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ECONOMETRIC TREND ASSESSMENT AND IMPACT OF CLIMATE CHANGE ON COCOA OUTPUT IN NIGERIA: 1975 – 2018

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Abstract
The study assessed the trend and impact of climatic change on output of cocoa crop in Nigeria from 1975-2018. Secondary data were used for the study. The data were analyzed by means of log linear trend analysis, quadratic equation, means and percentages and ordinary least square regression. Findings showed that cocoa output and climatic parameters of rainfall, temperature, radiation, relative humidity and sunshine exhibited significant positive trends during the 1975 -2018 period. Cocoa output had a compound growth rate of 2.0% per annum, while the climatic parameters of temperature, rainfall, radiation, sunshine and relative humidity had a compound rate of growth of 0.1%, 0.7%, 0.9%, 1.5% and 0.8% per annum respectively. Cocoa output and temperature showed stagnation in growth during the period under study. There were no significant differences in the average rate of growth between either of cocoa and each pair of the selected climatic parameters considered. In the long run, cocoa output was influenced by current values of area harvested of cocoa, rainfall, relative humidity, sunshine and time variable, while, in the short run, cocoa output was influenced by one year lag values of area harvested of cocoa, cocoa output, rainfall, radiation, relative humidity, sunshine and temperature based on the specified model. There was a fast adjustment to long run equilibrium among the short run independent variables that estimated the response of cocoa output to climatic change. The study shows that climatic change affected the production of the cocoa in Nigeria within the period under study. It is therefore, recommended that, if cocoa output is to be increased and sustained, those activities that encourage global warming should be avoided where possible or reduced to a bearable minimum in Nigeria.

Keywords: **Econometric, Trend, Assessment, Climate parameters, Climate change, Cocoa**

Introduction
Nigeria is an agriculture oriented country. This is because about 70% of her population is engaged in agricultural production; although at a subsistence level, regardless of the fact that the country depends heavily on oil sales for its budgetary revenue (NBS, 2018). Although Nigeria's wide range of climatic elements allows it to produce wide varieties of food and cash crops, however, food production are not keeping pace with population growth, and food shortage is therefore linked with changes in the climatic factors (Adejuwon, 2004). Agriculture largely depends on climate to function (Ibeagwa, 2018). Kurukulasuriya and Rosenthal (2003), described the four ways in which climate affect agricultural production. Firstly, changes in climatic factors such as sunshine, temperature and precipitation directly affect crop production by influencing the rate of light available for crop photosynthesis, controlling the rate of physio-chemical reaction and rate of evaporation of water from crop leaves and soil surface. Secondly, changes in climatic factors such as temperature and rainfall determine the distribution of crops and animal along the agro-ecological zones. Thirdly, increased CO_2 is expected to have a positive effect on agricultural production due to greater water use efficiency and higher rates of plant photosynthesis. Runoff or water availability is critical in determining the impact of climate change on crop production, especially in Nigeria, and agricultural losses can result from climate variability and the increased frequency of changes in temperature and precipitation (including drought and floods).

Cocoa has been identified as a unique exportable agricultural product in Nigeria starting from the late nineteenth century (Oyekale *et al*., 2009). For Cocoa (*Theobroma cacoa*) production, studies had shown that environmental conditions exert considerable influence on the location of cocoa production in Nigeria. After years of trial and error by farmers, the conditions under which cocoa thrives well are now better appreciated than during the initial stages of its cultivation. The crop is produced in two main moisture belts: western Nigeria, within the 1143-1524mm rainfall areas, and southeastern part of Nigeria in areas with rainfall distribution of 1905-3048mm. Moisture conditions which are almost double those of the western states in Nigeria are considered favorable for early cocoa crops in Cross River State of Nigeria and other zones in the country that shared the same rainfall distribution. Although, heavy rainfall encourage high incidence of black pod disease (FAO, 2005). The differences in the amount of total annual rainfall and temperature under which cocoa is produced in the country suggest that other aspects of moisture supplies will be important for its cultivation. Cocoa is very sensitive to drought and more than three months of dry season is injurious to the plant. This also suggested that the amount of dry season rainfall is the most important climatic element in the early stages of cocoa production. In the dry season, the young cocoa plant undergoes considerable stress, some rainfall is vital for its survival, while prolonged drought can lead to its complete destruction (Oyekale *et al*., 2009). The severity of the dry season period is therefore an important limiting factor to cocoa cultivation in the drier northern parts of Nigeria. Cocoa needs moderate moisture supplies throughout the year with short dry season. Regions and states that had made a remarkable progress over time in the production of cocoa in Nigeria include; Lagos (Agege), Ibadan, Ondo, Cross-River (Ikom), Ogun, Oyo, Abia (Ibere), Ekiti, Imo, and Edo (parts of Owan, Akoko Edo, Etsako, Western Benin and Ishan) etc.

Cocoa is highly sensitive to variation in climatic factors, most especially in rainfall distribution and temperature (FAO, 2005). Several views have been expressed about the impact of irregularity of climate on cocoa production. Some noted that rural and poor cocoa farmers are most affected. The concern is on how best to tackle climate change on the selected cash crops production (Oyekale, *ibid*). Chikaire and Nnadi (2020), indicated that in Nigeria, climate change will affect all four dimensions of food security, stability of food supplies and food utilization. Nigeria's first National communication to the United Nations framework convention on climate change (updated with CBN, 2006 data) showed that production of some crops in the country has declined (Ezeh and Eze, 2016). All these evidence, could be true due to agricultural production in Nigeria is whether dependent. Climate variability and change have a direct, often adverse influence on the quantity and quality of agricultural production in Nigeria (Chikaire and Nnadi 2020). It therefore becomes imperative to find out to what extent the changes in climatic parameters have influenced the output performance of cocoa in Nigeria from the periods 1975 – 2018.

Methodology

This study was carried out in Nigeria, the most populous African Country South of the Sahara (Akpan and Atan, 2010); it is a geopolitical and sovereign entity that is composed of 36 states and the Federal Capital Territory (FCT Abuja). Nigeria is situated along the coast of West Africa between latitudes 4^0 and 14^0N and longitude 3^0 and 15^0E, it shares a common boundary with Niger on the West, Cameroun Republic on the East, and Gulf of Guinea on the South. Nigeria occupies a land area of 98.3million hectares of which only about 34.2million hectares are actually been cultivated and less than 1% of the arable land is irrigated (NBS, 2018), its terrain ranges from southern coaster swamp to tropical forest, open woodlands, grass lands and semi-desert in the far north. The country enjoys an annual rainfall ranging from 38cm along the coast to 64cm or less in the far north. The mean annual temperature ranges from 28^o – 31^oC in the South (Ibeagwa, 2018). In 2017, the total population of the country was approximately 193million as provided by the National Population Commission (NBS, 2018). Nigeria enjoys a comparative resource advantage in the form of favourable climatic, edaphic and ecological condition which enables the cultivation of many crops and harvesting of natural product, rearing of animals and aquaculture. Major Agricultural commodities produced in the country are divided into crops, livestock and fishery products and forestry products. Crop production in the country is usually for food or export purposes (Aruocha (2019). The principal food crops include; maize, millet, sorghum, rice, wheat, beans, cassava, potato, yam, cocoyam, plantain and vegetables. Export crop include; groundnut, cotton, rubber, oil palm, cocoa, tobacco, coffee etc. Livestock products include; poultry, goat, meat, lamb/mutton, beef, pork, milk and egg. Fishery products of the country are obtained from such activities as artisanal coastal and brackish water catches, artisanal inland rivers and lakes catches, industrial coastal fish and shrimps catches and fish farming.

The study made use of secondary data mostly time series type. Agricultural production and other variables were collected from the publications of CBN, National bureau of Statistics (NBS), National Planning Commission (NPC), Nigeria Meteorological Center (NIMET), Food and Agricultural Organization (FAO), and other official sources served as supplementary data sources data utilized by the research covered the period 1975 to 2018. Trend in the climatic parameters and in crop output was analyzed using log-linear analytical method. The annual experimental trend or log linear trend analysis was used to estimate the growth rate in climate parameters such as temperature, rainfall, radiation, relative humidity and sunshine and output of cocoa in Nigeria. The method has been variously applied in past trend studies in Nigeria's agriculture (Onyenweaku and Okoye, 2005; Udom 2006; Ojiako *et al*., 2007; Nnamerenwa, 2012).

The exponential trend equation is given as:

$$C_{it} = \beta_0 + \beta_1 t_1 + e_i \text{ .... (1)}$$
$$Cp_{it} = \beta_0 + \beta_1 t_1 + e_i \text{ .... (2)}$$

Where,

Cit = Climate parameter (rainfall and temperature, measured in millimeters (mm) and centigrade (^{o}C) respectively.

CP_{it} = Output of selected cash crop (cocoa) measured in tones.

t = Time interval/trend measure in years

β_0 and β_1 = Parameters estimated
e_i = error term
The linear form of equations (1) and (2) is specified thus:
$\text{Log } C_{it} = \beta_0 + \beta_1 t_1 + e_i$ .... (3)
$\text{Log } Cp_{it} = \beta_0 + \beta_1 ti + e_i$ .... (4)

Where,
Log C_{it} and log Cp_{it} are the natural logarithm of the climatic parameters and other variables as previously defined.
The annual exponential of compound growth rate (gr) in climate change and selected cash crop production will be estimated following Onyenweaku (2004), and Nnamerenwa (2012) thus:

$gr = (e\beta_i - 1) \times 100$ ....(5)

Where,
e = Eulers exponential constant (2.71828)
β_i = estimated coefficient in equations (1) and (2) each.

To investigate evidence of stagnation, acceleration or deceleration in the output of the selected crop and climatic parameters of temperature and rainfall over the period 1975 – 2018, a quadratic equation in the time trend variables was fitted to the data for the entire period 1975 – 2018 covered in the analysis.
The quadratic equation is as follows:

$\text{Log } Cit = \beta_0 + \beta_1 t_1 + \beta_2 t^2_2 + e_i$ ...... (6)
$\text{Log } Cpit = \beta_0 + \beta_1 t_1 = \beta_2 t^2_2 + e_i$ ...... (7)

Where;
Log C_{it} and log Cp_{it} and t variables are as previously defined in equations (3) and (4). β_0, β_1 and β_2 are parameters estimated in the specifications in equation (6) and (7). The linear and quadratic time terms indicates the circular path in the dependent variables (C_{it}) and (Cp_{it}), while the quadratic term (t_2) indicates the nature of growth followed by the dependent variables (C_{it}) and (Cp_{it}) (Onyenweaku and Okoye, 2005). Our major interest was on the co-efficient of t_2, which is β_2. If β_2 is positive and is statistically significant, it implies evidence of acceleration in growth of the variables (C_{it}) and (Cp_{it}). If β_2 is negative and statistically significant, it implies evidence of deceleration in growth of the variables (C_{it}) and (Cp_{it}). If β_2 is not statistically significant, it implies evidence of stagnation in the growth process for the variables (C_{it}) and (Cp_{it}) following Onyenweaku, and Okoye (2005), Nnamerenwa (2012), and Okezie *et al*. (2020).

To examine the mean percentage growth rate of crop output and each of the selected climatic parameters, means and percentages were employed. Thereafter a paired sample Z– test (n = 44 years) was employed to test for differences between the mean growth rates in the output of the selected cash crop (cocoa) and for each of the examined climatic parameters.
The Z – statistics is given as:

$$Z \text{ cal} = \frac{\bar{X}_i - \bar{X}_j}{\sqrt{\frac{S^2 X_i}{ni} + \frac{S^2 X j}{nj}}}$$

Where,
$\bar{X}i$= Average growth rates for the selected crop (cocoa) $\bar{X}j$= Average growth rates for each of climate parameters (rainfall, temperature, relative humidity, radiation and sunshine) each
$S^2\bar{X}i$=Squared standard error for the selected cash crop (cocoa)
$S^2\bar{X}jX$= squared standard error for each of the considered climatic parameters (rainfall, temperature, relative humidity, radiation and sunshine) each
n_i = Number (years) of output for the selected cash crop (cocoa).
n_j = Number (years) of change for each of the considered climatic parameters (rainfall, temperature, relative humidity, radiation and sunshine) each

To analyze the influence of climatic factors on cocoa crop production, the ordinary least square (OLS) regression model was employed. Long run and short run regression models of the response of cocoa output to climatic change were estimated. To capture the long run and short run of the response of cocoa output to climatic change, the error correction model (ECM) using the Engle-Granger methodology was estimated (Granger and Newbould, 1974). The model used to estimate the response of cocoa output to climate change in both the long-run and short-run periods is presented thus:

Long-Run Model estimation for Cocoa Output
The long- run model used to estimate the response of cocoa output to climate change is given as:

$\text{Log } Q_{it} = \beta_0 + \beta_1 \text{logAHC}_t + \beta_2 \text{logRain}_t + \beta_3 \text{logTemp}_t + \beta_4 \text{logRH}_t + \beta_5 \text{logRad}_t + \beta_6 \text{logSun}_t + \beta_7 \text{logTrend}_t + \mu_i$

Where,
Log = Natural logarithm of the variables
Q_{it} = Quantity of cocoa output in period t
AHC_t = Area harvested of cocoa in period t
$Rain_t$ = Average annual rainfall in millimeters in period t
$Temp_t$ = Average annual temperature in centigrade in period t
RH_t = Relative humidity in percentage in period t
Rad_t = Radiation in percentage in period t
Sun_t = Sunshine in hours in period t
$Trend_t$ = trend time (T = 0, 1... 44), a proxy for technology, which measures productivity effect
μ_i= Stochastic disturbance term
$\beta_0 - \beta_7$ = Parameter estimates
Following *a priori*, it was expected that the coefficient estimates for AHC_t, $RAIN_t$, $TEMPt$, RHt, RADt, SUN_t, $TREND_t > 0$.

Short-Run Model for Cocoa Output
To estimate the short-run cocoa output, following the error correction model approach, co-integration test was performed using the ADF test procedure. This tends to confirm that the residuals of the non-stationary series that were integrated in order one are actually integrated at order zero. Co- integration test for the presence of unit roots was performed on the residual series generated from the long-run estimation of the response of cocoa to climate change using the Augumented Dickey-Fuller

(ADF) test procedure. The short- run model used to estimate the response of cocoa output to climate change is given as:

$$\text{Log } Q_{it} = \beta_0 + \beta_1 \log AHC_{t-1} + \beta_2 \log Rain_{t-1} + \beta_3 \log Temp_{t-1} + \beta_4 \log RH_{t-1} + \beta_5 \log Rad_{t-1} + \beta_6 \log Sun_{t-1} + \beta_7 \log Q_{it-1} + \beta_8 ECM_{t-1} + \mu_i$$

Where,
Log = Natural logarithm of the variables
Q_{it} = Quantity of cocoa output in period t;
AHC_{t-1} = Area harvested of cocoa in period t-1
$Rain_{t-1}$ = Average annual rainfall in millimeters in period t-1
$Temp_{t-1}$ = Average annual temperature in centigrade in period t-1
RH_{t-1} = Relative humidity in percentage in period t-1
Rad_{t-1} = Radiation in percentage in period t-1
Sun_{t-1} = Sunshine in hours in period t-1
Q_{it-1} = Quantity of cocoa output in period t-1
ECM_{t-1} = Error correction mechanism in period t
μ_i = Stochastic disturbance term.
$\beta_0 - \beta_8$ = parameter estimates
t-1 = lag time period
Following *a priori*, it was expected that the coefficient estimates for AHC_{t-1}, $RAIN_{t-1}$, $TEMP_{t-1}$, RH_{t-1}, RAD_{t-1}, SUN_{t-1}, $Q_{it-1} > 0$ and $ECM_{t-1} < 0$.

Results and Discussion

The result in Table 1 shows that previous output of cocoa, previous annual rainfall, current annual rainfall, current hours of sunshine and previous hours of sunshine were the only variables found to be stationary at order of integration zero (0). All the other variables were found to be stationary at order of integration one, I (1) or at first difference. Therefore, all the logged variables used for the study were integrated of order one, I(1) except for the previous output of cocoa, previous annual rainfall, current annual rainfall, current hours of sunshine and previous hours of sunshine, which were used at level, I(0). The difference- stationary values for the variables found to be stationary at order one, I (1) were generated and used for analysis.

Table 1: Unit root test estimates for logged variables used in the analysis

Variable	Level	First difference	Order of integration
Area Harvested of $Cocoa_t$	-1.321	-7.271***	I(1)
Area Harvested of $Cocoa_{t-1}$	-1.094	-7.368***	I(1)
$Cocoa_t$	-3.098	-7.639***	I(1)
$Cocoa_{t-1}$	-15.676***	-	I(0)
$Radiation_t$	-1.968	-6.995***	I(1)
$Radiation_{t-1}$	-2.069	-6.787***	I(1)
$Rainfall_t$	-3.587**	-	I(0)
$Rainfall_{t-1}$	-3.494**	-	I(0)
$Temperature_t$	-1.816	-5.389***	I(1)
$Temperature_{t-1}$	-5.633***	-	I(0)
Relative $Humidity_t$	-1.933	-6.848***	I(1)
Rel. $Humidity_{t-1}$	-2.076	-6.843***	I(1)
$Sunshine_t$	-3.687**	-	I(0)
$Sunshine_{t-1}$	-4.401***	-	I(0)

Critical value at 1% = -4.234, 5% = -3.540 and 10% = -3.202; first difference (critical value) at 1% = -4.244, 5% = -3.544 and 10% = -3.205. *, ** and *** represent 10% and 5% and 1% significant levels respectively

Trend in Growth Rates of Climate Variables and Output of Cocoa

The results of trends, compound growth rates and investigation of acceleration, deceleration and stagnation of growth in the growth trend of output of cocoa and climate variables are presented in Table 2. Results show that the output quantities of cocoa and climate parameters of temperature, rainfall, radiation, relative humidity and sunshine significantly grew during the period under review. The estimation results showed that the estimated coefficient of the time variable was positive and statistically significant at 1% with respect to cocoa output, temperature, rainfall, radiation, sunshine and relative humidity within the period under investigation. This implies that time trend variable was a major factor in determining quantity of cocoa output, temperature, rainfall, radiation, sunshine and relative humidity within the period under review and thus, cocoa output, temperature, rainfall, radiation, sunshine and relative humidity significantly increased within the 1975 -2018 periods respectively. Result shows further that the coefficient of multiple determinations (R^2) were high and the F-statistic significant at ($p<0.01$) for significant growth in cocoa output, temperature, rainfall, radiation, sunshine and relative humidity respectively. This implies that growth in cocoa output, temperature, rainfall, radiation, sunshine and relative humidity respectively were highly time dependent.

Table 2: Estimated trend equation for output quantities of selected cash crop and selected climatic parameters

Dependent variable	β_0	β_1	R^2	Adjusted R^2	F – ratio
Cocoa	5.023 (40.022)***	0.020 (3.361)***	0.244	0.222	11.294***
Temperature	3.476 (697.890)***	0.001 (3.741)***	0.286	0.265	13.991***
Rainfall	7.076 (131.000)***	0.007 (2.818)***	0.185	0.162	7.939***
Radiation	2.548 (84.535)***	0.009 (6.209)***	0.524	0.511	38.550***
Sunshine	1.552 (72.446)***	0.015 (14.727)***	0.861	0.857	216.874***
Relative Humidity	4.083 (433.127)***	0.008 (16.871)***	0.891	0.887	284.644***

Note: ***, ** represent 1% and 5% levels of significance respectively. Figures in bracket are t-values. Source: Computed by the author from CBN (2019) Annual Report and Statement of Accounts for the year Ended 31st December, 2019 and CBN (2019) Statistical Bulletin

The result of growth rates analysis in Table 3 showed that cocoa output maintained a positive growth rate within the period under review and recorded an exponential or compound growth rate of 2.0% per annum. Similar studies on crops production have revealed compound growth rates of 4.17% and 4.36% respectively for cassava and yam during the 1961-2005 period (Ojiako *et al*. 2007). Also, Aruocha (2019) estimated a compound growth rate 5.3% during the period 1980-2016, Onyenweaku and Okoye (2005) estimated a compound growth rate of 4.17% for cassava output from 1960/61-2003/04. Similarly, Table 3 showed that the compound growth rates of the climatic parameters maintained a positive growth rate within the period under review and recorded an exponential or compound growth rate of 0.1% per annum for temperature, 0.7% for rainfall, 0.9% for radiation, 1.5% for sunshine and 0.8% for relative humidity. Among the selected climatic parameters, sunshine had the fastest compound growth rate, while temperature was slowest. The compound growth rates of temperature, rainfall, radiation and relative humidity were slower than that of sunshine by 1.4%, 0.8%, 0.6% and 0.7% respectively, while, compound growth rates of rainfall, radiation, sunshine and relative humidity were more than that of temperature by 0.6%, 0.8%, 1.4% and 0.7% respectively. This result suggests that the production capacity of Nigerian farmers would be influenced mainly by the changes in sunshine, rainfall, radiation and relative humidity than the changes in temperature. Similar study on climate changes in Nigeria have revealed compound growth rates of 5.4% and 0.1% for rainfall and temperature respectively during the 1970-2010 period (Uguru, 2012).

Table 3: Compound growth rates of cocoa and climatic parameters of rainfall, temperature, radiation, relative humidity and sunshine (1975 -2018)

Variable	Parameter (β_1)	Exponential Growth rates (%)
Climate Parameters		
Temperature	0.001***	0.1
Rainfall	0.007***	0.7
Radiation	0.009***	0.9
Sunshine	0.015***	1.5
Relative Humidity	0.008***	0.8
Crop output		
Cocoa	0.020***	2.0

***** and ** represent 1% and 5% significance levels respectively.***

Source: Computed by the author from the estimated coefficients of the trend variables in Table 2

The result in Table 4 shows that the coefficient of the time variable (t^2) for cocoa production was positive but not statistically significant, confirming stagnation in the growth of real cocoa output. Thus, Nigerian cocoa production remained the same in growth rate within the period under review. For the climate change variables, the coefficients of the time variable (t^2) for sunshine, rainfall, radiation and relative humidity were positive and highly significant ($p<0.01$) each, reflecting a case of statistical significant acceleration in the real conditions of sunshine, rainfall, radiation and relative humidity in Nigeria. Thus, Nigerian climatic parameters in terms of sunshine, rainfall, radiation and relative humidity increased at an increasing rate in growth within the period under study. However, the coefficient of the time variable (t^2) for temperature was negative but not statistically significant, confirming stagnation in temperature intensity. Thus, the variability in temperature in Nigerian remained the same within the period under review. Efforts in controlling climatic variability in order to promote crop production in Nigeria now and in the future, should concentrate on regulating sunshine, rainfall, radiation and relative humidity variability to benefit farmers. For instance, high relative humidity may favour crop flowering and fruiting, but may pose a treat for drying processed farm produces like cocoa seed.

Table 4: Quadratic trend estimates in time variables for output of cocoa and climatic parameters

Dependent variable	B_0	B_1	B_2	R^2	Adj. R^2	F-Statistic
Cocoa	5.164	-0.004	0.001	0.269	0.226	6.244***
	(28.410)**	(-0.173)	(1.071)			
Temperature	3.483	0.000	-32780	0.321	0.281	8.031
	(487.040)***	(0.315)	(-1.328)			
Rainfall	7.273	-0.027	0.001	0.466	0.434	14.822***
	(112.952)***	(-3.208)***	(4.228)***			
Radiation	2.687	-0.015	0.001	0.783	0.770	61.426***
	(89.678)***	(-3.840)***	(6.375)***			
Sunshine	1.488	0.026	0.000	0.893	0.887	141.894**
	(53.758)***	(7.318)***	(3.187)***			
Relative humidity	4.049	0.013	0.000	0.926	0.922	213.955***
	(355.795)***	(9.131)	(4.072)***			

Note: *** and ** is significant at 1% and 5% level respectively. Figures in brackets are t-values.

Source: Computed by the author from CBN (2019) Annual Report and Statement of Accounts for the year Ended 31st December, 2019 and CBN (2019) Statistical Bulletin

Variability in the Mean Growth Rates of Selected Climatic Parameters and Cocoa Crop Output

Evidence from the Z-test results presented in Table 5 shows that the average growth rate of cocoa over the entire period was 16%, while, the average growth rate of temperature, rainfall, radiation, relative humidity and sunshine were 0.3%, 2.8%, 1.6%, 1.1% and 1.9% respectively over the entire period under study. On the average, for all the paired categories (i.e. the growth rate of each of the selected climatic parameters paired with the growth rate of cocoa output), the difference in the average growth rate between climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine and the output quantity of cocoa were not statistically significant for each pair respectively (Z=1.281 for cocoa-temperature pair; 1.057 for cocoa-rainfall; 1.184 for cocoa-radiation; 1.221 for cocoa-relative humidity; and, 1.136 for cocoa-sunshine). The average growth rate in cocoa output in Nigeria is low. Onyebinama *et al*. (2007) also reported that growth rate of agricultural output was slow. The non-significance of the difference in the average growth rate of cocoa output and climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine, suggest that cocoa output depends more on the variability in temperature, rainfall, radiation, relative humidity and sunshine. Therefore, fluctuations in the climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine probably would affect the output quantity of cocoa.

Table 5: Test of significant difference between the mean growth rates of selected climatic parameters and cocoa crop output

Sample	Mean	Standard Deviation	Standard Error Mean	DF	Z-statistics
^{a}Cocoa$_t$	15.982	74.650	12.272		
^{b}Temperature$_t$	0.338	1.555	0.256		
a - b	15.643	74.286	12.213	43	1.281
^{a}Cocoa$_t$	15.982	74.650	12.272		
^{b}Rainfall$_t$	2.756	15.776	2.594		
a – b	13.225	76.113	12.513	43	1.057
^{a}Cocoa$_t$	15.982	74.650	12.272		
^{b}Radiation$_t$	1.576	7.253	1.192		
a – b	14.405	74.002	12.166	43	1.184
^{a}Cocoa$_t$	15.982	74.650	12.272		
^{b}Relative Humidity$_t$	1.117	2.244	0.369		
a – b	14.864	74.065	12.176	43	1.221
^{a}Cocoa$_t$	15.982	74.650	12.272		
^{b}Sunshine$_t$	1.903	5.083	0.836		
a – b	14.078	75.406	12.397	43	1.136

$^{a-b}$ represents paired sample differences

Source: Computed by the author from CBN (2019) Annual Report and Statement of Accounts for the year Ended 31st December, 2019 and CBN (2019) Statistical Bulletin

Effect of Climate Changes on Cocoa Output

The results in Table 6 showed that the coefficient of multiple determination (R^2) for cocoa output was 0.808. It indicates that the independent variables included in the model explained 80.8% of the variations in cocoa output in the long-run. The F-statistics was significant and confirms the significance of the entire model. The Durbin Watson (DW) value of 1.980 and 2.153 for cocoa output indicated that auto-correlation was not a problem in the model. Current values of area harvested of cocoa, rainfall, relative humidity, sunshine and time variable were the significant factors that influenced cocoa output in Nigeria in the long-run.

Table 6: Regression result of the effect of climate change on cocoa output in Nigeria (1975-2018)

Variable	Cocoa
Area harvest of crop	2.003 (2.352)**
Rainfall	1.524 (2.594)**
Temperature	-3.047 (-0.980)
Relative humidity	1.502 (2.523)**
Radiation	-0.089 (-0.179)
Sunshine	1.214 (2.490)**
Trend	0.018 (1.890)*
Constant	9.204 (2.086)**
R^2	0.808
Adjusted R^2	0.780
F – statistic	49.786***
DW – statistic	1.980

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively. Figures in brackets are t-values.
Source: Computed by the author from CBN (2019) Annual Report and Statement of Accounts for the year Ended 31st December, 2019 and CBN (2019) Statistical Bulletin

Area harvested of cocoa, rainfall, relative humidity, sunshine and time variable were significant and directly (positively) related to cocoa output. This is an indication that cocoa output increased as area harvested of cocoa, rainfall, relative humidity, time variable and sunshine increased. This result further showed that cocoa requires a higher amount of rainfall, relative humidity, sunshine and technological change in its production process to increase its output quantity. The quantity of crops planted by a farm firm depends on the quantity of land available to it (Nnamerenwa, 2012). According to Onyebinama (2004), limited access to land limits the size and scale of the farm business. Crop planted is likely to increase as the area of land increases. As the area planted with cocoa increased, cocoa output increased. Nigerian agriculture is rainfall dependent and increase in adequate and timely annual rainfall enables crops to grow and produce fruits (Nnamerenwa, 2012). Increase in fruit production by cocoa plant will likely lead to an increase in cocoa output, as a result, cocoa output increased as annual rainfall increased. Relative humidity as a percentage ratio of the amount of water in the air at a given temperature to the maximum amount it could hold at that temperature ensures that cocoa plant remained moisturized throughout the day, thereby aiding fruiting and seed maturity. Sunshine is an important factor in crop production as it provides the radiant energy that aids crop photosynthesis. Photosynthesis is the process of converting carbon dioxide into organic compounds using energy from sunlight or artificial light. The length and extent of light as provided by the sunshine determines the growing processes of plants such as sprouting, growing, budding, blooming, flowering, and finally the production of seed (Mustapha and Saitoh, 2008). Plants are dependent on light to generate food, induce the growing cycle and allow for healthy development. Without light, natural or artificial, most plants would not be able to grow or reproduce, photosynthesis would not occur without the energy absorbed from sunlight and there would not be enough oxygen to support life nor will crops yield as expected. As a result cocoa output increased as sunshine hour increased. In the presence of improved technologies, a farm firm will innovate to increase subsistence production (Nnamerenwa, 2012). A change in current level of technology (total factor productivity) is brought about by such factors as increased knowledge about production methods and education. An increase in the adoption of new methods of production by cocoa farmers will lead to an increase in cocoa output. The elasticity of response of cocoa output relative to area harvested of cocoa, average annual rainfall, relative humidity, sunshine and technological change are 2.003, 1.524, 1.502, 1.214 and 0.018 respectively. This suggests that a 10% increase change in area harvested of cocoa, average annual rainfall, relative humidity, sunshine and technological change will increase cocoa output by 20%, 15.24%, 15.02%, 12.14% and 0.2%, respectively.

The result of the co-integration presented in Table 7 which is a precondition for the specification of an error correction model indicates presence of co-integration in the cocoa output models. This is evident as shown by the stationary of the residuals of the static regression for the crop. This is shown by the stationary of the residual of the static regression for cocoa output in Nigeria within the period under study and therefore, Error Correction Model (ECM) was specified. The one period lagged residual for annual data used to estimate the response of cocoa output to climatic variables acted as the error correction factor.

Table 7: Co-integration test for cocoa output

	Level	1st Difference	Order of Integration
Cocoa	-3.763	-	I (0)

Note: ***critical values of 1% = 4.244 and 5% = -3.544***

Table 8: Regression result of the effect of climate change on cocoa output in the short-run including ECM in Nigeria (1975-2018)

Variable	Cocoa
Area harvest of crop $_{t-1}$	2.188 (3.791)***
Crop output $_{t-1}$	0.292 (2.435)**
Rainfall $_{t-1}$	0.311 (2.333)**
Temperature $_{t-1}$	-0.384 (-2.720)**
Radiation $_{t-1}$	0.548 (1.703)*
Relative humidity $_{t-1}$	0.648 (2.083)**
Sunshine $_{t-1}$	0.837 (2.688)**
ECM $_{t-1}$	-0.811 (-5.244)***
Constant	3.522 (5.420)***
R^2	0.811
Adjusted R^2	0.753
F – statistic	13.95***
DW – statistic	2.116

Note: ***, ** and * represent 1%, 5% and 10% significance level respectively. Figures in brackets are t-values.
Source: Computed by the author from CBN (2019) Annual Report and Statement of Accounts for the year Ended 31st December, 2019 and CBN (2019) Statistical Bulletin

Results in Table 8 show that the coefficient of multiple determinations (R^2) for the crop indicates that the regressors included in the model explained 81.1% of the variations in cocoa output in the short run. In the short run, cocoa output responded positively to the changes in the one year lag of area harvested of cocoa, cocoa output, rainfall, radiation, relative humidity and sunshine and negatively to changes with one year lag in temperature. This implies that the increases in the previous year's values of area harvest of cocoa, cocoa output, rainfall, radiation, relation humidity and sunshine increased cocoa output in Nigeria, while the increase in the previous year value of temperature reduced cocoa output. The coefficient of the error correction factor which measures the speed of adjustment of the independent variables towards a long-run equilibrium carried the surmised negative sign and significant at 1%. This shows that a long-run equilibrium exist among the independent climatic variables that estimated cocoa output in Nigeria in the period under study. The error correction model of -0.811 suggest that a feedback of 81.1% of the previous years' disequilibrium from the long-run values of the independent climatic variables was evident. Thus, there was a fast adjustment to long-run equilibrium among the independent variables included in the model which estimated the response of cocoa output to changes in the independent variables within the period investigated and a feedback of 81.1% of the adjustment towards long-run equilibrium for cocoa output was completed in one year.

Conclusion

Cocoa output quantities and climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine have significant growth during the period under review (1975 – 2018). Time trend variable was a major factor determining quantity of cocoa output, temperature, rainfall, radiation, sunshine and relative humidity within the period under review. The growth in cocoa output, temperature, rainfall, radiation, sunshine and relative humidity respectively were highly time dependent. The compound growth rates of cocoa output, temperature, rainfall, radiation, sunshine and relative humidity were slow during the periods under study. There was stagnation in the growth rate of cocoa and temperature and acceleration in the growth rate of rainfall, radiation, relative humidity and sunshine within the period under review. Cocoa production remained the same in growth rate within the period under study. Climatic parameters in terms of sunshine, rainfall, radiation and relative humidity increased in growth rate, while temperature remained the same. The difference in the average growth rate between cocoa and each of the climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine were not significant. The average growth rate in cocoa was low. The fluctuations in the climatic parameters of temperature, rainfall, radiation, relative humidity and sunshine affected the growth rate of cocoa output within the periods under study. In the long run, current values of area harvested of cocoa, rainfall, relative humidity, sunshine and time variable significantly influenced cocoa output in Nigeria, while, in the short run, one year lag values of area harvested of cocoa, cocoa output, rainfall, radiation, relative humidity, sunshine and temperature significantly influenced cocoa output in Nigeria. The short run independent variables that estimated the response of cocoa output to climatic changes adjusted quickly to long-run equilibrium. Therefore, there is need for stakeholders in agriculture to make effort to contain the effect of the changes in such climatic parameters as rainfall, sunshine, radiation, relative humidity and temperature on cocoa production by educating farmers on possible adaptation and mitigation strategies to climate changes, as this will boost the production of this cash crops in Nigeria. Efforts should also be made by government through its metrological sections across the nation to inform farmers on time on the possible changes in climatic parameters and how to cope with such changes.

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