668345) was negative and statistically significant at the 10% probability level. This implies that a unit increase in methane emissions will decrease rice production by -6.668345 units in the long run *ceteris paribus*. Similarly, the coefficient of nitrous oxide emissions (-2.376071) was negative and statistically significant at the 5% probability level. This implies that a unit increase in nitrous oxide emission will decrease rice production by -2.376071 units in the long run *ceteris paribus*. Therefore, the null hypothesis three ($H0_3$), which stipulated that there is no significant long run effects of GHGs emissions on cereal crop production in Nigeria is hereby rejected. This is in line with findings by Amaefule *et al*. (2023) who reported a significant long-run relationship between carbon emissions and agricultural productivity, indicating that increases in CO_2 emissions and intensity harmed Nigeria's agricultural productivity,

The findings indicate that all three GHGs—carbon dioxide, methane, and nitrous oxide—have significant long-term negative impacts on rice production in Nigeria. This suggests that emissions from various sources are affecting crop yields over time. Among the three GHGs, methane emissions have the most considerable negative effect on rice production, followed by nitrous oxide and carbon emissions. This hierarchy highlights that efforts to mitigate methane emissions could be particularly beneficial for rice yields. While the impact of carbon emissions is less pronounced, it still indicates that all emissions should be carefully managed to optimize rice production.

Table 9: Long Run Effects of Greenhouse gas emissions on Rice Production

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO2	-1.373772	1.786117	-2.769139**	0.0470
LNCH4	-6.668345	3.059385	-2.179636*	0.0657
LNN20	-2.376071	0.798840	-2.974400**	0.0207
LNTGH	-5.688114	4.691082	-1.212538	0.2646
C	-32.295390	6.608357	-4.887053	0.0018

* significant at 10%, ** significant at 5%, *** significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023.

4.5.3 Long Run Effects of Greenhouse gas emissions on Wheat Production

Results in Table 10 showed that in the long run, the coefficient of carbon emissions (-4.566085) was negative and statistically significant at the 1% probability level. This implies that a unit increase in carbon emissions will decrease wheat production by -4.566085 units in the long run *ceteris paribus*. The substantial negative coefficient for carbon emissions suggests that even a moderate increase in carbon emissions can have a significant detrimental effect on wheat yields, which is a critical consideration for agricultural sustainability. Fagbemi *et al.* (2024) investigated the impact of carbon emissions on food production in Nigeria. They reported that that CO_2 emissions significantly affect food production, with increased emissions leading to acute food shortages.

The result further showed that methane emissions and nitrous oxide emissions do not have a significant effect on rice production. The results indicate that methane emissions do not have a significant effect on wheat production in the long run. This suggests that, while methane is a potent greenhouse gas, its direct impact on wheat yields may be mitigated by other factors or practices in agricultural systems. Similarly, nitrous oxide emissions also do not show a significant effect on wheat production in the long run. This indicates that their influence might be overshadowed by other variables or that their impacts are less direct compared to carbon emissions.

Table 10: Long Run Effects of Greenhouse gas emissions on Wheat Production

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO2	-4.566085	3.389203	-3.347245***	0.0078
LNCH4	-3.372977	5.821101	-0.579440	0.5782
LNN20	1.887806	1.512546	1.248099	0.2473
LNTGH	-4.559814	8.850247	-0.515219	0.6203
C	26.787143	12.855975	2.083634	0.0707

* Significant at 10%, ** Significant at 5%, *** Significant at 1% respectively

Source: Computed from FAOSTAT and World Development Indicators Data 1990-2023.

5. CONCLUSION AND POLICY IMPLICATIONS

This study examined the effects of greenhouse gas (GHG) emissions on cereal crop production in Nigeria using historical data from 1990 to 2023. The findings revealed that carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions significantly impact maize, rice, and wheat production, with methane emissions having the most pronounced negative effect. The study confirmed the existence of a long-run relationship between GHG emissions and cereal crop production, highlighting the vulnerability of Nigeria's agricultural sector to climate change. In the short run, increases in CO_2, CH_4, and N_2O emissions led to declines in maize, rice, and wheat production, while the long-run analysis indicated that continued emissions would further reduce yields, exacerbating food insecurity.

Given these findings, there is an urgent need for targeted policy interventions to mitigate the negative effects of GHG emissions on cereal production. The Nigerian government should promote climate-smart agricultural practices, such as conservation tillage, crop rotation, and agroforestry, to enhance soil fertility and reduce carbon footprints. Additionally, investments in climate-resilient crop varieties are essential to sustain productivity under changing climatic conditions. Policymakers should encourage the adoption of low-emission fertilizers and improved irrigation systems to reduce nitrous oxide emissions while maintaining soil health.

Furthermore, there is a need for stricter regulation of industrial emissions and gas flaring, particularly in the Niger Delta, where excessive flaring significantly contributes to GHG accumulation. The government should strengthen carbon pricing mechanisms and provide incentives for renewable energy adoption in the agricultural sector. Expanding access to climate finance and insurance schemes for farmers can help mitigate risks associated with climate change, ensuring greater food security and economic stability.

In conclusion, addressing the impact of GHG emissions on cereal crop production requires a multi-faceted approach involving policy reform, technological innovation, and sustainable farming practices. By implementing these strategies, Nigeria can enhance its agricultural resilience, reduce emissions, and secure food production for future generations.

REFERENCES

Ackerman, F., and Munitz, C. (2026). A critique of climate damage modelling: Carbon fertilization, adaptation, and the limits of FUND. *Energy Research and Social Science, 12*, 62–67. https://doi.org/10.1016/j.erss.2015.11.008

Akinro, A. O., Opeyemi, D. A., and Ologunagba, I. B. (2008). Climate change and environmental degradation in the Niger Delta region of Nigeria: Its vulnerability, impacts and possible mitigations. *Research Journal of Applied Sciences, 3*(3), 167–173.

Ali, S., Yan, Q., Razzaq, A., Khan, I., and Irfan, M. (2023). Modeling factors of biogas technology adoption: A roadmap towards environmental sustainability and green revolution. *Environmental Science and Pollution Research, 30*(5), 11838–11860. https://doi.org/10.1007/s11356-022-22894-0

Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *Environmental Sustainability, 2*(2), 95–96. https://doi.org/10.1007/s42398-019-00078-w

Asseng, S., Foster, I., and Turner, N. C. (2011). The impact of temperature variability on wheat yields. *Global Change Biology, 17*, 997–1012. https://doi.org/10.1111/j.1365-2486.2010.02262.x

Ayinde, O. E., Muchie, M., and Bessler, D. (2011). The impact of climate change on agricultural production in Nigeria: A stochastic production frontier analysis. *African Journal of Agricultural and Resource Economics, 6*(1), 1–17.

Aye, G. C., and Edoja, P. E. (2017). Effect of economic growth on CO_2 emission in developing countries: Evidence from a dynamic panel threshold model. *Cogent Economics and Finance, 5*(1), 1379239. https://doi.org/10.1080/23322039.2017.1379239

Ayinde, O. E., Muchie, M., and Olatunji, G. B. (2011). Effect of climate change on agricultural productivity in Nigeria: A cointegration modeling approach. *Journal of Human Ecology, 35*(3), 185–194. https://doi.org/10.1080/09709274.2011.11906406

Bennetzen, E. H., Smith, P., and Porter, J. R. (2016). Decoupling of greenhouse gas emissions from global agricultural production: 1970–2050. *Global Change Biology, 22*(2), 763–781. https://doi.org/10.1111/gcb.13120

Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R., and Riahi, K. (2008). *IPCC Climate Change 2007: Synthesis report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC).

Çakan, V. A., and Tipi, T. (2024). What are the implications of climatic and non-climatic factors on crop production? Evidence from Turkey. *International Journal of Environmental Research, 18*, 10. https://doi.org/10.1007/s41742-023-00560-8

Dickey, D. A., and Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*(366a), 427–431. https://doi.org/10.2307/2286348

Eboh, E. (2009). Implications of climate change for economic growth and sustainable development in Nigeria. *Enugu Forum Policy Paper 10*. African Institute for Applied Economics.

Edoja, P. E., Aye, G. C., and Abu, O. (2016). Dynamic relationship among CO_2 emission, agricultural productivity and food security in Nigeria. *Cogent Economics and Finance, 4*(1), 1–13. https://doi.org/10.1080/23322039.2016.1229345

Enders, W. (2014). *Applied econometric time series* (4th ed.). Wiley.

Fagbemi, F., Oke, D. F., and Akinyele, O. D. (2024). Carbon emissions and food production: Why climate change is a threat to Nigeria's food security. *Journal of Environmental Studies and Sciences*. https://doi.org/10.1007/s13412-024-00916-2

Food and Agricultural Organization Statistics (FAOSTAT). (1990–2023). *FAO database*. Rome, Italy: FAO.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., and Robinson, S. (2010). Food security: The challenge of feeding 9 billion people. *Science, 327*(5967), 812–818. https://doi.org/10.1126/science.1185383

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37*(3), 424–438.

Gul, A., Ali, S., and Khan, M. (2022). How climate change is impacting the major yield crops of Pakistan? An exploration from long- and short-run estimation. *Environmental Science and Pollution Research, 29*, 26660–26674. https://doi.org/10.1007/s11356-021-17579-z

Hawkesford, M. J., Araus, J. L., Park, R., Calderini, D., Miralles, D., Shen, T., Zhang, J., and Parry, M. A. (2013). Prospects of doubling global wheat yields. *Food and Energy Security, 2*(1), 34–48. https://doi.org/10.1002/fes3.15

Högy, P., and Fangmeier, A. (2008). Effects of elevated atmospheric CO_2 on grain quality of wheat. *Journal of Cereal Science, 48*(3), 580–591. https://doi.org/10.1016/j.jcs.2008.01.006

Howden, S. M., Soussana, J. F., Tubiello, F. N., Chhetri, N., Dunlop, M., and Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences, 104*(50), 19691–19696. https://doi.org/10.1073/pnas.0701890104

Watson, R. T., Zinyoera, M. C., and Moss, R. H. (1997). *The regional impacts of climate change: An assessment of vulnerability*. Cambridge, UK: Cambridge University Press.

You, L., Rosegrant, M. W., Wood, S., and Sun, D. (2009). Impact of growing season temperature on wheat productivity in China. *Agricultural and Forest Meteorology, 149*(6–7), 1009–1014. https://doi.org/10.1016/j.agrformet.2008.12.012