THE LONG RUN RELATIONSHIP OF CLIMATE CHANGE AND SUGARCANE PRODUCTION IN NIGERIA

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ABSTRACT

In recent years, there has been a reduction in the output of sugarcane per hectare in Nigeria from 19.2 tons per hectare in 2009 to 16.3 tons per hectare in 2016 due to rising temperature and unpredictable rainfall. This study examined climate change and sugarcane production in Nigeria from 1970 to 2021 using error correction model. Time series data were employed for the study. The results showed that temperature and rainfall adversely affected sugarcane output in Nigeria during the period studied with temperature depicting a warming trend. Furthermore, results showed a negative relationship between sugarcane output and temperature and a positive relationship between sugarcane output and rainfall in the short run. The results of error correction model showed that sugarcane output was affected by other variables included in the model both in the long and short-runs. The coefficient of the error correction term (ECT_1) was negative and significant at 5% level, indicating that sugarcane production adjusted to equilibrium given any changes in climatic variables. Consequently, for this model in the short-run, sugarcane production was adjusted by 3% of the past year's deviation from equilibrium. The variance decomposition result showed that rainfall drastically affect sugarcane output. It is therefore recommended that for Nigeria to mitigate the negative consequence of climate change on sugarcane production, there is a need for the promotion of irrigation systems.

Keywords: climate change, sugarcane output, error correction model, Nigeria.

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1 INTRODUCTION

The agricultural sector in most developing countries is a vital part of the economy. It depends on climatic variables and is extremely susceptible to climate variability such as changes in temperature and rainfall (Joshi, Maharjan, & Piya, 2011). The outcomes of rising temperatures and fluctuating rainfall will lead to low or poor agricultural products. Climate change has been demonstrated through evidence as already affecting crop yields in many countries (Apata, 2012; Building Nigeria's Response to Climate Change [BNRCC], 2008; Deressa, Hassen, Alemu, Yesuf, & Ringler, 2008; Food and Agriculture Organization of the United Nations [FAO], 2015; Intergovernmental Panel on Climate Change [IPCC], 2007, Malhi, Kaur & Kaushik, 2021, Otitoju & Enete, 2016, Raza eta al., 2019, Syed, Raza, Bhatti, & Eash, 2022). According to Akpan et al. (2017), this has adversely affected the output and yield of agricultural commodities and this poses a serious threat to the realization of food self-sufficiency drive of the Federal Government of Nigeria.

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, due to natural variability or as a result of human activity (IPCC, 2007). Climate change drives extreme weather events such as floods and drought losses in crop yield all of which affect the economic sector to some degree, with the agricultural sector being the most vulnerable (Ajokporise, 2011; Ayandele, et al., 2010). The effect of climate can be measured in terms of impact on crop yield, availability of soil water, soil erosion, incidents of pests and diseases and decrease in soil fertility (Adejuwon, 2004; Alvaro et al., 2009; Fraser, 2008). According to Sowunmi and Akintola (2010), the climate of an area is highly correlated with the crops cultivated and thus predictability of climate is imperative for planning of farm operations. Climate change and its resultant impacts will have effects to the agricultural sector but particularly on infrastructure systems facilitating agricultural production. Not only will this harm the performance of the sector but can unleash future risks and uncertainties on how infrastructure systems will function (Goyol & Pathirage, 2017). Furthermore, infrastructure systems mutually depend on one another in order to operate so that damage on an individual infrastructure can precipitate disruptions in other infrastructure facilities and services (Chappin & van der Lei, 2014). Climate change in the long term will have further implications on infrastructure as they are increasingly becoming vulnerable to loss and damage due to their currents state as most are found to be in poor conditions thereby less resilient to adverse conditions (Goyol & Pathirage, 2017). As stated by Victor (2011), it is not valid that global warming is just an environmental problem, but that it is also rooted in economics because even though While GHGs are naturally created, they are also a result of human economic activity. IPCC (2007) forecasted that in the year 2100, the amount that will be spent on climate variation may affect the Gross domestic product of developing countries.

An output model based on time series data for describing the output of an agricultural product was developed by Nerlove (1956, 1958). According to Nerlovian model, output can be estimated by a partial adjustment model, dynamic by nature and with a loss minimization function. Over the years, Nerlove's partial adjustment model has been extensively used (Nayarana & Parikh, 1981; Niamatullah & Zaman, 2009; Nosheen & Igbal, 2008; Mythili, 2006). One key limitation of this model is that it assumes a fixed target which according to Howard et al. (2016) is impracticable, because farmers face diverse conditions while they optimize their decision. To rise above this problem, several researchers have been using error correction modeling (ECM) in order to analyze the ouput of agricultural products (Hallam & Zanoli, 1993; Howard, et al., 2016; Nickell, 1985; Weliwita & Govindasamy, 1997). The error correction model is superior to Nerlove's output model, since the error correction model captures both the short-run dynamics as well as the adjustment towards the long-run equilibrium.

This study gives special attention to sugarcane because sugarcane contributes 60% of the total world sugar requirement while 40% comes from sugar beet and chewing raw sugarcane alone, accounted for between 55-65% of the total sugarcane production, while some are processed into a variety of products like sugar, molasses, bagasse and sweet use for brewing beer, soft drinks, confectionaries, pharmaceuticals etc (Busar & Misari, 2007). Consequently, self-sufficiency in sugarcane production had remained an important goal to reduce hunger and enhance food security. For this reason, improving sugarcane output will have a huge impact in terms of enhancing total sugarcane supply in Nigeria. Climate change is a serious threat to Nigeria agricultural sector and food security, because of its sensitivity and susceptibility to high temperature and rainfall fluctuations (Nte & Okoro, 2017). The short-run as well as long-run fluctuations in temperature and rainfall can affect agricultural production (Howard, et al., 2016). Given this situation, it is therefore imperative to understand the long run relationship of climate change and sugarcane production in Nigeria within 1970 an 2021.

2. LITERATURE REVIEW

Conceptual Review

Concept of Climate Change

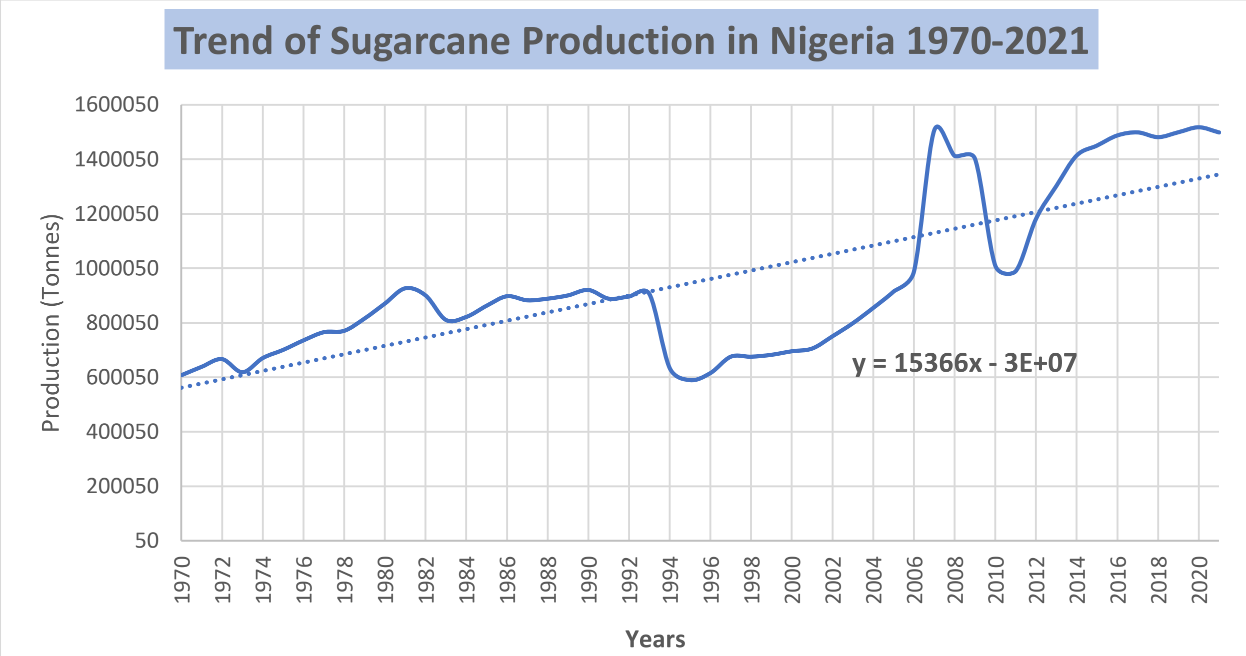
Climate Change Framework Convention of the United Nations [UNFCCC] (as cited in Onyeneke & Madukwe, 2010) defines climate change as a variation in climate that is in addition to natural climatic variability that has been seen across comparable time periods and that is directly or indirectly caused by human activity that changes the composition of the global and/or regional atmosphere. According to IPCC (2007), climate change is defined as a change in the state of the climate that can be determined (for example, through the use of statistical tests) by a change in the mean and/or the variability of its attributes, and that endures for a long time, generally decades or longer. Although the Earth's climate is constantly changing and global climate change occurs naturally, the rate of future climate change may be more rapid than at any time in the last 10,000years. The majority of scientists that research this issue worldwide come to the conclusion that human activity would cause this anticipated climate change to be different from prior climate changes. Climate change, then, is the gradual alteration of the global atmosphere's composition brought on by a variety of human activities, as well as by natural climate fluctuation through time (Koehler-Munro & Goddard, 2010).

Climate change refers to "changes to the average weather and weather variability of a region or the planet over time." The common indicators of climate change are changes in temperature, precipitation, and wind. The major climate change indicator that researchers or scientists commonly used is the earth's average surface temperature. Over the past 50 years, the global average temperature increased by 0.65°C (UN-Habitat, 2021).

Gaps in Literature

Several studies have been conducted on climate change (Aina, Ajijola, Ibrahim, Musa, & Bappah, 2015); production (Afolayan, 2020); (Abdullah, Shahriar & Kea, 2020); (Gama, Ahungwa & Folorunso, 2021), other studies were also reported on the Nigerian trade (Aliyu & Bawa, 2015; Oladipupo & Adedoyin, 2019), sugarcane competitiveness (Nwachukwu, Nnanna, Jude & George, 2010) and also political economy of sugarcane (Olaiya, 2016**),** some other climate-related studies, also in Africa, have analyzed factors affecting the perception to climate change and choice climate change adaptation strategies (Otitoju & Enete, 2014, Enete, Otitoju, & Ihemezie, 2015, George, Jennifer, & Charles, 2020, Otitoju, 2013; Otitoju & Enete, 2016). The studies of Ayinde, Muchiea and Olatunji (2011) and Abu, Okpe and Abah (2018) studied how climate change is having an impact on agricultural productivity in Nigeria, without being crop specific. None of these studies looked at using time series data covering a total of 51 years, however, there is a paucity of information in the literature regarding the long run relationship between climate change and sugarcane production in Nigeria. Yusuf and Tiri (2023) used ARDL to measure the relationship of agricultural output and financial development in Nigeria. Yahya and Nkwatoh (2021) examined long run relationship between natural gas utilization and economic activities in Nigeria.Musa (2021) examined the relationship between crop production and export diversification in Nigeria. Also, Iyoboyi (2020) assessed the long-run impact of institutions and economic growth. The fluctuation of sugarcane production may be attributed to change in climate parameters, hence the study seeks to ascertain this very claim in many literatures by examining this relationship.

Fig 1: Yearly trend of Sugarcane production data for Nigeria 1970-2021



Source: National Sugar Development Council, 2022.

3. METHODOLOGY

Data

Annual time series data on sugarcane output in tonnes was sourced from Nigeria's Annual Sugar Production, Importation and Consumption (2022) by National Sugar Development Council, and used for the analysis. Temperature (ºC) and rainfall (mm) data were obtained from the World Bank (2022) climate change knowledge portal. Purposive sampling technique was employed. The study used annual time series data for the period of 1970 and 2021, spanning a total of 51 years sample size. Weather variables in sugarcane model was computed using data from the following weather stations in sugarcane growing areas.

The Study Area

Nigeria has an estimated population of about 180 million people (World Bank, 2015) with a total area of 923,800 sq. km and occupies about 14 per cent of the land area of West Africa. The country lies between 40N and 14^0N, and between 3^0E and 15^0E. Nigeria is located within the tropics and therefore experiences high temperatures throughout the year. The mean for the country is 27^0C. Average maximum temperatures vary from 32^0C along the coast to 41^0C in the far north, while mean minimum figures range from 21^0C in the coast to under 13^0C in the north. The climate of the country varies from a very wet coastal area with annual rainfall greater than 3,500 mm to the Sahel region in the north western and north eastern parts, with annual rain fall less than 600 mm (Oyakhilomen & Zibah, 2014). Nigeria is a vast agricultural country endowed with substantial natural resources which consist of 68 million hectares of arable land, fresh water resources covering about 12 million hectares, 960 kilometres of coastline and an ecological diversity which enables the country to produce a wide variety of crops and livestock, forestry and fisheries products (Arokoyo, 2012).

Estimation Procedures

This study employed vector error correction model (VECM) to examine how climate change affects sugarcane production in Nigeria. An error correction model (ECM) was employed to model the causal influence among the non-stationary variables with evidence of long-run relationship. The VECM is useful for the evaluation of a short-term adjustment which adjusts towards the long-run equilibrium in each time period. If the variables are found to be co-integrated, a VECM is estimated because a co-integrating relationship deals only with long-run relationship without considering the short-run dynamics. The properties of these variables such as stationarity and long-term relationship were established prior to estimating the VECM model. This study employed the Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979; Phillips & Perron, 1988) to determine the presence of unit root, that is, to ascertain if the variables were stationary. The Johansen Co-integration test (Johansen, 1991) was conducted to determine the presence of a long-run relationship. It is important to mention that if co-integration is detected between series, there exists a long-term equilibrium relationship hence, it becomes appropriate to use VECM (Edoja et al., 2016). Lastly, variance decomposition was employed to show the percentage error in one variable due to one standard deviation shock of the variable itself (own shocks or variations) and other variables in the system (Alege, 2010). According to Iwayemi and Fowowe, (2010), variance decomposition shows the proportion of the forecast error variance of a variable that can be attributed to its own innovations and that of other variables. Variance decomposition is commonly used for the purpose of making reasonable forecasts of variables in the model over a specified time period (Edoja et al., 2016). In this study, the variable itself refers to sugarcane production and other variables are temperature and rainfall.

Model Specification

The relationship between sugarcane output, average annual temperature and average annual rainfall is expressed implicitly as:

$$SUGARCANE_{Output} = f(TEMP_t, RAINFALL_t) \quad \text{-- -- -- -- -- --} \quad 1$$

Where:

$SUGARCANE_{Output}$ is the output of sugarcane, $TEMP_t$ is the average annual temperature and $RAINFALL_t$ is the average annual rainfall. Given that climate variables, temperature and rainfall were the focus of this study, if the coefficient of temperature is negative and statistically significant, it will imply that global warming has a negative effect on sugarcane output. If it is positive and statistically significant, this will suggest that global warming has a positive effect on sugarcane output. Similarly, if the coefficient of rainfall is negative and significant, it can be said that increasing rainfall after a while leads to decreased sugarcane output. If it is positive and statistically significant, it can be argued that increase in rainfall has the effect of raising sugarcane output. Changing all the variables into log form, equation (1) can be written in the following form as in equation 2.

$$SUGARCANE_{Output} = \alpha_0 + \alpha_1 \log TEMP_t + \alpha_2 \log RAINFALL_t + \varepsilon_t \quad \text{---- -- -- --} \quad 2$$

In equation (2), ε is the random error term. For this study, an error correction model was developed, average annual temperature and average annual rainfall were used as explanatory variables with annual average output of sugarcane as the dependent variable. Consequently, following Engle and Granger (1987), an ECM model was specified for this study as shown in equation 3:

$$\Delta logSUGARCANE_{Output} = \alpha_0 + \alpha_1 \Delta \log TEMP_t + \alpha_2 \Delta \log RAINFALL_t + \alpha_3\, ECT_{t-1} + \varepsilon_t \quad -3$$

Where: $logSUGARCANE_{Output}$ is logarithm of sugarcane output in year t (tonne/ha), $\log TEMP_t$ is the is logarithm of average annual temperature (°C), and $\log RAINFALL_t$ is logarithm of average annual rainfall (mm) and ECT is the error correction term, Δ is the difference operator and ε_t is the error term which takes care of extra variables that may possibly have influence on sugarcane output but not specified in the model.

4. RESULTS AND DISCUSSION OF FINDINGS

Unit Root Test Results

Table 1 present the result of the ADF tests. The result shows that only Rainfall was stationary at level. Sugarcane production and temperature became stationary after first difference. The result of this study is similar to that conducted by Abu et al. (2018) in Nigeria on the effects of climate change from 1966 to 2015 using ADF and Phillips-Perron tests, the results indicated that all the data series were non-stationary at level but were stationary at first difference.

Table 1: Results of Augumented Dickey-Fuller Unit root Test at 5% of Significance

	At level			At first difference		
Variables	ADF Statistic	ADF Critical value	Remarks	ADF Statistic	ADF Critical value	Remarks
SP	-1.298445	-2.926622	Unit root	-5.759639	-2.931404	No unit root
Rainfall	-3.459164	-2.928142	No Unit root	-12.79924	-2.928142	No unit root
Temperature	-0.936359	-2.929734	Unit root	-9.834044	-2.929734	No unit root

Co-integration Test Results

Table 2: Johansen's Co-integration Trace test (Unrestricted Co-integration Rank Test)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value at 0.05	Prob.**
None *	0.564254	82.00169	29.79707	0.0000
At most 1 *	0.492899	46.28177	15.49471	0.0000
At most 2 *	0.327851	17.08282	3.841466	0.0000

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* Represents rejection of the hypothesis at the 0.05 level.

The Johansen's co-integration test result is presented in Table 2 and Table 3. Both the trace statistics and the Maximum eigenvalue statistics rejected the null hypothesis of no co-integration, thereby indicating the long-run relationship among variables. This shows that the three variables are co-integrated, thereby indicating the long-run relationship among variables. From the equation, all the independent variables considered significantly affects sugarcane production in Nigeria in the period studied. This study corresponds with the studies of Abu et al. (2018) and Ayinde, et al. (2010) on the effect of climate change using time series data.

Table 3: Johansen's Co-integration Maxim Eigenvalue Test (Unrestricted Co-integration Rank Test)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.564254	35.71992	21.13162	0.0002
At most 1 *	0.492899	29.19895	14.26460	0.0001
At most 2 *	0.327851	17.08282	3.841466	0.0000

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* Represents rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Long-Run Estimate of Sugarcane Production Response

Table 4: Long-Run Estimate of Sugarcane Production Response: 1970 – 2021

Co-integrating Variables	Co-integration coefficients
Sugarcane production	1.000000
Temperature	-6.27
Rainfall	0.87
Constant	0.05

SP = 0.87***Rainfall – 6.27***Temperature + 0.05

The long-run elasticities of sugarcane production with respect to temperature was negative and significant, suggesting that increase in temperature had a negative effect on sugarcane production in Nigeria during the period under study. Result further showed that sugarcane production during the period of study was affected by the other variables included in the model in the long-run. Specifically, the coefficient of sugarcane production was positive and significant at level suggesting that the farmers responded to the changes in climate by cultivating more land to increase sugarcane production in the long-run. In order words, a unit increase in the favorable climate will lead to an increase in sugarcane production by 1.0 tonnes all things being equal. In a similar manner, the negative and statistically significant coefficient of the temperature showed that when the production of other crop increases over a period of time, farmer will shift from sugarcane production to other crop production like rice and vice versa, all things being equal. This suggests that an increase in temperature will have a negative effect on sugarcane production. A unit increase in the temperature will decrease sugarcane production by about 1.0 tonnes. This showed that higher temperatures above the ideal temperature for sugarcane production may lead to a decrease in sugarcane production.

Nonetheless, a correlation between sugarcane production and rainfall was shown to be positive (Ayinde et al, 2010 and Abu et al, 2018).

Estimated Short Run Coefficients

Table 5: Short-Run Estimates of Sugarcane Production Response: 1970 – 2021

Short run dynamics	Estimated short run coefficients
Error correction term (ECT)	-1.9
Temperature	-1.98
Rainfall	0.12

Table 5 shows the speed of adjustment or adjustment parameter is the Error Correction Term (ECT) coefficient, which gauges how quickly the target variable or dependent variable (Sugarcane Output) returns to equilibrium following a change in the independent variable. The series are co-integrated and moving toward a long-term equilibrium since the ECT has a substantial negative sign. The negative sign indicates that each period compensates for a fraction of the long-term equilibrium's deviance. At an adjustment speed of 1.9%, the current period's divergence from long-run equilibrium is specifically rectified from the VECM. A percentage change in temperature is associated with 1.98% decrease in sugarcane production on average ceteris paribus in the short run. A percentage change in rainfall is associated with a 0.12% increase in sugarcane production on average ceteris paribus in the short run. In addition, the coefficient of temperature was negative and significant, suggesting that rising temperature had a negative effect of sugarcane production in Nigeria. The coefficient of rainfall was positively related to sugarcane production in the short-run. This showed that rainfall had positive effect on sugarcane production during the period studied. This result is against the consistent findings of Sowunmi and Akintola (2010) and Abu (2015) who found that rainfall negatively affected sugarcane production and sorghum yield, respectively. The coefficient of the ECT_1 indicated the speed of adjustment, which restores equilibrium in the dynamic model (Ogazi, 2009). A significant ECT_1 was a further proof of the existence of a stable long-run relationship (Bannerjee et al., 1998). The coefficient of the ECT_1was negative as expected and significant at level, indicating that sugarcane production adjusts to the equilibrium given any changes in climatic variables. Consequently, for this model in the short run, sugarcane production was adjusted by 3% of the past year's deviation from equilibrium. Although this authenticated the stability of the model, it indicated a low speed of adjustment towards the long-run equilibrium.

Variance Decomposition

Table 6. Variance Decomposition

Period	Sugarcane Production	Temperature	Rainfall
5 Years	91.75427	20.62785	88.44980
10 Years	91.58842	32.03160	88.94354

Variance decomposition was employed to show the percentage error in one variable due to one standard deviation shock of the variable itself (own shocks or variations) and other variables in the system (Alege, 2010). According to Iwayemi and Fowowe, (2010), variance decomposition shows the proportion of the forecast error variance of a variable that can be attributed to its own innovations and that of other variables. In this study, the variable itself refers to sugarcane output and other variables are temperature and rainfall.

The variance decomposition of sugarcane production (table 6) showed that in Nigeria, sugarcane production contributed about 91.8% to itself in the short-run and about 91.6% in the long-run. This suggests that both variables used in the model, i.e temperature and rainfall have drastic impact on sugarcane production in both short-run and in the long-run.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined the impact of selected climatic variables on sugarcane output in Nigeria from 1970 to 2021 using an error correction model. Results showed that the ADF test indicated that only Rainfall was stationary at level and Sugarcane output and temperature became stationary after first difference. Both the Trace statistics and the Maximum eigenvalue statistics rejected the null hypothesis of no cointegration, thereby indicating presence of long-run relationship among variables. All the independent variables considered significantly affects sugarcane production in Nigeria in the period studied. Furthermore, the results of error correction model showed that sugarcane production was affected by other variables included in the model both in the long and short-runs. The coefficient of the error correction term (ECT_1) was negative and significant at level, indicating that sugarcane production adjusted to the equilibrium given any changes in climatic variables. Consequently, for this model in the short-run, sugarcane production was adjusted by 3% of the past year's deviation from equilibrium. The variance decomposition result showed that rainfall had the most drastic effect on sugarcane production. It is therefore recommended that for Nigeria to mitigate the negative consequence of climate change on sugarcane production, there is a need for the promotion of irrigation systems.

6. REFERENCES

Abdullah, N., Shahriar, S., Kea, S. & Abdullahi, A. (2020). Nigeria Cocoa Export: Gravity Model Approach.*Agribusiness Journal on International Trade Research & International Trade on Agricultural Product, Santa Maria*, 51(11), 2021.

Abu, O. (2015). Long-run relationship between sorghum yield, rainfall and producer price in Nigeria. *International Journal of Food and Agricultural Economics,* 3(1), 77-86.

Abu, O., Okpe, A.E. & Abah, D.A. (2018). Effects of climate change and other Selected Variables on Rice Output Response in Nigeria. Nigerian *Journal of Agricultural Economics,* 8(1), 1-10.

Adejuwon, S.A. (2004). Impact of climate variability and climate change on crop yield in Nigeria. Lead Paper presented at the stakeholder workshop on "assessment of impacts and adaptation to climate change" *held at Obafemi Awolowo University, IIe-Ife, 20th - 21st*.

Afolayan, O.S. (2020). Cocoa Production Pattern in Nigeria: The Missing Link in Regional Agro-Economic Development. *A paper Presentation at Semantic-Scholar*, 30(1), 88-96.

Aina, O.S., Ajijola, S., Ibrahim, I., Musa, I.A., & Bappah, T.M. (2015). Economics analysis of sugarcane (saccharum officinarum) production in Moro Local Government Area of Kwara State, *Nigeria. International Research Journal of Plant Science*, 6(1), 1-6. Retrieved August 12, 2022 from http://www.interesjournals.org/IRJPS

Ajokporise, D. (2011). Perception and impact of climate variations on crop production in Sapele, Delta State, Nigeria. *Journal of Research in National Development*, 9(1), 131-137.

Akpan, S.B., Okon, U.E., & Udo, U.J. (2017). Influence of climate change indicators on agribusiness growth index in Nigeria. In: I. A. Ayinde, A. E. Obayelu, R.A. Sanusi, L. O. Okojie, and P.A. Okuneye (Eds.). *Agribusiness Development: Panacea for Economic*

Recession in Nigeria. Proceedings of 18th Annual Conference of Nigerian Association of Agricultural Economists (NAAE) held at Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, 16-19 October, 2017. Pp. 658-666.

Alege, P. O. (2010). Are there any feasible anti-cyclical policies for Nigeria in the era of global economic crisis. *Covenant Journal of Business and Social Sciences,* 3, 25–50.

Aliyu, S. & Bawa, S. (2015). Gravity Model by Panel Data Approach: Empirical Evidence from Nigeria. *International Journal of Trade and Global Markets*, 8, 42–57.

Alvaro, C., Tingju, Z., Katrin, R., Richard, S.J., & Claudia, R. (2009). Economy-wide impact of climate change on agriculture in Sub-Saharan Africa. International Food Policy Research Institute (IFPRI). *Discussion Paper*, 008731.

Apata, T. G. (2012). Effects of global climate change on Nigerian agriculture: An empirical analysis. *CBN Journal of Applied Statistics*, *2*(1), 31-50.

Arokoyo, T. (2012). Challenges of integrating small scale farmers into the agricultural value chains in Nigeria. Being a Lead Paper Presented at the 2012 edition of the annual National Agriculture Show tagged Promoting Sustainable Investment in Agriculture in Nigeria. Unpublished.

Ayandele, A., Odekunle, T.O., Orinmogunje, O.I., & Adeoye, N.O. (2010). Impact of climate variability on tuber crop in Guinea Savannah Part of Nigeria: AGIS Approach. *Journal of Geography and Geology,* 2(1), 27-35.

Ayinde, O., Falola, A., Babarinde, O., & Ajewole, O. (2016). Empirical Analysis of Poverty and Agricultural Growth in Nigeria. *International journal of Agricultural Economics, Management and Development* 6(1), 30-37.

Ayinde, O.E., Muchiea, M., & Olatunji, G.B. (2011). Effect of Climate Change on Agricultural Productivity in Nigeria: A Co-integration Model Approach. *Journal of human ecology (Delhi, India) 35(3): 189-194*

Banerjee, A., Dolado, J.J., & Mestre, R. (1998). Error correction model tests for co-integration in a single-equation framework. *Journal of Time Series Analysis*, 19(3), 267–83.

Building Nigeria's Response to Climate Change (BNRCC) (2008). 2008 Annual Workshop of Nigerian Environmental Study Team (NEST): The Recent Global and Local Action on Climate Change, held at Hotel Millennium, Abuja, Nigeria; 8-9th October, 2008.

Busari, L.D., & Misari, S.N. (2007). Traditional method of processing "Mazarkawaila and Alewa" from sugarcane. National Cereal Research Institute, Agricultural Information Documentation and Dissemination, No. 1, pp 1 – 21.

Chappin, E. J. L., & van der Lei, T. (2014). Adaptation of interconnected infrastructures to climate change: A socio-technical systems perspective. *Utilities Policy, 31*(0), 10-17. doi:http://dx.doi.org/10.1016/j.jup.2014.07.003

Deressa, T., Hassen, R., Alemu, T., Yesuf, M., & Ringler, C. (2008). Analyzing the determinants of farmers' choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethiopia. *International Food Policy Research Institute (IFPRI) Discussion Paper No. 00798.* Washington, DC: IFPRI.

Dickey, A. D. & Fuller, W. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association,* 74 (366a), 427-431.

Edoja, P. E., Aye, G.C., & Abu, O. (2016). Dynamic Relationship among CO2 Emission, Agricultural Productivity and Food Security in Nigeria. *Cogent Economics and Finance,* 4: 1204809. 1-13.

Enete, A. A., Otitoju, M. A. & Ihemezie, E. J. (2015). The choice of climate change adaptation strategies among food crop farmers in Southwest Nigeria, *Nigerian Journal of Agricultural Economics, 5*(1), 72-80. DOI:10.22004/ag.econ.267812

Food and Agriculture Organization of the United Nations (FAO) (2015). Climate change and food security: risks and responses. https://www.fao.org/3/i5188e/I5188E.pdf

Fraser, E. (2008). Crop yield and climate change. International Institute of Tropical Agriculture (IITA). Annual Report. pp. 24-30. Available at http//www.fao/org/waicent/fao/agricult/wrpurNigeribright.htm

Gama, E.N., Abdulsalam, R.Y. & Katanga, Y.N. (2021). Estimation of Short and Long-Run Effect of Cocoa Price Fluctuation on Export and Area Harvested in Nigeria. *Dutse Journal of Pure and Applied Sciences (DUJOPAS)*, 7(1), 326-338.

George, M. K., Jennifer, N., & Charles, O. (2020). Maize Output Supply Response to Climate Change in Kenya: An Econometric Analysis. European Scientific Journal, 16(3), 1857-7881.

Goyol, S. & Pathirage, C. (2017). Impacts of climate change on agrarian infrastructure and cascading effects on human and economic sustainability in Nigeria available at: http://usir.salford.ac.uk/43561/

Hallam, D., & Zanoli, R. (1993). Error correction models and agricultural supply response, *European Review of Agricultural Economics,* 20(2), 151-166.

Howard, J.C., Cakan, E., & Upadhyaya, K.P. (2016). Climate change and its impact on wheat production in Kansas. *International Journal of Food and Agricultural Economics,* 4(2), 1-10.

Intergovernmental Panel on Climate Change [IPCC] (2007). Contribution of working group II to the fourth assessment report of IPCC- summary for policymakers.Retrieved on June 10, 2022 from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2-spm.pdf.

Iwayemi, A., & Fowowe, B. (2010). Impact of oil price shocks on selected macroeconomic variables in Nigeria. *Energy Policy*, 39, 603–612.

Iyoboyi, M. (2020). Assessing the long-run impact of institutions on economic growth: the Nigerian experience. *Journal of Economics and Allied Research*, *4*(3), 140–151. Retrieved from https://jearecons.com/index.php/jearecons/article/view/173

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. *Econometrica*, 59, 1551–1580. http://dx.doi.org/10.2307/2938278

Joshi, N. P., Maharjan, K. L., & Piya, L. (2011). *Effect of climate variables on yield of major food - crops in Nepal-A time-series analysis* (MPRA paper no 35379). Retrieved on February 01,2023 from https://mpra.ub.uni-muenchen.de/35379/1/MPRApaper35379.pdf

Koehler-Munro, & Goddard, (2010). Climate change and agriculture, Agriculture and Rural Development. Government of Alberta retrieved September 12, 2021 from http://www.agric.gov.ab.ca/&department/deptdocs.nsf//all/cl9706

Malhi, G.S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*, 1318. https://doi.org/10.10.3390/su13031318

Musa, O. D. (2021). Crop production and export diversification in Nigeria. *Journal of Economics and Allied Research*, *6*(3), 108–117. Retrieved from https://jearecons.com/index.php/jearecons/article/view/156

Mythili, G. (2006). Supply Response of Indian farmers; Pre and post reforms. *Working paper*, WP 2006-009. Indira Ghandi Institute of Development Research.

National Sugar Developmenrt Council [NSDC] (2022). Nigeria's Annual Sugar Production, Importation & Consumption. https://www.nsdcnigeria.org/nigeria-sugar-data/

Nayarana, N. S. S., & Parikh, K.S. (1981). Estimation of farm supply response and acreage allocation: A case study of Indian agriculture. (Research Report. 81-1, February). *International Institute for Applied Systems Analysis*, pp. 4-7. Luxemburg, Austria.

Nerlove, M. (1956). Estimates of supply of selected agricultural commodities. *Journal of Farm Economics,* 38(2), 495-509.

Nerlove, M. (1958). *The dynamics of supply: estimation of farmers' response to prices*, Baltimore, Johns Hopkins University Press, Pp. 267.

Niamatullah, M., & Zaman, K.U. (2009). Production and acreage response of wheat and cotton in NWFP, Pakistan. *Pakistan Journal of Agricultural Research*, 22 (4), 101-112.

Nickell, S. (1985). Error correction, partial adjustment and all that: an expository note. *Oxford Bulletin of Economics and Statistics*, 47(2), 119- 129.

Nosheen, M., & Igbal, J. (2008). Acreage response of major crops in Pakistan. *ARPN Journal of Agricultural and Biological Sciences*, 3(6), 55-64.

Nte, I.N., & Okoro, F.N. (2017). Analysis of climate change effects on rice output in Ebonyi State, Nigeria: 1990-2015. In: Ayinde, I. A., Obayelu, A. E., Sanusi, R. A., Okojie, L. O. and Okuneye, P. A. (eds.). *Agribusiness Development: Panacea for Economic Recession in Nigeria*. Proceedings of 18thAnnual Conference of Nigerian Association of Agricultural Economists (NAAE) held at Federal University of Agriculture, Abeokuta, Ogun State, Nigeria, 16-19 October, 2017. Pp. 591-596.

Nwachukwu, I., Nnanna, A., Jude, N. & George, I. (2010). Competiveness and Determinants of Cocoa Export from Nigeria.*Publication in the Report and Opinion*, 2(7), 51-54.

Ogazi, C. G. (2009). Rice output supply response to changes in real prices in Nigeria. An Autoregressive Distributed Lag Model Approach. *Journal of Sustainable Development in Africa*, 11(4), 83- 100.

Oladipupo, O. & Adedoyin, F. (2019). Determinants of Bilateral Trade Flows of Nigeria: An Application of the Augmented Gravity Model. 2019. Available from: SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3439986 >. Accessed: Feb. 14, 2021.doi:10.2139/SSRN.3439986.https://doi.org/10.2139/SSRN.3439986.SSRN:https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3439986.

Olaiya, T. A. (2016). Examining the Political-Economy of Cocoa Exports in Nigeria.*The International Journal of Applied Economics and Finance*, 10, 1-13.

Onyeneke, R.U. & Madukwe, D.K. (2010). Adaptation measures by crop farmers in the southeast rainforest zone of Nigeria to climate change. *Science World Journal*, 5(1), 32-34.

Otitoju, M. A. & Enete, A. A. (2014). Climate Change adaptation strategies and farm-level efficiency in food crop production in Southwestern Nigeria. *Tropicultura*, *32*(3),113-120. http://www.tropicultura.org/eng/content/v32n3.html

Otitoju, M. A. (2013). The Effects of Climate Change Adaptation Strategies on Food Crop Production Efficiency in Southwestern Nigeria (PhD thesis), University of Nigeria, Nsukka, Nigeria.

Otitoju, M. A., Adebo, G. M. & Arene, C. J. (2014). Identification and stochastic analysis of factors influencing technical inefficiency of Nigerian smallholder soybean farmers. *Tropicultura 32(*4), 197-204. http://www.tropicultura.org/eng/content/v32n4.html

Otitoju, M.A. & Enete, A. A. (2016). Climate change adaptation: uncovering constraints to the use of adaptation strategies among food crop farmers in South-west, Nigeria using Principal Component Analysis. *Cogent Food & Agriculture*, *2*(1), 117859. http://dx.doi.org/10.1080/23311932.2016.1178692

Oyakhilomen, O., & Zibah, R. G. (2014). Agricultural production and economic growth in Nigeria: Implication for Rural Poverty Alleviation. *Quarterly Journal of International Agriculture*, 53 (3), 207-223.

Phillips, P., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335-346.

Raza, A., Razzaq, A., Mehmood, S. S., Zou, X., Zhang, X., Lv, Y., & Xu, J. (2019). Impact of climate change on crops adaptation and strategies to tackle its outcome: A review. *Plants, MDPI*, *8*(34), doi: 10.3390/plants8020034

Sowunmi, F.A., & Akintola, J.O. (2010). Effect of climate variability on maize production in Nigeria. *Research Journal of Environmental and Earth Science*, 2(1), 19-30.

Syed, A., Raza, T., Bhatti, T. T., & Eash, N. S. (2022). Climate Impacts on the agricultural sector of Pakistan: Risks and solutions. Environmental Challenges, 6, 100433, https://doi.org/10.1016/j.envc.2021

Victor, D.G. (2011). Global Warming Gridlock: Creating more effective strategies for protecting the planet. *aa* New York, United States of America.

Weliwita, A., & Govindasamy, R. (1997). Supply response in north-eastern fresh tomato market: Cointegration and error correction analysis. *Agricultural and Resource Economics Review*, 26(2), 247-255.

World Bank. (2017). Nigeria. Available at www.worldbank.org/country/Nigeria. Accessed 05/12/2022.

World Bank. (2022). Temperature and Rainfall historical data. Climate change knowledge portal for development practitioners and policy makers. Nigeria. Available at www.sdwebx.worldbank.org/climateport Accessed 05/12/2022.

Yahya, B., & Nkwatoh, L. S. (2021). Testing the long run relationship between natural gas utilization and economic activities in Nigeria. *Journal of Economics and Allied Research*, *6*(2), 123–133. Retrieved from https://jearecons.com/index.php/jearecons/article/view/163

Yusuf, S. N., & Tiri, G. D. (2023). Exploring the impact of financial development on agricultural output in Nigeria: The moderating role of institutional quality. *Journal of Economics and Allied Research*, *8*(4), 103–119. Retrieved from https://jearecons.com/index.php/jearecons/article/view/347