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Effects of Climate Change on Cereal Production in Nigeria

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ABSTRACT

Climatic elements are important inputs in agricultural production in developing countries, implying that most of the staple food produced is from climate-dependent agricultural practices. This study investigated the effects of climate change on cereal production in Nigeria. The annual secondary data used was from 1985 to 2022. Deterministic trend analysis, Augmented Dickey Fuller Test, Johansen Co-Integration Test, and Augmented Regressive Distributive Lag Model. The result shows that there was evidence of a trend in the average annual rainfall (β=7.36; p=0.00), average annual temperature (0.03; p= 0.00), annual CO_2 emission (β=2.02; p= 0.00), and annual cereal production (β=381098; p=0.00) in Nigeria. In the long run, previous value of temperature (β= 3826547; p=0.00) and land under cereal production (β=1.325; P=0.00) have a positive effect on cereal production, while previous value of rainfall (β=-23987.60; p=0.00) and population growth rate (β=-1.2E7; p=0.00) have a negative effect on cereal production in Nigeria. In the short run, the previous value of rainfall (β=8815.253; p=0.00) has positive effect on cereal production, while the current value of rainfall (β=-6270.92; p=0.00) and, previous value of temperature (β=-1218286; p=0.04) have a negative effect on cereal production. It was also confirmed that there was no significant relationship between CO_2 emissions and cereal production. Thus, cereal production is susceptible to climate change, that both the previous and the current weather elements. To reduce these effects, this study recommends that innovative and sustainable farming, which requires less use of resources, prevents land degradation, supports climate resilience, and ultimately improves productivity and productivity should be encouraged.

Key Words: Climate Change, Cereal production, Deterministic trend, Augmented Regressive Distributive Lag Model.

INTRODUCTION

According to Zougmoré *et al.* (2018), rainfall has been a crucial input to agricultural production in developing countries for time immemorial, implying that most staple foods are produced through rain-fed agricultural practices. Agricultural activities and climate change are related. Climate and weather events have control over the living and non-living organisms responsible for crop growth and thus agricultural production (Neupane *et al.*, 2022). It is also of great concern that temperature change and rainfall distribution patterns substantially affect the natural inputs used in the farming system (Sissoko *et al.*, 2011). This makes agriculture and those living off it dependent on the climate and its variability.

Cereals are grown in greater quantities than other food crops and serve as a higher source of food energy. In accordance, Sufiyan *et al.* (2020) mentioned that cereal is a widely accepted staple food globally. However, its growth and development are unfortunately controlled by climate elements, especially precipitation and temperature. As such, every element that affects its production is worth investigating to achieve food security, because the food availability dimension of food security has always been determined by food production. Evidence has shown that food production has been threatened by the "monster" called climate change, increasing the number of undernourished populations globally (Affoh *et al.*, 2022).

The implications of climate and its variabilities are vast and can be direct or indirect with varying degrees at different geographical locations (Abdisa *et al.*, 2022; Pickson *et al.*, 2020b). Akano *et al.* (2021) confirm a reduction in the yield of cereals such as maize and sorghum in Nigeria in response to temperature rise. In accordance, FAO (2015) predicted an increase in cereal consumption due to the increasing population. According to the World Bank Report, there is evidence of an increased food price index in the rise in prices of maize, wheat, and rice within a year by 8%, 14%, and 1% respectively. The result of the research is pertinent to improve cereal production, haven ascertained how climate change disrupt agricultural production in Nigeria.

Therefore, the broad objective of the study is to investigate the effects of climate change on cereal production in Nigeria. The specific objectives are to ascertain the presence of trends in some selected climate variables and cereal production in Nigeria and to evaluate the long and short-run relationship between climate change and cereal production. This research tested the following hypotheses:

Ho_1: Carbon dioxide emission has no significant effects on cereal production in Nigeria.
Ho_2: Rainfall has no significant effects on cereal production in Nigeria.
Ho_3: Temperature has no significant effects on cereal production in Nigeria.

MATERIALS AND METHODS

The study was carried out in Nigeria. In land area, the study area covers about 923,768 km^2 (Central Intelligence Agency, 2024). Nigeria experiences seven months of rainfall annually, with a maximum of about 3000mm and a minimum of 500mm precipitation based on the part of the country. The average temperature in Nigeria is 26.5 ^{0}C. The agricultural land in hectares is about 70.8 million (David, 2022).

Data Source and Data Collection

The national aggregate secondary data on climatic variables, cereal production and other control variables between 1985 and 2022 (38 years) used for this research were obtained from the Nigeria Metrological Agency (NIMET), the Food and Agriculture Organisation of the United Nations Statistics (FAOSTAT), and the World Bank.

Analytical Techniques

Inferential statistics tools and methods of variable measurement for each of the stated objectives are as follows:

Deterministic Trend Analysis

Trend analysis is a very useful tool for detecting the presence of a pattern in the behaviour observed and forecasting any possible variation in the future (Hui-Mean et al., 2018). Thus, the deterministic trend analysis was used to determine the trend by regressing the time series against time. The null hypothesis, H_0 = 0, implies a slope of zero. When the slope is statistically significant, there is evidence of a deterministic trend. The standard deterministic trend regression model is written as:

$$Y_t = \alpha + \beta t + \varepsilon_t \text{ --------------------------- } (1)$$

Y_t is the time series; α is the intercept(Constant); β is the slope of the trend (Rate of change over time); t *is the time*; ε_t is the error term.

Augmented Regressive Distributive Lag model (ARDL)

This model helps to estimate the long and short relationships that exist among variables. The model is given as:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{q} \beta_{xi}\, \Delta x_{t-i} + \sum_{i=1}^{q} \beta_{yi}\, \Delta y_{t-i} + \alpha_1 \mu_{t-1} + \varepsilon_t \text{ --------------------------- } (2)$$

Model Specification

This displays the model specification for the ARDL model used to estimate the long- and short-term relationship between climate change and cereal production (Objective 3).

$$\Delta CP_t = \alpha_0 + \sum_{i=1}^{p} \beta_{xi}\, \Delta CP_{t-i} + \sum_{i=1}^{q1} \beta_{x2}\, \Delta R_{t-i} + \sum_{i=1}^{q2} \beta_{x3}\, \Delta T_{t-i} + \sum_{i=1}^{q3} \beta_{x4}\, \Delta CO2_{t-i} + \sum_{i=1}^{q4} \beta_{x5}\, \Delta PG_{t-i} + \sum_{i=1}^{q5} \beta_{x6}\, \Delta CL_{t-i} + \pi_1 CP_{t-1} + \pi_2 R_{t-1} + \pi_3 T_{t-1} + \pi_4 CO2_{t-1} + \pi_5 PG_{t-1} + \pi_6 AL_{t-1} + \alpha_1 \mu_{t-1} + \varepsilon_t \text{ -- } (3)$$

Where: $\alpha_1 \mu_{t-1}$ is the error correction term; βs are the parameters to be estimated (the short-run coefficients indicating a short-run relationship between endogenous variables); π is the long-run coefficient; Δ reps the first difference operator; α_0 is the constant; t is 38 years; ε is the error term; CP is Cereal production(millions/annum); R is the Average annual rainfall(mm); T is the Average annual temperature(0^c); PR is the Population growth rate(%/annum); AL is the Land under Cereal Production(Hectares/annum); CO_2 is Carbon dioxide emissions(Metric tons/annum).

RESULTS AND DISCUSSION

Trend Analysis

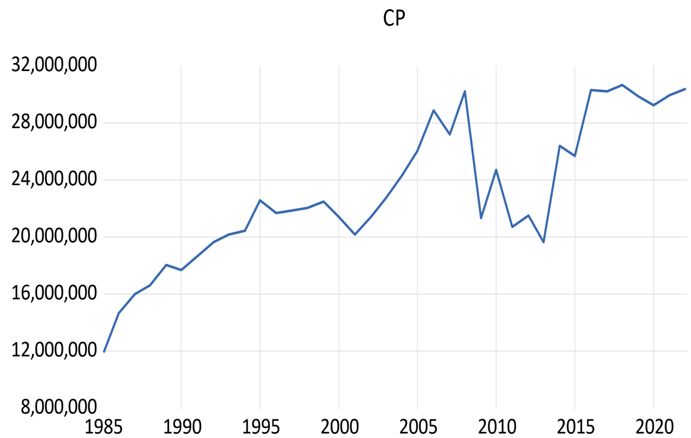
The deterministic trend analysis result shown in Table 1 reveals a significant positive trend in rainfall, temperature, cereal production, and CO_2 emission. This depicts an upward linear pattern in these variables over time. According to Figure 1, there was a sharp rise in cereal production from 1985 to 1995, followed by stability until the year 2000, when production declined. From 2010 to 2022, production increased gradually, indicating an overall upward trend in Nigeria. Figure 2 reveals CO_2 emissions rising from about 70 to 130 million tons by 2022. After a brief drop around 1987 and stability till 1993, emissions climbed sharply above 90 million tons, stabilised, then surged past 120 million tons in 2011, maintaining a steady rise thereafter. Figure 3 indicates that annual rainfall followed an irregular upward pattern—rising from 1,200 mm in 1987 to 1,800 mm in 2020, before dropping to 1,650 mm in 2022. Figure 4 shows population growth increasing until 2010, then declining slightly through 2022. Figure 5 reveals annual temperature fluctuating between 26.4°C and 28°C, rising from 26.9°C in 1985 to 27.6°C in 2022—an overall increase of about 0.7°C.

Table 1: Deterministic Trend Analysis (Trend Regression)

Variables		Coefficient	Prob
Rainfall	Constant	1342.27	0.000
	Trend	7.36	0.000
Temperature	Constant	26.90	0.000
	Trend	0.03	0.000
Cereal Production	Constant	16003229.00	0.000
	Trend	381098.90	0.000
CO_2 Emission	Constant	60.95	0.000
	Trend	2.02	0.000

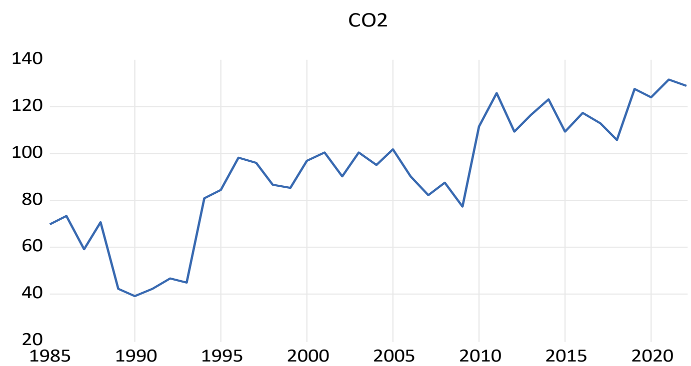
Source: Author's Computation using Eview 10 (2024)

Figure 1: Cereal Production Trend in Nigeria



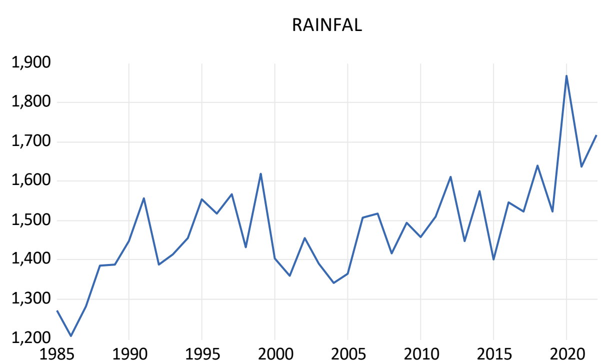
Source: Author's Computation with EViews (2024)

Figure 2: CO_2 Emission trend in Nigeria



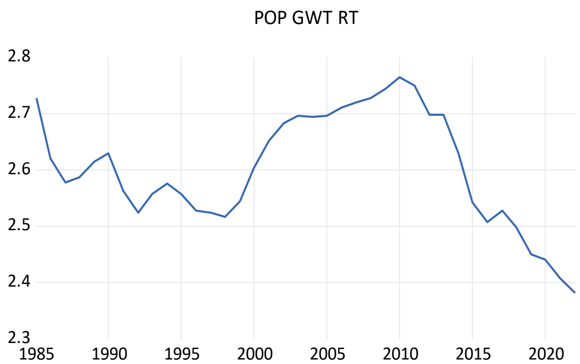
Source: Author's Computation with EViews (2024)

Figure 3: Rainfall Trend in Nigeria



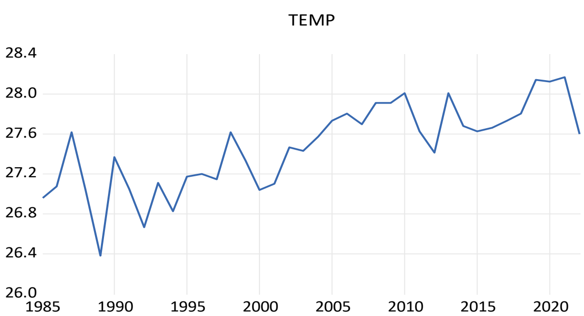
Source: Author's Computation with EViews (2024)

Figure 4: Population Growth Rate Trend in Nigeria



Source: Author's Computation with EViews (2024)

Figure 5: Annual Temperature Trend in Nigeria



Source: Author's Computation with EViews (2024)

Unit Root Test (Stationary)

The Autoregressive Dickey-Fuller, ADF's result in Table 2 reveals that cereal production is stationary at levels at ADF Statistic level of 3.612735 and 5% significance level. Land under cereal production is stationary at levels, therefore integrated at I(0) with ADF statistics level of 3.609 at 5%. Temperature has an ADF statistic of 5.013, which is significant at 1%. This implies that temperature is stationary at level and integrated at I(0). Likewise, CO_2 emission is stationary at levels with ADF statistics of 3.327179 and a 10% significance level. However, rainfall and population growth rates are stationary at the first difference, and integrated at I(1), at 1% significance level. Therefore, the ARDL bound test was used to test for co-integration, since the variables were integrated at levels I(0) and the first difference, I(1).

Table 2: Unit Root Test Result (ADF Test)

Variables	ADF Statistic at I(0)	ADF Statistic at I(1)	Critical value	Status
CP	3.612735		3.544284	I(0)**
CO_2	3.327179		3.20032	I(0)*
AL	3.609		3.536601	I(0)**
PR		4.140	3.627	I(1)***
R		11.921	4.235	I(1)***
T	5.013		4.227	I(0)***

Source: Author's Computation using Eview 10 (2024)

*** implies significant at 1%, ** implies significant at 5% and * implies significant at 10%.

Co-integration test (ARDL Bound Test)

The co-integration test shows that the F-statistic value is 3.7, which is significant at 10%, since the value is greater than 2.49 and 3.38, the critical lower and upper bound values, respectively, as revealed in Table 3. This implies that there is a co-integration among the variables; as such, a long-run equilibrium relationship exists among cereal production, land under cereal production, temperature, rainfall, CO_2 emission, and population growth in Nigeria. As a result, the ARDL and ECM were conducted to determine the long and short-term relationships among the variables.

Table 3: Co-integration ARDL Bound Tests Results				
Test Statistic	Value	Significance	I(0)	I(1)
=1000			Asymptotic: n	
F-Statistic	3.706542	10%	2.49	3.38
K	5	5%	2.81	3.76
		2.5%	3.11	4.13
		1%	3.5	4.63

Source: Author's Computation with Eviews 10, 2024

Table 4 shows the long-run relationship between the dependent and independent variables. It confirms that land under cereal production, population growth rate, rainfall, and temperature have a long-run relationship with cereal production in Nigeria. According to the result, temperature has a direct relationship with cereal production in Nigeria. According to FAO (2015b), the impact of temperature on food production will vary from region to region. Some crops will be hurt by the effect, while some will enjoy the increasing warmth to an extent. In addition, different crops have varying temperature requirements for optimal yield. Land under cereal production has a direct and positive relationship with cereal production. This result follows the a priori expectation. As the input in production increases, the output also increases. CO_2 emissions have an inverse relationship with the dependent variable. Abbass *et al* (2022) confirmed that CO_2 emissions have a negative long-term effect on cereal production, which aligns with the result of this study. Rainfall has a negative effect on cereal production in Nigeria. This result is consistent with Alehile *et al (2022)* , who recorded a negative effect of rainfall on crop output in the long run. Also, Idumah *et al* (2016) found a matching result that in the long-run, rainfall affects agricultural output. Population growth has a negative effect on cereal production in Nigeria. According to Malthusian theory, the expectation is that as the population grows, the input for cereal production will decrease. This is confirmed by the negative relation revealed by the results of this study.

The short-run result shows that all the independent variables are significant. The ECM value (-0.849) shows the adjustment speed of the model to equilibrium. This means that, in the case of disequilibrium, the average speed of correction back to the long run from the short run is 85%. The R-squared explained that the variables are responsible for 91% variation in cereal production in Nigeria. The coefficient and probability values show that the F statistic 29.435 reveals a perfect fit of the model used, and it is significant at 1%.

The short-run coefficient and the probability value of each variable reveals that the previous or lagged value of rainfall have a positive effect on cereal production, while the current value of rainfall has a negative influence on cereal production in Nigeria. In addition, the current value of temperature has a positive effect on cereal production, while the previous value of temperature has a negative effect on cereal production. These reflect the high sensitivity of cereal production in Nigeria to climate elements, its timing, and the aftermath of the past seasons.

Table 4 ARDL Long-run Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.4E+07	43236698	0.00	0.00
@TREND	268486.60	67565.13	3.97	0.00
CP(-1)	-0.849	0.10	-8.19	0.00
CO_2	-18949.90	14739.04	-1.29	0.21
T(-1)	3826547	1557844.00	0.00	0.00
PR	-1.2E+07	3167811.00	0.00	0.00
R(-1)	-23987.60	5619.48	-4.27	0.00
AL	1.325	0.16	8.48	0.00

ECM and Short-run result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-437 70714.000	3506903	0.00	0.00
@TREND	268486.6	25660.23	10.46	0.00
D(CP(-1))	-0.139	0.07	-2.08	0.05
D(CP(-2))	0.175	0.07	2.45	0.02
D(R)	-6270.92	1760.46	-3.56	0.00
D(R(-1))	8815.253	2075.09	4.25	0.00
D(R(-2))	5075.882	1765.21	2.88	0.01
D(T)	891830.3	474138.7	1.88	0.08
D(T(-1))	-1218286	538578.30	-2.26	0.04
CointEq(-1)*	-0.849	0.07	-12.63	0.00
R-squared	0.914			
Adjusted R-squared	0.883			
F-statistic	29.435			
Prob(F-statistic)	0			
Durbin-Watson stat	2.171			

Source: Author's Computation with Eviews 10 (2024)

Hypothesis Testing

Table 5 presents the results of the hypothesis of the ARDL ECM regression for the research on the effect of climate change on cereal production in Nigeria. The climate change variables used for this research are temperature, rainfall, and CO_2 emission. The hypothesis Ho_1, CO_2 emission has no significant effect on cereal production in Nigeria, was accepted at the 5% level of significance. Also, hypothesis HO_2, rainfall does not significantly affect cereal production in Nigeria, was rejected at 5% of significance. Likewise, the hypothesis of this study fail to accept HO_3 that temperature is not significantly related to cereal production in Nigeria. The study fails to accept the null hypothesis that there is no significant relationship between land under cereal production and cereal production in Nigeria. The study also fails to accept the null hypothesis that there is no significant relationship between population growth rate and cereal production. Accepting the alternative hypotheses denotes that there is a significant relationship between land for cereal production and population growth rate and cereal production because their calculated t-statistics (7.731 and 3.441 respectively) are greater than the tabulated t-statistics (2.042).

Table 5: Hypothesis Testing for the relationship between climate variables and cereal production

Hypothesis	Variable	Ttab (5%)	Tcal	Decision Rule	Remarks
Ho: β1 = 0	CO_2	2.042	1.314	Tcal>Ttab, Reject Ho	Ho Accepted
Ha:β1 > 0				Tcal<Ttab, Accept Ho	
Ho: β3 = 0	AL	2.042	7.731	Tcal>Ttab, Reject Ho	Ho Rejected
Ha: β3 > 0				Tcal<Ttab, Accept Ho	
Ho: β4 = 0	PR	2.042	3.441	Tcal>Ttab, Reject Ho	Ho Rejected
Ha: β4 > 0				Tcal<Ttab, Accept Ho	
Ho: β5 = 0	R	2.042	3.486	Tcal>Ttab, Reject Ho	Ho Rejected
Ha: β5 > 0				Tcal<Ttab, Accept Ho	
Ho: β6 = 0	T	2.042	2.733	Tcal>Ttab, Reject Ho	Ho Rejected
Ha: β6 > 0				Tcal<Ttab, Accept Ho	

Source: Author's Computation with Eviews 10 (2024)

Post-Estimation Test

As shown in Table 6, the heteroscedasticity test indicates that the variables are free from the heteroskedasticity problem, as the p-value of the F-statistic is greater than the 5% significance level. In the same vein, the Breusch-Godfrey Serial Correlation LM test result shows that there is no serial correlation among the variables considered to model the effect of climate change on cereal production in Nigeria since the p-values of the F-stat is greater than the 5% significance level. Similarly, the Ramsey Rest Set shows that variables are linearly related because the F-stat and the p-value are greater than 5% significance level.

In the normality test in the table below, the Jarque-Bera value and the probability value revealed that the model of the effect of climate change on cereal production in Nigeria is normally distributed since they are higher than 5% significance value.

Table 6: ARDL Post-estimation Tests

Test	Statistic	Value	Probability
Heteroskedasticity Test: Breusch-Pagan-Godfrey	F-statistic	1.5527	0.1796
Breusch-Godfrey Serial Correlation LM Test:	F-statistic	0.2513	0.6220
Normality Test	Jarque-Bera Statistic	1.2629	0.5318
Linearity Test: Ramsey RESET Test	F-statistic	0.12685	0.7256

Source: Author's Computation using Eview (2024)

CONCLUSION

In conclusion, this study provides evidence of climate change in Nigeria. The analysis showed a linear upward pattern in rainfall and temperature, which is a confirmation of sporadic rainfall patterns and an insistent rise in heat caused by high temperatures. The CO_2 emissions and cereal production also exhibited an increasing trend during the study period. Surprisingly the population growth rate in Nigeria has been increasing at a declining rate. The continuous increase in climate variables needs to be addressed to reduce the possible effects climate change imposes on society, the environment, and the economy.

Furthermore, the population growth rate and rainfall are detrimental to cereal production. This implies that as rainfall and population increase, cereal production decreases. Also, the higher the hectares of land used for cereal cultivation, the higher the aggregate output from cereal farming. The temperature rise has also been in favour of cereal production in Nigeria. In the short run result, the previous and current values of rainfall and temperature affect cereal production. As such, it indicates that cereal production is susceptible to changes in weather elements and the events caused by them in Nigeria.

According to Wellbery *et al.*, (2018), every sector should contribute to cutting down the harms done by climate variability by adopting both mitigation and adaptation measures. Thus, the following recommendations are drawn from this study for individuals, NGOs, policymakers, climate experts and government at all levels in Nigeria to have an aggregate result. Cereal farming should be made more lucrative and productive to encourage farmers in production by supporting innovative and technology-based agriculture, thereby improving food security in Nigeria. This will address the negative effects of the population growth rate on cereal production. In addition, sustainable farming practices such as precision/smart and regenerative farming should be encouraged to enable less use of resources, avoid land degradation and deforestation, encourage climate resilience, and ultimately improve productivity and profitability. This will further strengthen the positive effect of land used for production on cereal output.

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