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# Greenhouse gas emission and rice production in Nigeria: An ARDL bounds testing approach

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## Abstract

Rice cultivation is attributed as a major agricultural greenhouse gas (GHG) emitter which contributes to rising global temperatures impacting agricultural productivity, environment and livelihood. However, studies on greenhouse gas emissions in rice production is still limited in many developing countries, including Nigeria. This paper examines the relationship between greenhouse gas emission and rice production in Nigeria using the Autoregressive Distributed Lag (ARDL) bounds test. Annual time series data of four selected variables rice output, rice yield, rice harvested area, fertilizer usage and greenhouse emission ($CH_4$) in rice production was used over the period 1961 to 2017. Empirical results provide evidence of long run relationship between greenhouse gas emission and rice production in Nigeria. The result of the estimated elasticities of both the short run and long run analysis indicates that all the variables except fertilizer usage in the long run, significantly explain changes in greenhouse gas emission in rice production. The findings recommend the need to adopt new approaches to rice cultivation that will boost productivity using less energy and land resources in order to decrease GHG emissions. The use of improved seed varieties that will increase yield using less land area, fertilizer application, water usage and chemical in production could also be a good strategy of reducing GHG emissions in rice cultivation, which has an impact on atmospheric pollutions and global warming.



## Introduction

Agriculture is the most important economic activities that provides food, income and employment to more than 70 percent of the Africa's population. Agricultural practices are also considered as one of the world's major producers of greenhouse gas (GHG) emissions (Maraseni and Qu, 2016; Odegard *et al.*, 2015; Smith *et al*, 2014, Vetter *et al.*, 2017). Between the years 1990 and 2010, the GHG emission from the agricultural sector increased by approximately 8% and was predicted to increase to 15% by 2030 (Azuh and Matthew, 2010). The three main greenhouse gas emissions from agriculture are namely, methane ($CH_4$) caused from the fertilizer usage in production, nitrous oxide ($N_2O$) caused by the large amount of energy (fossil fuel) use of production inputs or burning of remains from farm residues and carbon dioxide ($CO_2$). IPCC (2001) reported that with continued increase GHG emissions; the average global temperature is forecasted to increase by about 1.8 8C by the year 2025 and 3.8 8C by the end of the century. Investigating the GHG emissions in agriculture is therefore crucial given the rise in concentration of the GHG emissions in the atmosphere which contributed significantly to rising the Earth's average temperature leading to global warming.

A large body of literature documented that rice production is among the major sources of agricultural GHG emissions (Tongwan and Moeletsi, 2018; Smith *et al.*, 2014; Bhattacharyya, 2012; US-EPA, 2006), and rice is an important staple food crop consumed by more than half of the world population especially in Asian and Africa. It occupies one-third of the world's total area planted to cereals and provides 35–60% of the calories consumed by 2.7 billion people (Naresh *et al.*, 2016). Rice cultivation involves the use of organic and inorganic fertilizers, agrochemicals, water inputs and farm residues which may likely decay or burnt to the ground and these practices make rice to produce both $CH_4$ (methane) and nitrous oxide $N_2O$ emissions (Bellarby *et al.*, 2008). At global level, rice cultivation account for over 10% of the global agricultural greenhouse gas (GHG) emissions and about 1.3% - 1.8% of the anthropogenic GHG emissions (Maraseni *et al.*, 2007).

Nigeria is the West Africa's largest and World $16^{th}$ producer of paddy rice (FAOSTAT, 2014). Rice is among the major important cereal crops produced and consumed by 70% of the population in Nigeria.

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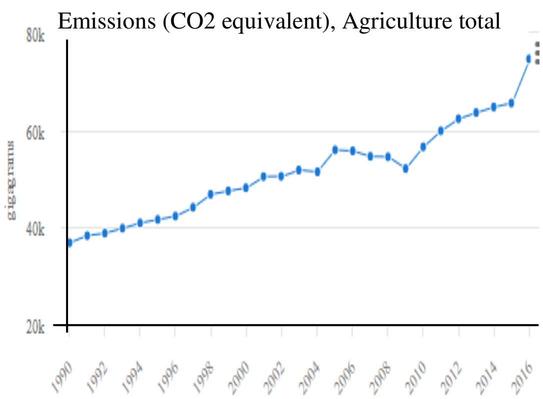
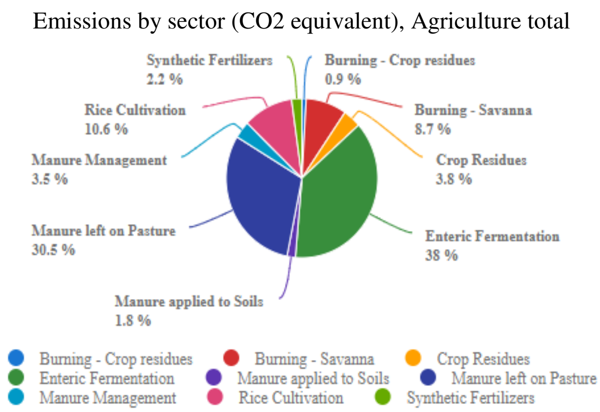
The country has three rice production environments and their coverage are rainfed lowland (69.0%), irrigated lowland (2.7%), and rainfed upland (28.3%). More than 90% of lowland and rainfed are the major rice production ecology in the country, rainfed account for dominant percentage of 50% with smallholder farmers cultivating less than a hectare of land are the majority of most rice production (Nwilene, *et al*., 2008) while the rest less than 10% is produced by corporate/commercial farmers. Majority of these resource poor small-scale rice farmers are in the rural areas lacking adequate capital and technology to boost production.

Despite the important of rice as food consume compared to other cereal crops produce in Nigeria, there is a wide gap between domestic demand and supply. Between 2017 and 2010, the production of paddy rice in Nigeria increased from 9.86 million to 3.298 million ton, respectively, but there is still a wide gap between domestic demand and supply. To meet local demand, rice import increased from 2.2 million ton in 1990 to 7.8million ton in 2000 and reached 22.6million ton by 2016, making Nigeria the world largest importer of rice importer (CBN, 2018). Akinbile (2013) stated that over US$1 billion was spent on rice import by Nigeria in year the 2010 in order to meet domestic demand. The government has implemented various policies and measures to improve domestic rice production and discourage imports but the gap between local demand and production still keep increasing. As a result, many farmers increase cultivation and adopt the use of high pesticides, agrochemical and synthetic fertilizer and water resources in order to boost rice production which induces more GHG emissions. FAOSTAT (2019) reported that the GHG emissions in rice cultivation that ranges 20% - 70% in Nigeria between 1960 and 1990, has doubled, reaching 240.7% and 537.8% in 2000 and 2017, respectively. Figure 1 plots the total agriculture emission ($CO_2$) equivalent and the average emission by sector over the period 1990 to 2017 in Nigeria. We can see that the $CO_2$ emission from agriculture increased continuously over the period and rice cultivation produce about 10.6%, which is the third largest emission in agriculture after enteric fermentation and manure left on pasture in Nigeria.




Source: Food and Agricultural Organization of the United States, 2019

Fig. 1. Total agriculture emission ($CO_2$) equivalent and the average emission in Nigeria by sector over the period 1990 to 2017

The main objective of this paper is to estimate the relationship between greenhouse gas (GHG) emission and rice production in Nigeria using econometric models. The majority of the previous studies in this area focused on Asia and advanced countries (Milne *et al*., 2015; Mondani *et al*., 2017; Vetter *et al*., 2017; Maraseni *et al*., 2017, Himics *et al*, 2018 etc). Some studies were conducted using review analysis (Boeteng *et al*., 2017, Tongwane and Moeletsi, 2018; Ngwabie *et al*., 2019). Other studies employed natural science base approaches (Ahmed *et al*, 2009; Wei-ling *et al*., 2009, Battachariyya *et al*., 2012, Ku *et al*., 2017, Pendrill *et al*., 2019). To the best of our knowledge there are very few studies on greenhouse gas emission in rice production using an econometrics approach (Osabohien *et al*., 2019), and also research in this area is inadequate in Nigeria and Africa in general. This paper adds to the literature by examining the relationship between GHG emission and rice production in Nigeria using the Autoregressive Distributed Lag (ARDL) bound test approach. The empirical analysis is conducted using annual time series data over the period of 56 years from 1961 to 2017. The findings will provide information that can assist in effective policy decision of improving rice production and mitigating GHG emission which has a high risk on human life and the environment.

## Materials and Methods

*The study area*

The research was carried out in Nigeria, in the West African tropical zone which is located between latitudes 4° N and 14° N, longitudes 2° 2'E and 14° 30'E with total area of 923,770 square kilometers (km$^2$). Nigeria has three board ecological zones, namely the Northern Savanna, the Guinea Savanna and the Southern forest.

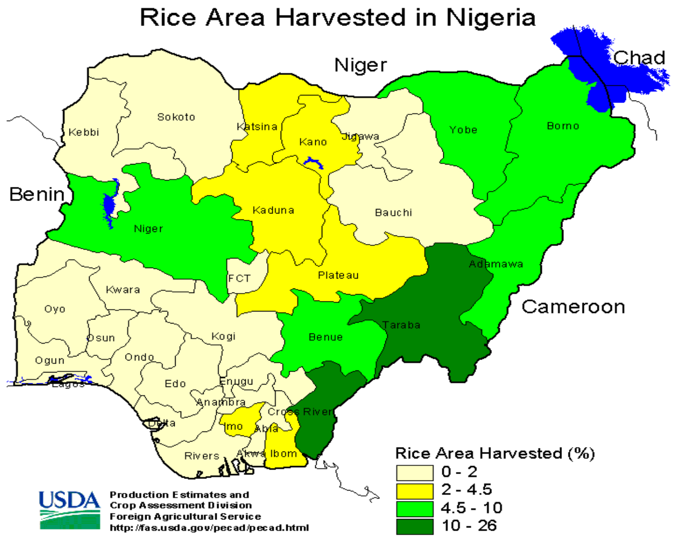



Fig. 2. Map of Nigeria and rice harvested areas in the country

Rice is an important crop produce in Nigeria in three environments and their coverage are rainfed lowland, irrigated lowland, and rainfed upland.

### *Cointegration Test*

The paper employs the Autoregressive Distributed Lag (ARDL) bound testing cointegration approach proposed by Pesaran and Shin (1999) to investigate the relationship between greenhouse gas and rice production in Nigeria. The ARDL bound test overcomes the shortcomings of the alternative methods because it allows data to be handled in a flexible way, the technique is robust for finite samples, even in the presence of phenomena of shocks and regime shifts and useful when the integration of variables is of a different order (Fuinhas and Marques, 2012). The ARDL model specification of the long run relationship between the greenhouse gas and the selected variables can be written as follows:

$$\Delta Rghg_t = \beta_0 + \sum_{t=1}^{k} \beta_1 \Delta Rghg_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta Rpd_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta Rha_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta Ryd_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta Rfrt_{t-i} + \alpha_1 Rghg_{t-i} + \alpha_2 Rpd_{t-i} + \alpha_3 Rha_{t-i} + \alpha_4 Ryd_{t-i} + \alpha_5 Rfrt_{t-i} + \varepsilon_t \quad (1)$$

Where, rice greenhouse gas emission is (Rghg), rice production (Rpd), rice harvested area (Rha), rice yield (Ryd) and rice fertilizer usage (Rfrt). The coefficients $\beta_0$ and $\varepsilon_t$ represents the intercept and the error term, respectively. First, the best optimal lag length of the model would be chosen based on the Shwartz Information Criterion (SIC) or Akaike Information Criterion. The equation (1) test the null hypothesis $H_0 : \alpha_1 = \alpha_2 = \alpha_3 = 0$, there is no cointegration relationship between the variables against the alternative hypothesis $H_0 : \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$ using the bounds testing procedure based on the joint F-statistic or Wald statistic tests. Secondly, the null hypothesis of the no cointegration is rejected when the F-statistic has higher values than the upper and lower bound, and then estimates the conditional ARDL long run model. Lastly, the short-run relationship can be established by estimating the model with an error correction model (ECM):

$$\Delta Rghg_t = \beta_0 + \sum_{t=1}^{k} \beta_1 \Delta Rghg_{t-i} + \sum_{i=1}^{k} \beta_2 \Delta Rpd_{t-i} + \sum_{i=1}^{k} \beta_3 \Delta Rha_{t-i} + \sum_{i=1}^{k} \beta_4 \Delta Ryd_{t-i} + \sum_{i=1}^{k} \beta_5 \Delta Rfrt_{t-i} + \delta ECM_{t-1} + \varepsilon_t \quad (2)$$

Where, $\varepsilon_t$ represent the residual and $\delta$ is the coefficient for the error correction model which measure the speed of adjustment of the short run to long run equilibrium position. The coefficient $\delta$ is expected to be negative and statistically significant for short run convergence to take place.

### *Data and its properties*

The paper used annual time series data for rice greenhouse gas emission $CH_4$ (gigagram), rice production (tonnes), rice harvested area (hectare), rice yield (tonnes) and fertilizer usage (NPK) (tonnes) in Nigeria covering the period 1961 to 2017. Data were sourced from Food and Agriculture Organization of the United Nations (2019) except fertilizer usage, which was obtained from Ricepedia (2019). The choice of the study period was based on the availability of data. These variables were selected because they are considered as the major determinants of rice production. The notations used for the selected variables are: Rghg (greenhouse gas emission), rice production (Rpd), rice harvested area (Rha), rice yield (Ryd) and fertilizer usage (Rfrt).

Table 1. Descriptive statistics of the selected variables

| | Rghg | Rfrt | Rha | Rpd | Ryd |
|---|---|---|---|---|---|
| Mean | 154.217 | 6.62649 | 240500 | 483858 | 1.71263 |
| Median | 132.251 | 5.56000 | 1208.00 | 2427.00 | 1.75000 |
| Maximum | 613.924 | 17.8000 | 560764 | 1134608 | 2.79000 |
| Minimum | 16.3125 | 0.06000 | 149.000 | 33.0000 | 0.89000 |
| Std. Dev. | 133.326 | 5.14428 | 1052439 | 2120619 | 0.38379 |
| Skewness | 1.10277 | 0.33142 | 4.32380 | 4.33242 | 0.27016 |
| Kurtosis | 4.44295 | 1.95342 | 20.3767 | 20.4712 | 2.68366 |
| Jarque-Bera Prob | 16.498 | 3.6450 | 894.73 | 903.26 | 0.93103 |
| | (0.000) | (0.1616) | (0.000) | (0.000) | (0.6278) |

Note: Figures in bracket are Jargue-bera probability which indicate that all the variables except Rfrt and Ryp are not normally distributed.

Table 1 shows the summary statistics of the selected variables. The result indicates that the sample mean and standard deviation are higher for rice production. All the variables show positive skewedness, implying that they are characterized by a fatter tail than the normal distribution. The result indicates that all the variables have kurtosis greater than 3, indicating that they leptokurtic except rice fertilizer usage. The Jarque–Bera test indicates that all the variables except rice production and the rice harvested area are not normally distributed.

## Results and Discussion

### *Unit root test*

Table 2 presents the result of the ADF unit root test conducted with two specifications: (1) constant and (2) constant and trend. The result of the unit root test both with constant and constant and trend specification indicates that all the variables are non-stationary in their level at 5% significant levels. However, the result shows that except the rice harvested area and rice production, all the variables are stationary in their first difference which implies that they are integrated of order one and they are I (1). The paper therefore employs the ARDL bound test which deals with time series variables that have mixed order of integration to investigate the relationship between greenhouse gas emission and rice production in Nigeria.

Table 2. Result of the unit root test

| Variables | Constant | | Constant and trend | |
|---|---|---|---|---|
| | (i) | (ii) | (i) | (ii) |
| Rghg | -1.656 | -5.453* | -0.672 | -5.881* |
| Rpd | -7.343 | -0.593 | -6.463 | -1.011 |
| Ryd | -2.244 | -8.187* | -2.212 | -8.133* |
| Rha | -6.811 | -0.972 | -5.933 | -1.506 |
| Rfrt | -1.665 | -7.519* | -2.160 | -7.449* |

Note: * denote statistical significance at the 5% level. The specifications (i) and (ii) represent level and first difference of the unit root test, respectively.

### *Cointegration test*

Table 3 presents the result of the ARDL bound cointegration test using the linear trend in the analysis. The optimal lag length 1, 1 was selected based on the Akaike Information Criterion. The estimated result indicates that we reject the null hypothesis of the ARDL bound test at both 1% and 5% significant levels because the F-statistics test indicates a value of 29.62 which is higher than the critical values of the upper and lower bounds. This result shows evidence of the existence of a longrun cointegration relationship between greenhouse gas emission, rice production and the other selected variables rice yield, rice harvested area and rice fertilizer usage during the study period. This result implies that greenhouse gas emission and the selected variables do not diverge from each other in the long run. This result is also confirmed by the negative and significant sign of the error correction coefficient, which is -0.4582 reported in Table 4.

Table 3. Results of the Bounds ARDL Test

| Test Statistic | Value | k |
|---|---|---|
| F-statistic | 29.62053 | 4 |
| Critical Value Bounds | | |
| Significance | I0 Bound | I1 Bound |
| 10% | 2.68 | 3.53 |
| 5% | 3.05 | 3.97 |
| 2.50% | 3.4 | 4.36 |
| 1% | 3.81 | 4.92 |

Decision rule: reject the null hypothesis if the F-value is higher than the upper and lower bound

Table 4 report results of the short run and long run analyses. The short run estimated elasticities indicates that all the independent variables are statistically significant at the 5% level in explaining changes in greenhouse gas emission. The coefficient of rice production shows positive and statistically significant relationship with greenhouse gas emission. The result shows that a 1 unit increase in rice production will increase greenhouse gas emission by 0.002% in Nigeria. Fertilizer usage is significant and positive which implies that increase in the application of fertilizer will contribute to increase in GHG emission by 2.22% in rice production. However, the results indicate that the coefficients of the rice harvested area and rice yield are both negative but statistically significant which suggests their influence on GHG emissions in rice production in the short run despite the fact that they have wrong signs. This result implies that increase in rice production will have a positive influence in increasing GHG emissions through increase in fertilizer usage (both organic and inorganic), pesticides, water and energy usage from other rice production inputs and other process. The coefficient of the error correction term is negative and statistically significant at 5% level showing the speed of adjustment of the variables to the long run equilibrium position. The result implies that about 0.45% of the divergence between greenhouse gas emission, rice production and other selected variables converge to form a long run equilibrium. The result of the estimated long run elasticities indicates that all the variables except fertilizer usage are statistically significant at the 5% level in explaining changes in greenhouse gas. This implies that these variables contribute significantly in influencing greenhouse gas emission in rice production in Nigeria. The coefficient of the rice production shows a positive and statistically significant relationship with greenhouse gas emission, suggesting that increase in rice production will increase greenhouse emission even though the influence is not high in the long run.

Similar to the short run analysis the result indicates that the coefficients of the rice harvested area and rice yield are both negative and statistically significant in explaining greenhouse gas emission.

Table 4. Results of the short run and long run estimates

| Short Run | | | | |
|---|---|---|---|---|
| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
| DRfrt | 2.216133 | 1.047372 | 2.115899 | 0.0395** |
| DRha | -0.004533 | 0.000402 | -11.287029 | 0.0000* |
| DRpd | 0.002266 | 0.000199 | 11.400839 | 0.0000* |
| DRyd | -31.917114 | 10.92369 | -2.921826 | 0.0053* |
| C | 43.943801 | 6.330415 | 6.941694 | 0.0000* |
| ECM(-1) | -0.458165 | 0.072455 | -6.323897 | 0.0000* |
| Long Run | | | | |
| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
| Rfrt | 3.037263 | 1.718467 | 1.767425 | 0.0734*** |
| Rha | -0.009499 | 0.00293 | -3.241389 | 0.0021* |
| Rpd | 0.004749 | 0.001457 | 3.25965 | 0.0020* |
| Ryd | -86.596206 | 23.46152 | -3.690989 | 0.0006* |
| @TREND | 6.76235 | 0.438096 | 15.435784 | 0.0000* |

Note: *,**and *** represents significant at 1%, 5% and 10% levels, respectively

Lastly, the result indicates that fertilizer usage has a positive and significant relationship with greenhouse gas emission at 10% level of significant contrasting the short run analysis. The finding shows that compared to the other variables, fertilizer has less influence on GHG emission in both the short run and long run. Overall, the result shows that there exists a long run relationship between GHG emission and rice production in Nigeria. The result suggests that rice production will contributes to GHG emission in the long run supporting Vetter *et al*. (2017), Maraseni *et al.* (2016) and Osabohien *et al* (2019), Boeteng *et al.* (2017) who shows that agriculture and crop production contribute significantly in inducing GHG emissions.

## Conclusion and Policy Implication

This paper conducts an empirical study to investigate the relationship between greenhouse gas emission and rice production in Nigeria during the period 1961 to 2017 using the Autoregressive Distributed Lag (ARDL) bounds approach. The result indicates the presence of a long run cointegration relationship between greenhouse gas emission and rice production in Nigeria. The estimated elasticities of both the short run and long run analyses indicates that rice output, rice yield and rice harvested area significantly influenced changes in greenhouse gas emission in rice production while fertilizer usage is insignificant in the short run.

The paper has important policy implications from the findings, there is need to adopt new approaches to rice cultivation that will boost output using less energy and land area in order to decrease GHG emissions in Nigeria. Government should introduce strategies and measures that will encourage farmers to increase yield using improved seed varieties that requires the use of less land area, fertilizer application, water usage and chemical in production to reduce GHG emission.

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