Autoregressive Distributed Lags (ARDL) Modelling of the Impacts of Climate Change on Rice Production in Kebbi State

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Abstract—**Autoregress Distributed Lag (ARDL) is an econometric model that determines the long run a d short run association between the Serial (Stationary/ non-stationary as well as reparameterizing them to Error correction model (EMC). Rice cultivation and production is a major source of income for millions of households around the globe especially in Nigeria. It is also a major staple food, but Climate change poses great threat to the stability and sustainability of rice production for sufficient agricultural system, since most Nigeria consumes rice more than other foods and Kebbi state, is one of the major states contributing to the total rice output of the country. Climate change is the major challenge facing rice production. This study therefore, investigates the long-run and short run effect of factors affecting rice production in Kebbi State. 1000 simulations of data were obtained from the data collected between the period of 2005 to 2016 from the state Ministry of Agriculture. The result showed that rainfall has impact both in the long run and short run; 100% increase in rainfall, will tend to give 99.98% increase in rice production in the long-run. However, temperature tends to show insignificant impact on rice production. The result of this paper facilitate understanding for government and agriculturist in the linkages between climate change variables and rice production which can boost and increases the production of rice in Kebbi State.**

Keywords-*Climate change, rice production, ARDL, long-run, short-run.*

I. Introduction

The impact of climate change can be vast, climate change and agriculture are interrelated processes, both of which take place on a global scale, and global warming is projected to have significant impact on conditions affecting agriculture [1]. Rice is the second largest produced cereal in the world; it is a crop that cuts across regional, religious, cultural, national and international boundaries, apart from wheat: with very high demand [2]. Rice cultivation is the principal activity and source of income for millions of households around the globe and several countries of Asia and Africa are highly dependent on the rice as source of foreign exchange earnings and government revenue. Kebbi state is strategic location for rice production in Nigeria, hence one of the leading rice producing states in the country. Rice farming depends greatly on the environmental factors.

Background to the Study

One of the most serious long-term challenges to achieve sustainable growth in rice production is Climate change [3]. Rice productivity and sustainability are threatened by biotic and abiotic stresses, and the effects of these stresses can be further aggravated by dramatic changes in global climate. Thus the major challenge is the potential adverse effect of changing climate on rice production and being the factor limiting increase in annual yield.

Basak [4] concluded that climate change was likely to have predominately adverse impacts on the yield of Boro rice. They found that if climate change was to result in significantly high temperatures, this would cause grain sterility during the growing season and hence a reduced yield. They also found that while changes to the level of atmospheric carbon dioxide and solar radiation might offset the impact of increased temperatures to some degree, that it would not be sufficient to mitigate it altogether. Sarker [5] performed time series analysis to assess three major rice crops (Aus, Aman and Boro) in Bangladesh at the aggregate level using both Ordinary Least Squares and Median Quantile Regression. The authors used maximum and minimum temperature and rainfall as climate variables and found a significant relationship between climate change and agricultural productivity. They found that minimum temperature was significant only for the Aman and Boro varieties, with a negative impact on output in the former case and a positive impact in the latter. Maximum temperature was found to be significant for all varieties, with a positive impact on output of Aus and Aman and a negative impact on Boro output.

Climate change can have negative effects on plant growth and high atmospheric temperatures will drive the main sites of rice production further north. Then, water shortages caused by climate change will be the utmost problem for rice production. Since one of the most serious long-term challenges to achieve sustainable growth in rice production is climate change. Therefore, there is a need to know which of the climate factors that has good or adverse effect on rice production. Hence, the aim of this study is to determine the short-run and long-run level of association between the rice productivity and some climatic factors (such as rainfall and temperature) with a view to achieve the following objectives: To study the interrelationship between the effect of climate change on rice production and determine the short run and long run association of these variables on rice production.

II. Research Methodology

Data and source

The data used in this study are annual time series data on the record of rice production(tons), annual average rainfall and annual range of temperature(degree Celsius)are collected from the State Ministry of Agriculture in Kebbi state from 2005- 2016. Due to unsatisfactory length of data points, the R package was used to simulate 1000 data observations used in analysis.

The Autoregressive Distributed Lags (ARDL) Model

The method of analysis used in this study is an econometric model pioneered by Pesaran et al. [6] which is acronym as Autoregressive Distributed Lags (ARDL), the ARDL determines the long run and short run association between the series (stationary / non stationary). It also gives flexibility relationship between stationary/non stationary variables and reconciles the short run dynamic with long run equilibrium and investigates the existence of cointegration relationship among variable.

The linear model of the efficient relationship between the rainfall and temperature, is given as:

$$RICE_t = \beta_0 + \beta_1 t + RFALL_t + TEMP_t + \varepsilon_t \qquad (1)$$

where,

$RICE_t, \beta_0, RFALL_t, TEMP_t$ and ε_t are Rice production, Intercept, Trend, Amount of Rainfall, Amount of Temperature and Stochastic Error Term respectively

ARDL Model

$$\Delta RICE_t = \alpha + \sum_{i=0}^{n} \beta_{1i}\,\Delta RICE_{t-i} + \sum_{i=0}^{n} \beta_{2i}\Delta\, RFALL_{t-i} + \sum_{i=0}^{n} \beta_{3i}\Delta\, TEMP_{t-i} + \beta_4 RFALL_{t-1} + \beta_5 TEMP_{t-1} + \varepsilon_{1t} \qquad (2)$$

where, $\beta_{1i} \cdots, \beta_{3i}$ measure the short run dynamics in the model and β_4, β_5 measure the long rundynamics. n is the optimal lag. Wald test or F-statistic is computed to test the null hypothesis based on

$$H_0: \beta_4 = \beta_5 = 0 \qquad (3)$$

III. Results And Discussion

Visual Representation of the Data

The series was tested for stationarity using the plot diagram in Figure 3.1 and also performing Unit-root test. The graphical representation of the series against time indicates that the underlying series exhibit an increasing trend over time and has a random walk time series with a non-zero mean and a non-constant variance. Hence, the plotted graph provides a clear cut indication that the underlying series is non-stationary in its level.

Figure 3.1 below showed a conspicuous and sharp upward trend between the periods under investigation. This will tend to result in an unstable mean, though the data points are fairly scanty.

In Figure 3.2 showed one thousand (1,000) simulated data points of rice production. The plot demonstrated an upward trend between the first 100 and 200 points; later followed by drastically downward trend and this depicted instability in mean and variance of the series, though there was a fair stability between 200 to 600 points.

Result of Unit Root Test

In order to confirm if the variables under study have the same order of integration, three different test were employed; they are Augmented Dickey-Fuller (ADF), KwaitKowski Phillips Schmidth and Shin (KPSS) [7] and Schmdth- Phillips unit root tests.

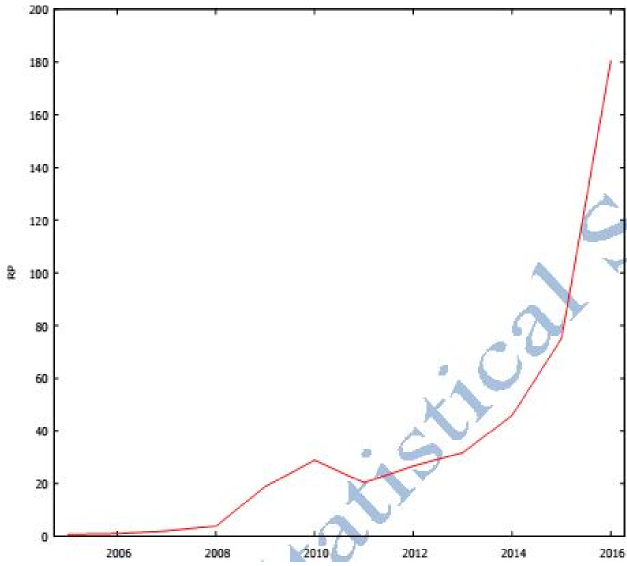

Figure 3.1: Time-plot of yearly record of Rice Production in Kebbi State 2005-2016.

Table 1 above showed that since the value of Test statistic is greater than the critical value at 5% level of significance. Therefore, we fail to reject null hypothesis thus conclude that there is presence of unit root in rice and there is need to take the first difference.

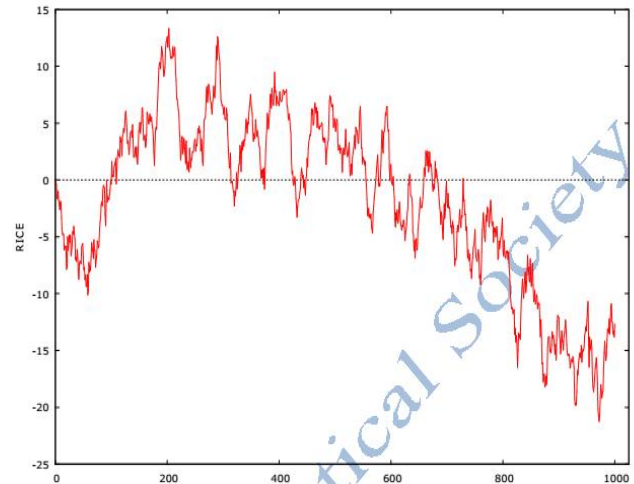

Figure 3.2: Time-plot of the 1000 Simulated data Points for Rice Production.

Table 2 showed that after taking the first difference the value of Test statistic is less than the critical value at 5% level of significance therefore we reject null hypothesis and conclude that series is stationary.

Table 3 below showed that temperature is stationary since the value of Test statistic is less than the critical value at 5% level of significance. Therefore, there is evidence to reject null hypothesis thus conclude that the series of temperature is stationary.

Table 4 reveals that rainfall is not stationary since the value of Test statistic is greater than the critical value at 5% level of significance. Therefore, we fail to reject null hypothesis thus conclude that there is presence of unit root in rainfall and there is need to take the first difference.

Table 1: Unit root Test for Rice Production

TEST	LAG	TEST STATISTIC	CRITICAL VALUES 5%	DECISION
ADF	1	-1.6813	-1.94	Present of unit root
KPSS	2	18.0691	0.463	Not stationary
Schmdth-Phillips	2	-14.3120	-18.1	Present of unit root

Table 2: Unit root Test for Rice Production after taking the first difference

TEST	LAG	TEST STATISTIC	CRITICAL VALUES 5%	DECISION
ADF	1	-23.4435	-1.94	Absence of unit root
KPSS	2	0.0567	0.463	stationary
Schmdth-Phillips	2	-813.9636	-18.1	stationary

Table 3: Unit root Test for temperature

TEST	LAG	TEST STATISTIC	CRITICAL VALUES 5%	DECISION
ADF	10	-0.0656	-1.94	Absence of unit root
KPSS	2	0.0446	0.463	stationary
Schmdth-Phillips	2	-785.1579	-18.1	stationary

Table 4: Unit root Test for Rainfall

TEST	LAG	TEST STATISTIC	CRITICAL VALUES 5%	DECISION
ADF	2	-1.8490	-1.94	There is present of unit root
KPSS	2	24.2560	0.463	Not stationary
Schmdth-Phillips	2	-20.7863	-18.1	There is present of unit root

Table 5: Unit root Test for Rainfall after taking the first difference

TEST	LAG	TEST STATISTIC	CRITICAL VALUES	DECISION
ADF	1	-22.34352	-1.94	Sationary
KPSS	2	0.0467	0.463	stationary
Schmdth-Phillips	2	-813.9636	-18.1	stationary

Table 5 showed the unit root after taking the first difference that the value of Test statistic for rainfall is less than the critical value at 5% level of significance therefore we reject null hypothesis and conclude that series is stationary.

ARDL Bound Test for Co-integration

Having established that the rice production and rainfall are integrated of order one, and temperature of order zero therefore, the existence of the long-run relationship and short-run are tested using Auto-regressive distributed lags (ARDL) model.

The result of bounds tests is reported in table 6. Bound test result showed that the F-statistic of 107.1235 is found to be higher than the critical value of 3.79 of the Lower Bound I(0) and 4.85 of the Upper bound I(1) at the 5% level, thus null hypothesis is rejected. Therefore, the variables under study are co-integrated. In other word there exist a long-run relationship among rice production, rainfall and temperature.

Table 6:ARDL Bound Test for Co-integration

Variables	F-Statistics For k-2	Co-integration
F(RICE, RFALL, TEMP)	107.1235	Co-integration
Critical Value	Lower Bound I(0)	Upper Bound I(1)
5%	3.79	0.5193 *(0.1807)*

Table 7: Estimated Long Run Relation for Rice Production

Variables	Coefficient	Std. Error	T-Statistic	P-Value
Constant	0.658094	0.619879	1.061650	0.2887
RAINFALL	0.999783	0.001937	516.068134	0.0000
TEMP	-0.020710	0.019596	-1.056874	0.2908

Table 7 shows a long-run coefficients of the ARDL model, the result shows that Rainfall has a significant impact on Rice production at 5% level. That is, 100% increase in rainfall will tend to give 99.98%increase in Rice production. This result shows that there exist a positive long-run relationship between Rice production and Rainfall while Temperature do not a have significant impact on Rice production.

Table 8: Estimated Short Run Relation

Variable	Coefficient	**Std. Error**	T-Statistic	**P-value**
Constant	1.173377	0.773254	1.517454	0.1295
$\Delta RICE_{t-1}$	0.004660	0.031759	0.146734	0.8834
$\Delta \boldsymbol{RAINFALL}\ t$	0.305135	0.014655	20.82174	0.000
$\Delta RAINFALLt - 1$	0.689107	0.023052	29.89392	0.0000
$\Delta \boldsymbol{RAINFALL}\ t - 2$	0.000920	0.026491	0.034746	0.9723
$\Delta TEMPt$	-0.010740	0.013702	-0.783817	0.4333
$\Delta TEMP\ t - 1$	-0.010730	0.013687	-0.783959	0.4333
$\Delta TEMP_{t-2}$	-0.015524	0.013694	-1.133614	0.2572

The result in Table 8 showed that only Rainfall is found to be statistically significant at 5% level, in the short-run. The short-run coefficients of the ARDL model is given as

RICE = 0.0062262385106*RICE (1)

+ 0.305002465164*RAINFALL + 0.68855541703*RAINFAL -

0.00977468314737*TEMP - 0.0108066009193*TEMP (-1) + 0.6539969503

The langrage-multiplier (LM)
The langrage-multiplier (LM) showed that there is no serial correlation at the chosen lag as shown in Table 9.

Table 9: Diagnostic Test

Test	**Coefficient**	**Prob.**
Autocorrelation (L.M Statistic)	1.580809	0.1924
JarqueBera Residual Normality Test	12.253784	0.08194
Residual Hetroskedasticity Test	4.762724	0.2324

In addition the model passes the normality test through the joint JarqueBera (JB) statistic indicating that residual have normal and identical distribution. It also passes through the heteroskedasticity test with chi-square distribution. The adjustment coefficient is also significant and correctly signed i.e. negative which indicates that the restrictions are meaning full.

IV. Conclusion

ARDL model offers a good technique for predicting any long-run and short-run relationship between selected variables. It has been shown that the ARDL (1, 1, 1) found to be the best fit model for Showing a long-run and short-run relationship between rain fall, temperature, and rice production.

It can be concluded that the performance of rice production in the short-run seems to be influenced by climate change variable, such as temperature, while rainfall has a positive impact on rice production in the long-run, thus this finding suggest that government and agriculturalists can really understand the linkages between climate change variables and rice production and this useful information can facilitate them to boost their productivity and increases the production of rice in Kebbi state.

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References

[1] Adams, S.O., Ipinyomi R.A. and Yahaya H.U. (2017). IPCC (2007): Fourth Assessment Report of the Intergovernmental Panel on Climate Change The Impacts, adaptation and vulnerability (Working Group III). Cambridge University Press, United Kingdom and New York, NY, USA

[2] Africa Rice Center (2007), Africa Rice Trends: Overview of Recent Developments in the Sub Saharan African Rice Sector. Africa Rice Center Briefs, Africa Rice Center Rice),Cotonou, Benin, 8pp

[3] Wassmann, R & Jagadish, Krishna & Heuer, Sigrid & Ismail, A.M. & Redona, E & Serraj, Rachid & Singh, Rakesh & Howell, G & Pathak, Dr Surendra & Sumfleth, K. (2009). Climate Change Affecting Rice Production: The Physiological and Agronomic Basis for Possible Adaptation Strategies. Advances in Agronomy. 101.

[4] Basak, J.K., Ali, M.A., Islam, M.N., and Rashid M.A., (2010), Assesment of the Effect of Climate Change on Boro Rice Production in Bangladesh using DSSAT Model, Journal of Civil Engineering (IEB), 38(2), pp 95-108

[5] Sarker, M.A.R., Alam, K., & Gow, J., 2012, 'Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data', Agricultural Systems, 112, pp. 11-16.

[6] Pesaran, M.H., Shin, Y., and Smith, R. (2001) Bounds testing approaches to the analysis of level relationship, Journal of Applied Econometrics, 16,289-326.

[7] Kwaitkowski, D., Phillips, P., and Shin, Y. (1992). Testing for the null hypothesis of stationary against the alternative of a unit root. Journal of Econometrics, 54, 59-178.

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