European Journal of Agriculture and Forestry Research
Vol.11, No.1, pp.43-55, 2023
Print ISSN: 2054-6319 (Print),
Online ISSN: 2054-6327(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Climate change effect on Cocoa Production in Central Agricultural Zone of Cross River State, Nigeria

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doi: https://doi.org/10.37745/ejafr.2013/vol11n14355 Published August 7 2023

Citation: Oniah, M.O. (2023) Climate change effect on Cocoa Production in Central Agricultural Zone of Cross River State, Nigeria, *European Journal of Agriculture and Forestry Research*, Vol.11, No.1, pp.43-55

ABSTRACT*: The study examined climate change's effect on cocoa production in the central agricultural zone of Cross River State, Nigeria. It specifically investigated the socioeconomic characteristics of cocoa farmers and the effect of climate variables on cocoa production in the study area. Both primary and secondary data were used for the study. Primary data were collected from 240 respondents and analyzed using descriptive statistics and the Likert scale techniques, Regression and correlation analysis were used to analyse the secondary data collected. The results of the descriptive statistics revealed that cocoa production was carried out by both men and women with men taking the production lead at 65.8% as compared to 34.2% of the women. On age distribution, the study revealed people within the age bracket of 18-50 years majorly cultivate cocoa in the area. The educational level revealed that the farmers had some form of formal education with good farming experience of between 11-20 years in cocoa production. The farmers had family sizes ranging largely between 6-15 persons in a household. The result also showed that 40% of the respondents inherited their farm holdings while 27.5%, 21.7%, and 10.8% of the respondents hired, purchased and rented their farm holdings respectively. The results of the multiple regression analysis revealed that about 78% of the climate variables influenced cocoa output in the area. It indicated that maximum temperature (X_1), relative humidity (X_4), wind (X_6), and evaporation (X_7) had an inverse relationship with cocoa output, whereas minimum temperature (X_2), rainfall (X_3), and sunshine hours (X_5) had a direct relationship with cocoa output in the study area. The correlation analysis revealed that maximum temperature (X_1), relative humidity (X_4), and wind (X_6) are negatively correlated with cocoa output while minimum temperature (X_2), rainfall (X_3), sunshine hours (X_5) and evaporation (X_7) are positively correlated with cocoa output in the study area. The most common strategies adopted by cocoa farmers to mitigate the effect of climate variables on cocoa production were the planting of cocoa-resistant varieties and intercropping cocoa with some tree crops to foretell bad weather conditions.*

KEYWORDS*:* climate change, effect, cocoa production, Cross River State, Nigeria.

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INTRODUCTION

Climate change describes global warming which involves the ongoing increase in global average temperature and its effects on Earth's climate system and previous long-term changes to Earth's climate, (Wikipedia, 2021). Climate change has many facets, including changes in temperature, rainfall, drought, cloud cover, floods, and heat regimes with increasing year-to-year variability, (United Nations, 2021). The report by the United Nations Intergovernmental Panel on Climate Change [UNIPCC] (2021), forecasts that the global average temperature will rise to between 1.5-2℃, and may continue to be exceeded this century unless we make deep efforts to cuts CO_2 and other greenhouse gas emissions in the coming decades.

Cocoa is generally known to be a tropical tree crop, part of the evergreen family that produces the world's chocolate in raw form before fat, sugar, and other sweeteners are added. Cacao thrives at altitudes of 30 to 300 meters (100 to 1,000 feet) above sea level in areas where temperatures do not range much below 20 °C (68 °F) or above 28 °C (82 °F). Rainfall requirements depend upon the frequency and distribution of rain and the degree of water retention by the soil; the minimum necessary rainfall is about 100 cm (39 inches) evenly distributed throughout the year, but 150–200 cm (59–79 inches) is optimal (Russell, 2022).

Agriculture always faces risks due to various reasons. Among the enormous risk, climatic risks are the most important ones as there are unavoidable and unexpected, especially under a rainfed ecology. Increased temperature, changes in precipitation conditions and increased CO_2 content in the atmosphere are the major climatic factors affecting crop production, (Neenu, Biswas, and Subba, 2013). A rise in atmospheric temperature will lead to loss of soil moisture and will increase the crop demand for water. The amount and availability of water stored in the soil will be affected by changes in both the precipitation and seasonal and annual evapotranspiration regimes. Suitable weather condition is essential at every stage of cocoa production, (Enoch and Abubakar, 2022).

Cocoa remains the main agricultural export in Nigeria, accounting for roughly 20 per cent of all non-oil exports and accounting for about 45 per cent of total labour employment (Taiwo and Matthew, 2018). Kehinde, Adeola and Molatokunbo (2022), reported that during the pre-independent and early independence years (1950s to the mid-1960s), the Nigerian economy largely depended upon the export of cocoa. By the mid-1950s, Nigeria had become one of the world's leading cocoa exporters, with volumes reaching around 280,000mt. As a result, cocoa became the country's top foreign export crop, accounting for approximately 30 per cent of its foreign-exchange earnings.

This production euphoria gradually declined due to the discovery of petroleum in Nigeria after which the agricultural sector was partially neglected. Despite the rapid growth in its production and positive impact on the nation's economy, cocoa production has been witnessing a drastic reduction when compared with the percentage of the population involved in agriculture since the discovery of crude oil in commercial quantity in Nigeria, (Afolayan 2020).

According to Dominican Today (2022), Cocoa is rich in nutrients such as fibre, proteins, carbohydrates, and minerals, which favour cell and tissue renewal. In addition, it has antioxidant properties, which help to reduce cholesterol levels, stress, and blood pressure and provides essential vitamins and minerals. Cocoa is used locally to produce cocoa-based products such as cocoa butter, cocoa cake, cocoa powder, and cocoa wine among others. It is usually used for making beverages, wine chocolate, cream, and livestock feed.

Given the importance of cocoa in the economy of Nigeria as a foreign exchange earner and its use locally in our infant industries and its contribution to the Gross Domestic Product (GDP), it is then necessary to investigate the recent decline in its production. Ajagbe (2022) revealed that Cocoa production in Nigeria witnessed a downward trend after the 2005 reveals season when its export declined from 450,000 metric tons in 2006 to 350,000 metric tons in 2020. Could this decline be attributed to the prevailing climatic parameters such as temperature, rainfall, wind, sunshine, and relative humidity among other factors?

There are about fourteen (14) States in Nigeria known to be mainly cocoa producing States. Among them are Ondo, Ekiti, Oyo, Osun, Ogun, Delta, Edo, Cross River, Akwa Ibom, Kwara, Kogi, Abia, Taraba and Adamawa with Ondo state considered the highest cocoa-producing state (Oluyole, Emaku, Aigbekaen and Oduwole, 2013). Similarly, the major cocoa-producing agricultural zone in Cross River State is the Central agricultural ecological zone comprising the following Local Government Areas; Etung, Boki, Ikom, and Obubra. In this zone, Etung and Boki Local Government Areas are known to be the highest cocoa-producing areas in the state.

Though, many studies, however, have been conducted about cocoa production in areas of agronomic practices, soil fertility and suitability, pests and disease control. But no relevance if any for now has been carried out in Central Cross River State of Nigeria to adequately determine the change in climatic factors affecting the production of cocoa in the area. Given this doubt, the study examined the extent to which climate variables affect the production of cocoa in the zone and how correlated the variables influenced cocoa output in the area.

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METHODOLOGY

Study Area

This research was carried out in Cross River State, Nigeria. Cross River State is located in the South-South geopolitical zone of Nigeria. It is located between longitudes 80 and 90 00" East of the equator and latitudes 400 4 South and 600 30 North. The State is bordered on the north by the state of Benue, on the east and west by the states of Akwa Ibom, Abia, and Ebonyi, and on the south by the Atlantic Ocean. The State is divided into three Agroecological zones: the mangrove forest in the south, the tropical rain forest, and the guinea savanna in the middle and north. These zones have annual rainfall ranging from 1500 mm to 2000 mm. The region supports the development of food crops such as cassava, maize, yam, cocoyam, palm oil, and tree crops like rubber, cashew, and cocoa. The majority of the population in Cross River State are small-scale peasant farmers. Rain-fed agriculture is used extensively in the region, with mixed cropping being the most popular farming method.

Data collection

Data for this study were sourced from both primary and secondary data. The primary data were collected through a questionnaire in which case the questionnaire was structured to generate the required data for the study. The secondary data include parameters information on temperature, rainfall, relative humidity, sunshine hours, wind, evaporation and cocoa output between the period of 1990 to 2022. This information was collected from the Meteorological station at Ikom Local Government Area of the state; while cocoa output data was gotten from the Cocoa produce office, Ministry of Agriculture, Calabar, Cross River State. Personal visits were also made to some of the farmers to attest to the validity of the information provided by the respondents in the questionnaire.

Analytical technique

The statistical tools employed to achieve the stated objectives are descriptive statistics, ordinary least square regression analysis, correlation analysis and the Likert scale techniques

Descriptive statistics were used to discuss the socio-economic characteristics of cocoa farmers and to examine farmers' perceptions of the effect of climate variables on cocoa production. The regression analysis was used to determine the effects of climate variation on cocoa production and is expressed implicitly thus;

$$Y = b_0 + b_1Tn + b_2Tm + b_3Rf + b_4RH + b_5Ss + b_6Wd + b_7E \ . \ . \ . \ + U_t. \ . \ . \qquad (1)$$

Where;

Y = cocoa output (tones).

Tm = mean annual maximum temperature (0°C).

Tn = mean annual minimum temperature (0°C)

Rf = mean annual rainfall (mm)

RH = mean annual humidity (mm)

S|s = mean annual sunshine, (per day)

Wd = mean annual wind, (m/s)

Eva = mean annual evaporation. (%)

b_1-b_7 = regression coefficients; and

U_t = disturbance term

Explicitly the equation was estimated using the three functional models such as the linear, semi-log and double-log functional forms. The three functional forms of the model are expressed below;

(i)Linear function: $Y = b0+b1X1+b2X2+b3X3+b4X4+b5X5+b6X6+ b7X7+ b8X8 + U_t$ ……(2)

(iii) Semi-log functional form: $Y = Lnb0+b1LnX1+b2LnX2+b3LnX3+b4LnX4+ b5LnX5+…+ bnLnX8 + U_t$ ..... (3)

(iv) Double log functional form: $LogY=Logb0+b1LogX1+b2LogX2+b3LogX3+b4\ LogX4 + .. + bnLogX_8 + U_t$.....(4)

Note: the model that provided the best fit was chosen for further discussion based on the following:

- The magnitude of the coefficients of the multiple determination (R^2);
- The magnitude and statistical significance of the regression coefficients; and

The signs of regression coefficients as they conform to a priori expectations.

Correlation analysis was used to determine the strength of the relationship between each of the climate variables expressed in cocoa production in the area while the Likert scale highlighted the perceived constraint of the climate parameters expressed in cocoa production in the study area.

RESULTS AND DISCUSSION

Table 1 Shows the Socio-economic characteristics of cocoa farmers in the Central Agricultural Zone of Cross River State, Nigeria

Variable	Parameter	Frequency	Percentage (%)
Sex	Male	158	65.8
	Female	82	34.2
	Total	**240**	**100**
Age	18-20 years	58	24.2
	21-30 years	108	45
	31-40 years	48	20
	41-50 years	22	9.2
	51 years and above	4	1.6
	Total	**240**	**100**
Level of Education	Never went to School	8	3.4
	Primary School	14	5.8
	Secondary School	108	45
	Tertiary Institution	110	45.8
	Total	**240**	**100**
Farming Experience	1-5 years	10	4.2
	6-10 years	18	7.5
	11-15 years	100	41.7
	16-20 years	110	45.8
	21 years above	1 2	5
	Total	**240**	**100**
Household size	1-5	22	9.2
	6-10	62	25.8
	11-15	108	45
	16 above	48	20
	Total	**240**	**100**
Farm holdings	Hired	66	27.5
	Inherited	96	40
	Purchased	52	21.7
	Rented	26	10.8
	Total	**240**	**100**

Source: Field survey, 2023

Table 1 revealed the socio-economic attributes of sampled farmers. Out of 240 respondents, 65.8% were male while 34.2% were female. This reveals that the production of cocoa is practised by both sexes in the study area. On age distribution, it was revealed that 24.2% of the respondents were between the age bracket of 18-20, 45% were within 21-30 years, 20% were within the age bracket

of 31-40 years, 9.2% were within the age bracket of 41-50 years and 1.6% were 51 years and above. This finding suggests that cocoa is mostly produced in the area by persons between the ages of 21 and 50 years, which indicates that these category of farmers are in their prime age of farming years. This result is consistent with Anyanwa, Agwu and Musa (2001), who found that people in their prime age are more likely to be active and innovative in farming. On an educational level, only 3.4%, of the respondents never attended school, 5.8% had primary education, 45% had secondary education and 45.8% had tertiary education. This shows that the majority of the farmers in the study area had some form of formal education, which suggests that if they were given the right technologies, they could adopt them and practice them appropriately. On farming experience, 4.2% of the respondents had 1-5 years of farming experience, 7.5% of respondents had between 6-10 years, 41.7% of respondents had between 11-15 years of farming experience 45.8% had between 16-20 years while 5% had between 21 years and above. From this finding, it can be inferred that the majority of the cocoa farmers about 87.5% have long-standing experience in cocoa production for between 11-20 years and so can report adequately well on their climate experience in cocoa farming in the study area as it affects them.

The variable of household size indicates that 9.2% of the respondents had a family size of between 1-5 members, 25.8% had 6-10 members and 45% had 11-15 members and 20% had 16 members and above. This result shows that about 70.8% of the cocoa farmers in the area have a family size of between 6-15 persons in a household. This may be so because the majority of the cocoa producers in the study area depended largely on family labour for the production of cocoa. In terms of farm holdings, the study revealed that 40% of the respondents inherited their cocoa farms, 27.5% of respondents hired their farms, 21.7% purchased their cocoa farms and only 10.8% of the respondents rented their cocoa farms. This indicates that the majority of cocoa producers depend on inherited farm holdings for farming.

Assessment of climate variables on cocoa production.

Table 2: Observation of climate change in cocoa production

Observation effect		**Frequency**	**%**
Do you observe any climate change in your cocoa farm?	Yes	240	100
	No	Nil	-
Total		240	100%
Does climate change have any effect on your cocoa farm?	Yes	240	100
	No	Nil	-
Total		240	100%

Source: Field survey, 2023

The response of the cocoa farmers in the study area revealed that 100% of the respondents observed climate change challenges in their cocoa farms as indicated in Table 2 above. This indicates that

cocoa farmers are experiencing climate change challenges in their farming practices in cocoa production over the years.

Multiple Regression Analysis results

Table 3: Multiple regression analysis result of climate variables on cocoa output

Determinant:	**Linear**	**Semi-log**	**Double-log**
Variable	**Coefficient**	**Coefficient**	**Coefficient**
Constant	475280.190	9.933	36.525
	(2.099) **	(4.039) *	(3.633) **
Maximum Temperature (X_1)	460.725	-0.017	-4.160
	(0.089)	(-0.303)	(-0.933)
Minimum Temperature (X_2)	2229.749	0.028	2.538
	(0.673)	(0.784)	(1.335)
Rainfall (X_3)	14.440	0.001	0.728
	(0.102)	(0.346)	(1.055)
Relative Humidity (X_4)	-6073.838	-0.068	-16.087
	(-3.057) ***	(-3.139) ***	(-3.868) *
Sunshine (X_5)	3594.176	0.049	0.501
	(0.871)	(1.094)	(0.977)
Wind (X_6)	-797.054	-0.007	-0.194
	(-3.957) *	(-3.248) **	(-2.610) *
Evaporation (X_7)	1180.888	-0.003	-0.71
	(0.160)	(-0.041)	(-0.179)
R^2	0.761	0.781	0.714
F – ratio	8.943*	7.721*	6.068*
Durbin-Watson	1.436	1.197	1.257

Source: Field study, 2023.

Note: *, **, *** represent significant at 1%, 5%, & 10% probability level respectively.
Values in parenthesis ‘’( )’’ are t-values

Based on the regression analyses of the functional models viz; linear, semi-log, and double log functional forms fitted to estimate the climatic variables on cocoa output, the semi-log functional form was chosen as the lead equation (LE) to discuss the variables based on the magnitude of the parameter estimates, apriori expectations, economic theory, and the diagnostic statistics. From the semi-log functional form, the value of the coefficient of determination (R^2) reveals that about 78% of the cocoa output is determined by the exogenous variables of the climatic elements fitted.

The variable of maximum temperature (X_1) -0.017 had an inverse relationship with cocoa output; while minimum temperature (X_2) 0.028 had a direct relationship with cocoa output in the study area. This indicates that very high temperature reduced cocoa yield while moderate temperature is suitable for cocoa production. This observation is in line with the work of Ojo and Sadig (2010), who noted that optimal temperature and minimal rainfall will give a better yield in cocoa production in Nigeria. It also conforms to the ICCO (2013) report, which reveals that too high or low temperatures will drastically reduce the yield of cocoa.

The coefficient of rainfall (X_3) 0.001 was positive, indicating that a good balance of rainfall can lead to high cocoa output in the study area. This conforms with the work of Oluyole et al (2013), who noted that rainfall and its characteristics in terms of intensity, amount, reliability, and distribution are known to influence crop growth and farm production. Sunshine (X_5) 0.049 was positive, indicating that an increase in the sunshine will influence cocoa output in the study area. This is in agreement with the work of Bentley, Boa and Stonehouse (2004), who said that cocoa productivity will increase if there is sufficient sunlight for photosynthesis.

The parameter estimates of relative humidity (X_4) -0.068, wind (X_6) -0.007 and evaporation (X_7) -0.003 were negative showing an inverse relationship with cocoa output. This indicates that if there is a high percentage of relative humidity, wind and evaporation they will affect and decrease the productivity output of cocoa.

The coefficient of determination (R^2) was 0.781 indicating that about 78% of the regressors (temperatures, rainfall, relative humidity, sunshine, wind and evaporation) influenced cocoa output. The F-ratio was 7.72 which indicates that there were interactions between the independent and the dependent variables and was significant at 1%. The Durbin-Watson statistic was 1.197 indicating a positive correlation between the variables.

Correlation Relationship

Table 4: Correlation relationship of climate elements with Cocoa Output.

Variable	Strength of Relationship	Remarks
Maximum temperature (X_1) & Cocoa Output	-0.122	Weak negative relationship
Minimum temperature (X_2) & Cocoa Output	0.246	Weak positive relationship
Rainfall (X_3) & Cocoa Output	0.133	Weak positive relationship
Relative Humidity (X_4) & Cocoa Output	-0.637	Strong negative relationship
Sunshine (X_5) & Cocoa Output	0.257	Weak positive relationship
Wind (X_6) & Cocoa Output	-0.807	A very strong negative relationship
Evaporation (X_7) & Cocoa Output	0.064	Weak positive relationship

Source: From field data, 2023

Correlation Relationship Result

Table 4 above shows the correlation relationship between cocoa output and climate variables. The result revealed that Maximum temperature (X_1) had a weak negative correlation with cocoa output indicating that maximum temperature negatively affects cocoa cultivation in the area. Relative humidity (X_4) and cocoa output had a strong negative relationship, indicating that high relative humidity negatively affects cocoa production. Wind (X_6) and cocoa output had a very strong negative correlation relationship. This indicates that high wind storms would result in a decline in cocoa output. This is so because wind storms can break the trunks of growing cocoa and even dispersed the flowers of cocoa pods in the area.

Minimum temperature (X_2) had a positive weak positive relationship with cocoa output. This implies that an increase in minimum temperature favours cocoa production in the area. Rainfall (X_3) had a positive weak correlation with cocoa output, indicating that average rainfall favours cocoa production but excessive rainfall reduces cocoa output. Sunshine (X_5) and Evaporation (X_7) had a positive correlation with cocoa output implying that an increase in their relationship will increase cocoa production.

The general finding is that maximum temperature (X_1), relative humidity (X_4), and wind (X_6) negatively influenced cocoa output while minimum temperature (X_2), Rainfall (X_3), Sunshine hours (X_5) and evaporation (X_7) had a positive relationship with cocoa output in the study area. This finding corroborates with the positions of ICCO (2013) and Russell (2022) who identified favourable climatic conditions to enhance the production and output of cocoa.

Climate variables affecting cocoa production in the area

Table 5: Effect of climatic variables on cocoa production in the study area.

Variables	Very severed	Severed	Moderately severed	Not severed	Total	Result	Remarks
Temperature	94	82	36	28	722	3.01	Critical
Rainfall	70	128	32	10	738	3.08	Critical
Relative Humidity	10	84	78	68	516	2.15	Not critical
Wind	126	52	52	10	774	3.23	Critical
Sunshine	52	54	112	22	616	2.57	Critical
Evaporation	10	10	28	192	308	1.28	Not critical

Source: Field survey, 2023.

The results of the Likert scale analysis as presented in Table 5 indicate that temperature (3.01), rainfall (3.08), wind (3.23) and sunshine hours (2.57) were considered as critical constraints by the respondents, while relative humidity and evaporation were not considered as constraints in cocoa production in the area.

Strategies Adopted to Mitigate the Effect of climate variations on Cocoa Production.
Table 6: Strategies adopted to mitigate the effect of climate variations in cocoa production.

Attribute	Number	%	Rank
Planting of resistant cocoa varieties to a climate effect	118	49.17	1
Planting of cocoa with other tree crops	34	14.17	2
Planting of cocoa with plantain	28	11.67	3
Increase spacing in the planting of cocoa seedlings	26	10.83	4
Increasing the number of hectares of cocoa farm	14	5.83	5
Reduction in the number of hectares to plant cocoa	12	5	6
Stop farming cocoa	8	3.33	7
Total	240	100%	

Source: Field survey, 2023

Table 6 shows the strategies adopted by the respondents to mitigate the effect of climatic variables on cocoa production in the study area. The result shows that the respondents (49.17%) adopted the method of planting resistant cocoa varieties to bad weather conditions, 14.17% of the respondents adopted the method of planting cocoa with other tree crops like Ogbonor, cola nut, pear, avocado, 11.67% of the respondents used the method of planting plantains with cocoa, while 10.83% responded that they adopted an increase in spacing in the planting of cocoa seedlings, 5.83 sorted to increase the number of hectares of cocoa farm, 5% responded that they decreased the sizes of their hectarage of cocoa farms. About 3.33% of the respondents attempted to stop cocoa farming

entirely. The result showed that the majority 96.67 of the cocoa farmers adopted so many strategies to mitigate the effect of climatic variables in cocoa farming rather than to stop farming cocoa entirely.

CONCLUSION AND RECOMMENDATIONS

The study examined the effect of climate variables on cocoa production in the central agricultural zone of Cross River State, Nigeria. The socioeconomic characteristics reveal that cocoa is cultivated by both males and females in the study area.

The study found that the climatic factors of temperature, rainfall, relative humidity, sunshine hours, wind, and evaporation influenced the output of cocoa by about 78%. It also concludes that maximum temperature (X_1), relative humidity (X_4), and wind (X_6) negatively influenced cocoa output while minimum temperature (X_2), rainfall (X_3), sunshine hours (X_5), and evaporation (X_7) positively correlated with cocoa output in the study area. The most common strategies adopted by cocoa farmers to mitigate the effect of climate variables on cocoa production are the planting of resistant cocoa varieties and the planting of cocoa with other tree crops to foretell bad weather conditions.

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