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The Effect of Weather on Cocoa Production in Different Agro-Ecological Zones in Nigeria

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Abstract: This study investigated the effects of weather on cocoa production in different agro-ecological zones in Nigeria. Weather data for twenty three years were used for the study and the data were analysed using Descriptive statistics, Analysis of Variance (ANOVA) and Multi-variate Regression Analysis. The results of the descriptive analysis showed that Mangrove/Swamp agro-ecological zone has the highest rainfall with 40.4% of the total rainfall in all the zones while the highest temperature (26.7%) was recorded in the derived savannah zone. The highest cocoa output was recorded in rainforest zone with 54.0% of the total cocoa output in all the zones. Analysis of Variance (ANOVA) showed that there was significant difference in rainfall as well as cocoa output in all the zones ($p<0.01$). Also, results showed that rainfall is a critical factor in determining the output of cocoa in Mangrove/Swamp, Rainforest as well as Derived savannah zones ($p<0.01$). In addition, temperature is also a determinant of cocoa output in Derived savannah zone ($p<0.05$). It was recommended that irrigation facility should be provided where rainfall is a limiting factor and that government should provide some encouragement packages to the farmers in order to expand their hectarage cultivation.

Key words: Weather variables · Cocoa production · Agro-ecological zones · Analysis of variance · Regression analysis

INTRODUCTION

Agriculture used to be the mainstay of Nigerian economy providing 65% of the Gross Domestic Product (GDP) in the 1960s [1], but its contribution has dropped in recent times to about 26% [2]. This could be traced to the reduced influence of cash crop (such as cocoa) subsector on Nigerian economy [3]. Cocoa which has been variously described as *"food of the gods"* by the Greeks was introduced into Nigeria in 1874 [4]. Since its introduction in Nigeria, its cultivation has gained prominence rapidly in Nigeria such that in the early seventies, cocoa production has spread to all the agro-ecological zones in Nigeria. Presently, there are fourteen states producing cocoa in the country viz: Ondo, Cross River, Osun, Ekiti, Ogun, Oyo, Edo, Delta, Kwara, Kogi, Abia, Taraba, Adamawa and Akwa Ibom. The production of cocoa increased gradually from 3000 tons in 1910 and peaked at 307,000 metric tons in 1970/1972 cocoa season [5]. In fact, during the early 1970s, Nigeria was the world's second largest cocoa producer in the whole world [6]. Cocoa as a major cash crop in Nigeria has contributed immensely to Nigeria's economy. For instance, it has since being an important foreign exchange earner, remaining the second largest foreign earner after crude oil [7]. The crop has contributed tremendously to infrastructural development in Nigeria and has provided job for the people. In fact, the crop has substantially imparted on about ten million people who live and work in the cocoa belt [8]. However, the modest growth in cocoa subsector has been traced to among other things including favorable weather conditions. Cocoa production is highly sensitive to weather variables, from length and intensity of sunshine, to rainfall and water application, soil condition and temperature due to evapotranspiration effects. It has been reported widely that weather also plays a major role in altering the development of cocoa pests and pathogens and shifting their interactions [9]. Cocoa is highly susceptible to drought and the pattern of cropping of cocoa is related to rainfall distribution. Planting of cocoa is highly determined by the start of the rain and cocoa seedling mortality is encouraged by a prolonged drought. In bearing (mature) plant, the existence of drought can result in lower yield by way of reducing bean size and an increase in the level of mirid infestation. On the other hand, too much rainfall causes blackpod infestation. Black

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pod disease is one of the most serious disease of cocoa in Nigeria. It is caused by a soil-borne fungus, *Phytophthora palmivora* and is prevalent only during the wet season. The disease is therefore worse in areas of heavy rainfall. Major damage from the disease is the rotting of both small and large pods. Choupons, seedlings (in the nursery) and leaves of trees are attacked and killed under specially severe disease conditions following long periods of cool and rainy weather. Losses due to black pod disease vary from place to place and from variety to variety [10]. As for sunshine, solar radiation is necessary to speed up the photosynthetic rate. Apart from this, it produces solar energy for warming the soil, plants, air and metabolic processes. Sunshine is also necessary to reduce the water content of cocoa beans during drying thereby enhances the quality of cocoa beans. In general, weather variables are major factors influencing variations in crop yields, production, soil utilization and conservation. Yield uncertainties due to excessive drought or too much rainfall are common phenomenon in agriculture [11]. According to [12], yield per day is often higher in the tropics where temperature is higher and growth season is shorter while [13] asserted that crop yield is consistently found to be higher in temperate regions where temperature is low. Because of the variability in weather elements, some agricultural crops and cropping system have been developed for, adapted to these varied regimes of climate [12]. The climate of a place in general determines the vegetation of such a place and of course informs the ecology of the area. Therefore, the ecology of an area is essentially a response to the climate of such a place. Nigeria has two broad agro-ecological zones namely forest and the savannah. Forest is the ecological zone in which trees are the dominant species while savannah is a grassland area with no forest cover. Derived Savannah however is a transition from forest to savannah. Notable agro-ecological zones in Nigeria where cocoa is produced are Mangrove\Swamp forest, Rain forest, Derived Savannah and Montainic Savannah. Each of these agro-ecological zones has distinct weather and hence the intensities of the weather elements vary from one ecological zone to the other and this in turn determines the level of crop yield [13]. This study therefore assessed the effect of weather on cocoa production in different agro-ecological zones in Nigeria. Essentially, the study determines the relative magnitude of each weather elements (specifically rainfall, temperature and sunshine) and cocoa output in different agro-ecological zones; determined whether there is significant variation in weather elements among the different zones and also determined the extent of the effect of each weather elements on cocoa output in different agro-ecological zones.

Methodology: The study area included the four cocoa producing agro-ecological zones in Nigeria. These zones are Mangrove/Swamp zone, Rainforest zone, Derived savannah zone and Montainic zone. The fourteen cocoa producing states in Nigeria include Ondo, Cross River, Osun, Oyo, Ogun, Edo, Ekiti, Abia, Kwara, Kogi, Delta, Akwa Ibom, Taraba and Adamawa.

Mangrove/swamp Agro-ecological Zone-the cocoa producing states that fall within this zone are Akwa Ibom, Delta and Cross River.

Rainforest Zone-the cocoa producing states in this zone include Ondo, Ogun, Osun, Oyo, Edo, Ekiti and Abia.

Derived Savannah Zone-two cocoa producing states that fall within the zone are Kwara and Kogi State.

Montainic Savannah Zone-the cocoa producing states in this zone are Taraba and Adamawa states.

The data used for this study was collected on Mean Annual Temperature (MAT), Mean Annual Rainfall (MAR), Mean Annual sunshine hours (MAS) and Mean Annual Cocoa Output for each of the agro-ecological zones for the period between 1980 and 2002 (Twenty three years). Three analytical techniques were employed to analyse the data collected. These are Descriptive Statistics, Analysis of Variance (ANOVA) and Multi variate Regression Analysis.

Descriptive Statistics: This was used to analyse the relative magnitude of the weather elements as well as the output of cocoa in each agro-ecological zones.

Analysis of Variance (ANOVA): This was used to determine whether there's significant difference in the weather elements as well as cocoa output among the four agro-ecological zones.

The Hypotheses That Were Tested for are:
Temperature:

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$ (There's no significant difference in the amount of temperature in the four agro-ecological zones)

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$ (There's significant difference in the amount of temperature in the four agro-ecological zones)

Rainfall:

H_0: $R_1 = R_2 = R_3 = R_4$ (There's no significant difference in the amount of rainfall in the four agro-ecological zones)

H_1: $R_1 \; R_2 \; R_3 \; R_4$ (There's significant difference in the amount of rainfall in the four agro-ecological zones)

Sunshine:

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4$ (There's no significant difference in the amount of sunshine hours in the four agro-ecological zones)

H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4$ (There's significant difference in the amount of sunshine hours the four agro-ecological zones)

Cocoa Output:

H_0: $C_1 = C_2 = C_3 = C_4$ (There's no significant difference in the amount of cocoa output in the four agro-ecological zones)

H_1: $C_1 \neq C_2 \neq C_3 \neq C_4$ (There's significant difference in the amount of cocoa output in the four agro-ecological zones)

Multiple Regression Analysis: The effects of temperature, rainfall and sunshine hours on cocoa output was estimated using multi-variate regression analysis.

$$\ln Q = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + u$$

Where:
β = Regression Coefficient;
Q = Cocoa Output (metric tons);
X_1 = Mean Annual Temperature (degree centigrade);
X_2 = Mean Annual Rainfall (millimeter);
X_3 = Mean Annual Sunshine hours (hours);
u = Random Error term.

RESULTS AND DISCUSSION

Relative Magnitude of Weather Elements and Cocoa Output in Different Agro-Ecological Zones: Table 1 shows the total annual temperature for the period 1980-2002 for different agro-ecological zones in Nigeria. The table shows that derived savannah zone had the highest temperature of 26.7% while montainic savannah had the lowest temperature of 21.6%. This shows that temperature is higher in derived savannah zone than any other cocoa producing agro-ecological zones. Temperature is likely to be low in montainic savannah zone because of the effect of mountain since the higher we go the cooler it becomes. From Table 2, it is observed that the highest rainfall was recorded in mangrove/swamp agro-ecological zone. It had the proportion 40.4% of the total rainfall recorded in the four zones whereas; the lowest rainfall was recorded in montainic savannah zone. Hence, mangrove/swamp forest had the highest rainfall than any other agro-ecological zones and this is followed by rainforest zone. Rainfall was higher in these zones because of the effect of monsoon wind which normally blows across the zones. Higher rainfall in these zones is also responsible for the forestry type of vegetation that is observed in these agro-ecological zones. It could also be observed in Table 3 that the highest sunshine was recorded in derived savannah with 29.1% of the total sunshine hours recorded in all the agro-ecological zones. This is quite obvious in as much that the zone falls within the savannah area of the country. The least sunshine hours was however recorded in mangrove/swamp agro-ecological zone with 20.4% of the total sunshine hours recorded in all the zones. Table 4 showed that the highest cocoa output for the period 1980-2002 was recorded in the rainforest zone. It had the proportion 54.0% of the total output from all the agro-ecological zones. This was followed by mangrove/swamp zone which had the proportion 35.0%. Cocoa production was likely to be higher in these zones simply because the weather variables in the zone favour cocoa production. The lowest output of 1.0% was recorded in montainic savannah zone.

Analysis of Variation of Temperature, Rainfall, Sunshine and Cocoa Output among the four Agro-Ecological Zones: Table 5 shows that there was significant difference in the amount of rainfall among the four agro-ecological zones ($p<0.05$). This is quite obvious knowing fully that there was much rainfall in the forest and mangrove/swamp zones than any other agro-ecological zones. It could also be observed on Table 5 that there was significant difference in cocoa output among the four agro-ecological zones ($p<0.05$). This result could be confirmed on Table 4 where the cocoa output recorded in the rain forest zone was much higher than any of the other zones. However, there was no significant difference in temperature as well as sunshine among the four agro-ecological zones ($p>0.05$). As for the significant

Table 1: Total annual temperature for the period 1980-2002 for different agro-ecological zones

Ecological zone	Total annual temp. /°C	Percentage
Mangrove/ Swamp	577.4	25.2
Rainforest	605.9	26.4
Derived Savannah	612.8	26.7
Montainic	493.2	21.6
Total	2289.3	100.0

Source: Meteorological Department, Ministry of Aviation.

Table 2: Total annual rainfall for the period 1980-2002 for different agro-ecological zones

Ecological zone	Total annual rainfall/mm	Percentage
Mangrove/Swamp	49,793.5	40.4
Rainforest	33,156.4	26.8
Derived savannah	22,555.3	18.2
Montainic savannah	18,210.9	14.8
Total	123,716.1	100.0

Source: Meteorological Department, Federal Ministry of Aviation, Nigeria.

Table 3: Total annual sunshine hours for the period 1980-2002 for different agro-ecological zones

Ecological zone	Total annual sunshine hours/hrs	Percentage
Mangrove/Swamp	1309.6	20.4
Rainforest	1435.8	22.4
Derived savannah	1864.1	29.1
Montainic savannah	1796.5	28.1
Total	6406.0	100.0

Source: Meteorological Department, Federal Ministry of Aviation, Nigeria.

Table 4: Total cocoa output for the period 1980-2002 for different agro-ecological zones

Ecological zone	Total annual cocoa output/Mt	Percentage
Mangrove/Swamp	1199.8	35.0
Rainforest	1851.1	54.0
Derived Savannah	341.8	10.0
Montainic savannah	34.3	1.0
Total	3427.0	100.0

Source: CBN (1997, 1998 and 2004).

Table 5: Summary of the result of the analysis of variance (ANOVA) for temperature, rainfall and cocoa output among the four agro-ecological zones

Variable	F-value	Pvalue
Temperature	1.639	0.063
Rainfall	5.175	$1.0201E^{-07}$
Sunshine	1.186	0.146
Cocoa output	4.905	$1.1268E^{-07}$

Source: SPSS Software Computer Analysis printout

Table 6: Differences in rainfall and cocoa output among the ecological zones

Ecological zones	Rainfall/mm	Cocoa output/Mt
Mangrove/Swamp	2164.94	52.16
Rainforest	1504.74	80.36
Derived savannah	980.67	14.90
Montainic	791.52	2.04

LSD at 5% significant level 188.83 4.95
Source: SPSS Software Computer Analysis printout
LSD = Least Significant Different.

Table 7: Results of regression analysis

Ecological zone	Constant	Temp(X_1)	Rainfall(X_2)	Sunshine(X_3)	R^2	Fvalue
Mangrove/Swamp	262.317	-0.487 (-1.227)	0.618 (2.959)***	0.052 (0.206)	0.603	3.656
Rainforest	49.615	-0.019 (-0.092)	0.582 (2.663)***	0.620 (2.658)***	0.612	3.714
Derived Savannah	57.182	-0.612 (-2.226)**	0.650 (2.746)***	0.589 (2.671)***	0.653	3.512
Montainic savannah	0.427	-0.146 (-0.713)	0.218 (0.963)	0.340 (1.148)	0.347	0.658

Source: SPSS Software Computer Analysis Printout.
Figures in parenthesis are t-values.
*** Significant at 1% level,
** Significant at 5% level.

variables (rainfall and cocoa output), further analysis as revealed on Table 6 showed that at 5% level of Least Significant Difference (LSD), there was significant difference in the amount of rainfall between mangrove/swamp and rainforest; mangrove/swamp and derived savannah; mangrove/swamp and montainic; rainforest and derived savannah; rainforest and montainic as well as between derived savannah and montainic. Also, for cocoa output, there was significant difference in cocoa output between mangrove/swamp and rainforest; mangrove/swamp and derived savannah; mangrove/swamp and montainic; rainforest and derived savannah; rainforest and montainic as well as between derived savannah and montainic.

The Effect of Weather Variables on Cocoa Output: Here, regression analysis was run for each of the four agro-ecological zones with cocoa output (Q) as dependent variable and mean annual temperature (X_1), mean annual rainfall (X_2) and mean annual sunshine (X_3) as independent variables. Based on the regression results, double log regression model was chosen for the four agro-ecological zones. The result was presented in Table 7. In the table, rainfall is the only variable that was significant in mangrove\swamp agro-ecological zone ($p<0.01$). This shows that out of all the variables in the ecological zone, only rainfall significantly affected the level of cocoa output. The positive sign connotes that as rainfall increases, cocoa output also increases. As for rainforest zone, rainfall and sunshine significantly affected cocoa output in the zone ($p<0.01$). The sign of the two variables, however, conforms with the apriori expectation of the variables. In derived savannah zone, rainfall, temperature as well as sunshine significantly affected cocoa output ($p<0.01$, $p<0.05$ and $p<0.01$ respectively). The positive sign of the estimate of rainfall and sunshine showed that the more these variables in the zone, the more cocoa output while the negative sign of the estimate of temperature connotes that as temperature increases, cocoa output decreases. In montainic savannah zone, there was no variable that was significant; hence no variable that significantly affected the level of cocoa output in the zone. This might be due to the high altitude nature of the zone. At high altitude, temperature decreases which may reduce the intensity of water evaporation and the reduction of water evaporation would definitely reduce the volume of rainfall. Hence, at the montainic savannah zone, temperature and rainfall may not significantly affect cocoa production.

CONCLUSION

The agro-ecological zones with the highest mean annual temperature is derived savannah zone with 26.7% of the total MAT in all the zones. Mangrove/Swamp zone had the highest mean annual rainfall with 40.4% of the total annual rainfall in all the zones.

The highest cocoa output was recorded in rainforest zone with 54.0% of the total output in all the four agro-ecological zones.

The result of Analysis of Variance (ANOVA) showed that there was significant difference in the amount of rainfall as well as cocoa output among the four agro-ecological zones, but there was no significant difference in the temperature and sunshine in the four agro-ecological zones.

Regression analysis showed that rainfall is a critical factor in determining the output of cocoa in mangrove/swamp zone; rainfall and sunshine are the critical factors in rainforest zone while temperature, rainfall and sunshine are the significant factors that determined the output of cocoa in derived savannah agro-ecological zone.

Recommendations:

- In as much that rainfall is a critical factor in cocoa production, then government should make an arrangement for irrigation facility in any zone where rainfall is a limiting factor so that production of cocoa could be favoured in such zones.
- Since cocoa output is negatively related to temperature in all the agro-ecological zones, therefore farmers could be encouraged to adopt farming practices that will reduce temperature within cocoa plantation. The practices may include the planting of shading crops like plantain within the plantation. This is likely to have positive impact on cocoa output in the study area.

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