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Effects of Climate Variation on Cocoa Production in Nigeria

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Abstract

This study investigates the impact of climatic variations, specifically precipitation, temperature, wind speed and relative humidity on cocoa production in Nigeria. Secondary data spanning forty one (41) years (1981 to 2021) was used. The study employed the Autoregressive Distributed Lag (ARDL) model to analyze the short and long-term effects of climate variability on cocoa yield. The results reveal significant findings regarding the relationship between weather variables and cocoa production. Harvested area (HA) and wind speed (WS) exert a long-run negative influence on cocoa production. However, precipitation (P), relative humidity (RH), and temperature (T), did not show any significant effect on cocoa yield in the long run. In the short run, HA exhibited mixed effects, negatively impacting yield in the next season but positively affecting yield in subsequent seasons. Precipitation has a short-run negative effect on cocoa yield, though there was a positive impact in the next season. Relative humidity (RH) negatively influenced cocoa yield in the short run, while an increase in T resulted in a notable short-run decline in cocoa yield. Cocoa yield was affected negatively by WS in the short run, with a 20% fall associated with a unit rise. The study recommends the development and adoption of climate-resilient cultivation strategies by cocoa farmers to address the challenges posed by changing climate. Government and stakeholders in cocoa value chain are encouraged to establish effective monitoring systems and early warning mechanisms for extreme weather events.

Keywords: Cocoa yield, Precipitation, Wind speed, Relative humidity, Temperature

Introduction

Agriculture is crucial to the development of third-world countries because it provides food, raw materials, employment, and foreign exchange earnings (Nugroho and Lakner, 2022). It also provides the main source of income for approximately 70% of the world's impoverished population (Tomich *et al*., 2019). Agriculture employs approximately 1.3 billion smallholder farmers worldwide (Agbenyo *et al*., 2022). Cocoa is an evergreen crop that is commonly grown in the warm and humid region yielding a larger percentage of output by smallholder cultivator in West Africa (Doe *et al*., 2022). It has been produced to be an important cash crop since 1874 when it was introduced to Nigeria (Owoeye and Adelomo, 2016). According to Abdullahi *et al.,* (2022), Nigeria was ranked as the fourth biggest maker of cocoa in Africa, generating about 12 percent of the Gross Domestic Product (GDP), Ivory Coast generate 35 percent while Indonesia and Ghana is 13%. It is glaring that Nigeria could generate cocoa on a global economy (Ogunwolu *et al*., 2022). It was recorded that Nigeria has achieved about 385,000 metric tons per annum on the productive potential with an increment of 215,000 metric tons from year 2000 production level (Busari *et al.*, 2022).

Meanwhile, despite being a major producer of cocoa in the world, experts believe that Nigeria is still not producing to its full potential, as authors report a significant fall in cocoa production in Nigeria due to cocoa yield vulnerability among changing climatic parameters. Ajagbe *et al.,* (2021) identified several environmental and socioeconomic factors that influence production of cocoa over the long and short terms. These include sunshine, annual rainfall, temperature, and CO_2 emissions. Some of the environmental CC offset possibilities that should be investigated, researched, and discussed in light of the impact of CC are nutrient cycling, carbon sequestration, habitat preservation, and hydrological cycling (Olabode, 2020). Climate change is characterized by significant and long-lasting variation in the statistical properties of the average weather condition over long periods of time, regardless of cause (Intergovernmental Panel on Climate Change, 2023) and can be defined as the variation in average weather caused by human activities as well as natural occurrences that change the atmosphere's composition over a comparable period of time.

Sultan and Gaetani (2016) discovered that the consequences of CC are more noticeable in Africa due to its geography, its entire reliance on agriculture and its specific inability to endure and tolerate climate. Harmful results of global warming remained to be a great hazard to the peasant farmers (Ghosh and Ghosal, 2021). In Nigeria, a greater number of rural farmers rely solely on rainfall for water. It is very important because enough atmospheric conditions are necessary for crop cultivation and growth (Haider, 2019). Some crops most especially cocoa, is extremely sensitive to atmospheric condition and ways to cultivate it is associated with the way how rainfall is being evenly distributed (Lahive *et al.*, 2019).

There are numerous factors affecting the production of this cash crop in Nigeria resulting in its decrease in output in the last few years (Olabode, 2020). Climate variability is among the critical factors. Climate variability has captured a prime focus among different frightening environmental factors that has been a constraint to the earth (Marks, 2019). The broad objective of this study was the effects of climate variation on cocoa production in Nigeria. The specific objectives were to:

1. examine the trend of weather variables on cocoa production over a period of time
2. evaluate the short and long run effects of climate variability on cocoa production

Materials and Methods

This study adopted annual secondary data for a period of forty one (41) years (1981 to 2021). The data for the weather variables considered were obtained from National Aeronautics and Space Administration (NASA), climate database (2023). While the data for cocoa yield was sourced from Food and Agricultural Organization database (FAO, 2023). Autoregressive Distributed Lag (ARDL) model by Pesaran *et al* (2001) was adopted to achieve the second objective of this study. This model was adopted against other co-integration/long-run models due to its ability to ascertain co integrating relationship even in the presence of variables with mixed order of integration as well as its suitability for small sample datasets.

Model Specification

The ARDL equation is specified thus:

$$LCOCY = \alpha_0 + \sum_{i=1}^{m} \beta_{1i} LCOCY_{t-i} + \sum_{i=1}^{n^1} \beta_{2i} LHA_{t-i} + \sum_{i=1}^{n^2} \beta_{3i} PREC_{t-i} + \sum_{i=1}^{n^3} \beta_{4i} RELH_{t-i} + \sum_{i=1}^{n^4} \beta_{5i} TEMP_{t-i} + \sum_{i=1}^{n^5} \beta_{6i} WINSP_{t-i} + \lambda_1 LCOCY_{t-1} + \lambda_2 LHA_t + \lambda_3 PREC_t + \lambda_4 RELH_t + \lambda_5 TEMP_t + \lambda_6 WINSP_t + \varepsilon_t \ldots. (1)$$

Where:

LCOCY= log of cocoa yield (hg/ha)

LHA= log of harvested area (ha)

PREC= precipitation (percentage mm/day)

RELH= relative humidity (2 meters measured in percentage)

TEMP=temperature (degrees).

ε_t=error term

α_0=intercept term

$\beta_1, \beta_2 \ldots \beta_6$= short run coefficients

$\lambda_1, \lambda_2 \ldots \lambda_6$= long run coefficients of the model.

Results and Discussion

The result of the ADF unit root test is presented in Table 1 below. The results show that the variables exhibit mixed orders of integration with cocoa yield (LCOCY) and harvested area (LHA) stationary at level 1, while precipitation (PREC), relative humidity (RELH), temperature (TEMP) and wind speed (WINSP) stationary at first difference. This result shows that the Johansen co-integration technique is not suitable for this model, hence, Autoregressive Distributive Lag (ARDL) model which allows for the estimation of variables which are of order and one was adopted for the study. The estimation of time series data requires stationarity test because the mean and variances in time series data are usually time variant which could result in spurious regression estimates (Smith, 2000).

Stationarity test or unit root test helps to ascertain the stationarity of the mean and variance. A unit root stationarity test helps determine if your data over time is stable and predictable or if it tends to wander unpredictably. This information is crucial for making accurate forecasts and building reliable statistical models. This study adopted the Augmented Dickey Fuller (ADF) unit root test. The result of the bounds test F-statistics is displayed in Table 2 below. In order to proceed with ARDL estimation, there is a need to test for co-integration using Bounds F-test framework. Cointegration is like a long-term relationship between two or more time series. Even if they seem to drift apart in the short run, they maintain a consistent relationship over time. This concept helps in understanding and predicting how different time series are related in the long run. The condition necessary for the presence of co-integration is that the F-statistics must be greater than the upper bound. According to the table below, the estimated F-statistics of 6.11 is greater than the upper limit of 3.38. Consequently, we affirm the existence of co-integration and long run relationship between our variables; hence we proceed to estimating the ARDL model.

Table 3 below shows the result of the long-run ARDL model estimated for the effect of weather variability on cocoa production in Nigeria. The ARDL model was estimated following the (1, 4, 3, 5, 2, 4) lag specification. The model selection criterion employed was the Akaike Information Criterion (AIC) and Schwartz Information Criterion (SIC).

The table reveals that harvested area has a long-run negative effect on cocoa production in Nigeria. One percent increase in harvested area will result in approximately 2 percent fall in cocoa yield in the long-run. An increase in harvested area can potentially have negative effects on cocoa yield due to various factors. These factors such as soil quality, efficiency of manpower, availability of water, and pests and diseases could result in lower cocoa yield even in the event of increased cultivation area. According to USDA and USHHS (2011), traditional cocoa farming practices, including the clearance of large forest tracts, can lead to reduced crop yields and significant impact on biodiversity.

Similarly, WS impacts cocoa yield negatively in the long-run. A percentage rise in WS will result in about 38 percent fall in cocoa yield in the long-run. Heavy wind impacts cocoa tree negatively; it often results in falling of leaves, breaking of branches, increased spread of diseases and dropping of unripe cocoa pods (Reis *et al.,* 2018). High WS can topple shade trees and cause significant damage to cocoa trees, which may lead to a reduction in shade tree density and, consequently, a decrease in cocoa yield (Adejuwon *et al.,* 2023). These ultimately results in a fall in the yield of such tree overtime. The result further shows that P, RH and T do not significantly affect cocoa yield in the long run.

Furthermore, the result for the effect of weather variability on cocoa yield in the short-run is presented in Table 4 below. The result depicts the short-run inter period dynamics between cocoa yield and weather variables. An increase in harvest in the current planting season does not significantly impact cocoa yield in the same season. However, it negatively impacts on yield in the following season. One percent rise in harvested area in the current season will result in about 1.5 percent fall in cocoa yield in the next season at 1 percent significance level. Contrarily, one percent rise in harvested area in the current season will increase cocoa yield by 1.12 percent by the next two seasons. This positive impact on yield is expected to be prolonged into the third season. An increase in harvested area may take time to impact cocoa yield positively due to several factors related to the biology of cocoa trees, agricultural practices, and environmental considerations (Suh and Molua, 2022).

Precipitation (P) has mixed effects on cocoa yield in the short-run. One percent rise in P per day in the current season results in 0.09 percent fall in cocoa yield in the same season. However, this negative effect will taper out in the second season due to the fact that cocoa plant required water to survive. One percent rise in P in the current season will result to approximately 0.2 percent rise in cocoa yield in the next season. According to Asante *et al* (2021) P, which includes rainfall, can have mixed effects on cocoa yield due to the complex interactions between water availability, cocoa plant physiology, and the overall environmental context. Cocoa trees require a certain amount of water for optimal growth and fruit development. Adequate rainfall during the growing season is crucial. However, excessive rainfall, especially in poorly drained soils, can lead to water-logging, root rot, and other adverse conditions that negatively impact cocoa trees (Kaur *et al*., 2020).

Relative humidity (RH) was shown to have a negative effect on cocoa yield in the short run. A one percent rise in RH in the short-run will result in about 0.05 percent fall in cocoa yield. High RH promotes the growth and spread of fungal diseases, such as black pod disease and witches' broom disease. These diseases can affect the cocoa pods and beans, leading to a reduction in yield and quality (Jiménez *et al*., 2021).

There is a negative relationship between (T) and cocoa yield in the short-run. An increase in average daily temperature by one degree in the current planting season will result in approximately 11.6 percent fall in cocoa yield in the same season. The rise in T in the current season is expected to impact cocoa yield in the next season by approximately 25 percent at one percent level of significance. This result is in line with the findings of Agbenyo *et al.,* (2022) who stated that high T can lead to heat stress in cocoa trees. Excessive heat can affect the process of photosynthesis, leading to reduced carbohydrate production and overall stress on the plant. This can result in decreased flower and pod development, ultimately impacting cocoa yield.

In addition, the table reveals that WS impact cocoa yield negatively in the short-run in Nigeria. A unit rise in the average WS will result in about 20 percent fall in cocoa yield in the short-run at one percent significance level. According to Effah *et al.,* (2023), high WS are often associated with storms and cyclones which cause physical damage to cocoa trees, including broken branches, uprooting, and defoliation. Such damage can lead to immediate losses in cocoa yield. Wind can facilitate the spread of pests and diseases. In the short run, increased WS may contribute to the rapid transmission of diseases or the dispersal of pests, affecting cocoa yield negatively (Lim *et al*., 2023).

The error correction term's coefficient (-0.713) satisfies the ARDL conditions of being negative less than one and statistically significant. The error correction coefficient implies that about 71 percent deviation from long-run economic growth caused by shocks in previous period converges back to long run equilibrium in the present period. The R-square value obtained shows that approximately 88 percent of variations in the dependent variable are explained by the exogenous variables. The Durbin-Watson statistics value of 2.291 indicates that there are no serial correlations between variables.

The analysis involved conducting tests to assess normality, the presence of heteroscedasticity, and the Ramsey RESET test for model misspecification. The Jarque-Bera normality test resulted in a probability value of 0.793, indicating that, at all significance level, the model conforms to a normal distribution. Consequently, there is insufficient evidence to reject the null hypothesis that residuals adhere to a normal distribution at the specified significance level.

A Serial Correlation Lagrangian Multiplier test was conducted to scrutinize the presence of heteroscedasticity within the model. The results confirm that residuals exhibit no serial correlation, as indicated by a probability value of 0.447, surpassing the 0.10 threshold. This suggests that residuals resemble white noise. Additionally, diagnostic testing affirms the validity of estimated parameters, indicating that the model is homoscedastic with a probability value of 0.736, according to the results of the Breusch-Pagan-

Godfrey Heteroscedasticity test. Consequently, it can be inferred that errors converge in the long run, suggesting an absence of heteroscedasticity. This conclusion is further supported by the ARCH test result, yielding a probability value of 0.768, indicating that error terms lack a discernible pattern or size. In summary, all the aforementioned diagnostic tests collectively indicate that the model is robust and meaningful, enabling the effective and efficient derivation of significant conclusions.

Table 1: Unit Root Test for the effects of climate variation on cocoa production in Nigeria

Variable	**Level**	**First Difference**	**I(D)**
LCOCY	-2.870105	-5.940146***	I(1)
LHA	-1.470197	-7.681948***	I(1)
PREC	-5.387491***		I(0)
RELH	-3.831202**		I(0)
TEMP	-5.565565***		I(0)
WINSP	-5.815730***		I(0)

Source: (NASA), climate database (2023) and FAO (2023)
****1%, **5% and *10%*

Table 2: Bounds F-test Result effects of climate variation on cocoa production in Nigeria

K	F-statistics	Lower Limit*	Upper Limit*
5	6.11	2.39	3.38

*Peseran *et al*., (2001): Critical values were selected for a significance level of 5%

Table 3: ARDL Long-run Results for the effects of climate variation on cocoa production in Nigeria

Dependent variable: LCOCY	Long-run coefficients	Standard Error	t- statistics
LHA	-2.024***	0.519	-3.902
PREC	-0.401	0.241	-1.659
RELH	-0.044	0.048	-0.917
TEMP	0.021	0.096	0.219
WINSP	-0.379**	0.168	-2.261
R-squared	0.884		
Adjusted R-squared	0.632		
Durbin-Watson stat	2.291		
F-statistic	3.503		
Prob (F-statistic)	0.017		

Asterisk * implies significance at the one percent level. Source: Authors Computation, (NASA), climate database (2023) and FAO (2023).

Table 4: ARDL Short-run Results for the effects of climate variation on cocoa production in Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LHA)	-0.032	0.39	-0.081	0.937
D(LHA(-1))	-1.544***	0.415	-3.719	0.003
D(LHA(-2))	1.119**	0.392	2.854	0.016
D(PREC)	-0.089*	0.042	-2.09	0.061
D(PREC(-1))	0.205***	0.051	4.013	0.002
D(PREC(-2))	0.091**	0.041	2.249	0.046
D(RELH)	-0.054***	0.015	-3.674	0.004
D(RELH(-1))	-0.006	0.012	-0.487	0.636
D(TEMP)	-0.116***	0.028	-4.2	0.002
D(TEMP(-1))	-0.246***	0.037	-6.68	0
D(WINSP)	-0.201***	0.033	-6.085	0
CointEq(-1)*	-0.713***	0.088	-8.13	0
R-squared	0.881			
Adjusted R-squared	0.755			
S.E. of regression	0.101			
Sum squared resid	0.174			
Durbin-Watson stat	2.291			

Table 5: Diagnostic Tests Result Summary for the effects of climate variation on cocoa production in Nigeria

Test	Probability
Jaurque-Beranormality TEST	0.793
Serial correlation LM TEST	0.447
Breusch-Pagan- Godfrey Heteroscedasticity TEST	0.736
ARCH TEST	0.768

Source: Extract from estimation output using E-views 10

Figure 1 and Figure 2 below present graphical representations of cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals squares (CUSUMSQ), respectively. To evaluate the robustness of our models, we utilized the structural stability test, which is based on the methods introduced by Pesaran and Pesaran (1997). Adhering to these guidelines shows that if the plots consistently remain within the 5% critical bound, it indicates that the model parameters are stable and reliable. The plots of our model unequivocally illustrate that CUSUM and CUSUMSQ consistently stay within these boundaries throughout the observed period, confirming the stability and reliability of our model. Consequently, the CUSUM and CUSUMSQ tests do not yield any evidence of instability in the model.

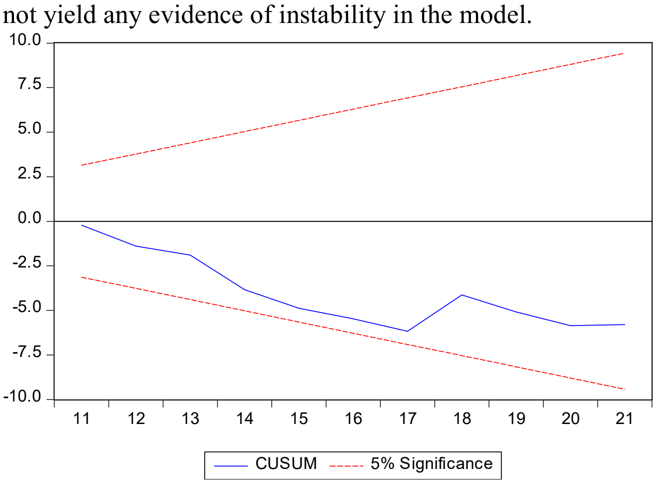

Figure 1: Cumulative Sum of Recursive Residuals (CUSUM) Diagnostic Test for the effects of climate variation on cocoa production in Nigeria

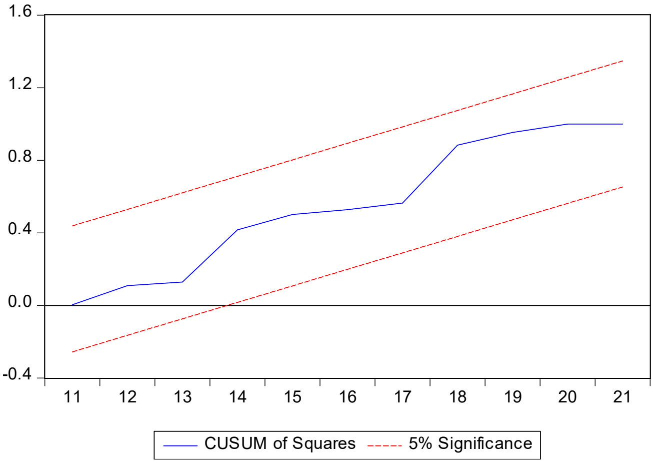

Figure 2: Cumulative Sum of Recursive Residuals Squares (CUSUM) Diagnostic Test for the effects of climate variation on cocoa production in Nigeria

Conclusion and Recommendation

In conclusion, the examination of cocoa yield trends underscores the vulnerability of cocoa production in Nigeria to climatic variations. Cocoa yield in Nigeria is significantly impacted by harvested area and wind speed in the long run.

Furthermore, harvested area demonstrates varying impacts on cocoa yield in the short term, with a negative effect in the first season but a positive influence in subsequent seasons. Precipitation, relative humidity, and temperature exhibit mixed effects on cocoa yield in the short run, emphasizing the intricate nature of these relationships. Resources should be channelled towards continuous research and development in the field of cocoa cultivation, focusing on innovative methods and technologies that enhance resilience to climatic variations. Furthermore, provision of training programs for cocoa farmers on climate-smart agriculture (CSA), emphasizing the importance of adapting to changing weather patterns and implementing sustainable practices. Similarly, farmers should diversify crop varieties to limit the impact of climate variability. Efficient irrigation systems, like drip irrigation, alongside rainwater harvesting should be undertaken by the farmers. Also, farmers should incorporate shade trees and inter cropping within plantations to create favourable micro climate and improve biodiversity. Cocoa production stakeholders should encourage the establishment of effective monitoring systems and early warning mechanisms for extreme weather events, allowing farmers to take timely actions to protect their cocoa crops.

Conflict of Interest: Authors declare that there is no conflict of interest in this work.

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