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Impact of Climate Variation on Cocoa Production in Akoko Region, Ondo State, Nigeria

ABIODUN DANIEL OLABODE

Abstract

Nigeria has suffered a reduction in cocoa production in recent years, owing to a number of factors including climate. This study examines impact of climate variability on the yield of cocoa crops with the aim to determining effect of weather parameters on crop production. Secondary data that include; rainfall, minimum and maximum temperature and crop yield were obtained from the Meteorology Department and the Department of Produce Services, Ministry of Natural Resources, Akure. The data covered a period of thirteen years (2003-2016). The period selected was based on the availability of both climate and yield data in the study area. Correlation analysis was used to establish inter-relationship among the crop and climate data. Coefficient of Variation (CV) was used to examine the degree of variation in the climate data. Regression analysis established the existing influence of rainfall and temperature on crop yield. Results showed that (i) seasonal change in rainfall and temperature influences crop yield, (ii) the examined climate data have 50% control over the yield (ii) R-value 0.71 indicating strong relationship of climate and cocoa yield. The study recommends adoption of climate copping strategy for farming practices, as well as utilizing early warning of weather forecasting systems for sustainable cocoa production.

Key words: Cocoa, Crop, Climate, Regression, Yield

1. INTRODUCTION

Climate change has taken a center point in the midst of diverse threatening environmental challenges facing the earth [1]. It has become the most threatening environmental problem in the present time, which forms a research subject among global scholars. The causes, long term effects, as well as how to combat the lingering impact is the concern. As noted by [2], the effects of climate change is more pronounced in African societies because of its geography, its sole dependence on Agriculture and its generalized incapacity to cope and adapt to climate extreme. Adverse effects of climate change continue to be a major threat to rural livelihoods [3].

In Nigeria, majority of local farmers depend on rain-fed faming. This is more so because adequate weather conditions are necessary for crop production [4]. Cocoa for instance, is highly susceptible to climatic condition, and pattern of its cultivation is related to rainfall distribution [5].

Cocoa is known to produce well with minimal but sustained water availability throughout the year [6]. It has been observed that persistent drought, flooding, off-season rain and dry spells have disrupted crop growing seasons in many Nigeria agro-ecological zones. This is because agriculture in Nigeria is mostly rain-fed as noted by [7]. Therefore, any change in climate is bound to impact productivity in particular and other socio-economic activities in the country. The impact could, however be measured in terms of effects on crop growth, availability of crop species, impact on crop yield, incidence of pest and diseases and decrease in soil fertility [8].

As noted by [9], Nigeria is the fourth highest Cocoa (*Cacao*) producing nation in the world after Ivory Coast, Indonesia and Ghana. It is obvious that Nigeria could produce cocoa on a world market scale. The production capacity of cocoa in Nigeria has reached about 385,000 metric tons per annum, an increase of 215,000 metric tons from year 2000 production level]9]. However, the production of this export crop in Nigeria has suffered a reduction in recent years owing to a number of factors including climate [10].

The vulnerability of cocoa production is better considered under climatic changes that influences the productivities of cocoa farmers. That is, the sensitivity of the farmers to these climatic conditions based on their local perception and their varying adaptive capabilities. In the study area for example, cocoa farming is being practiced at both subsistence and commercial levels. This particularly has categorized farming activities in this area under different sensitive climatic influences. For instance, during the period of high rainfall, cocoa crop tends to shedding of flowers prematurely, which most times necessitate low yield.

In the same vein, [11] observed that prolonged dry seasons result in cocoa seed mortality, whereas short dry seasons result in decreased pod filling, which affect the size of the beans. Increased rains and prolonged wet seasons slow the drying and processing of cocoa, which reduces the value of the bean and increases the cost of processing both in financial term and the time required.

In terms of production capacity, the study area is rated as the largest cocoa producing location in Nigeria. According to Nigeria Meteorological Agency [12], fluctuations in some climatic parameters, especially rainfall, temperature and sunshine hours are major concerns in terms of effective production of cocoa. [12] further noted that recently, some places in the South Western Nigeria including Ondo State recorded rainfall values that were 200-300 percent higher than normal. On this strength, this study considers how climatic variation affects cocoa production considering variations in seasonal trend and relationship of the monthly temperature, rainfall and cocoa yield in the study area.

2. MATERIALS AND METHODS

2.1 Literature Review

Recent researches have shown a tremendous decline in cocoa production in Nigeria. For example, [11] revealed that a number of factors were responsible for the vulnerability of cocoa yield decline among which climate parameters was one. Major climatic elements identified in the study were rainfall, temperature and sunshine.

There are other empirical studies which shown that environmental and socio-economic variables can also influence cocoa production over time. Available literature tends to discuss environmental impact in terms of shade cocoa biodiversity and habitat conservation, enhanced nutrient cycling, carbon sequestration to offset climate change effects, and hydrological cycling [13]. The extent of services of each of these functions is determined by each agro forests shade composition and density. The regional land use composite affect the degree and quality of ecosystem-level functions of which the individual cocoa farms are part.

The environmental impacts of sunlight on cocoa are potential contamination from agrochemicals, soil depletion, and increased threat of pests, deforestation, habitat loss, decreased fauna and flora populations and forest fragmentation [14]. However, there are cases where full sunned cocoa can bring environmental benefits by increasing the productivity per hectare to the extent that farmers do not encroach on primary or secondary forests, the land is used over the long-term on a rotational basis, and genetically improved cocoa varieties are used that reduce the need for inputs [13].

As reported by other researchers nutrient cycling is more efficient in shaded systems than in no- or low-shade cocoa farms. Farmers without shade are dependent on fertilizers to maintain soil nutrient levels [15]. Nutrient cycling in shaded cocoa farms is directly affected by the particular shade or fruit tree species and their management. Tree species differ in levels of above ground biomass productivity, rate of their biomass decomposition and fine root biomass productivity. The pruning regime and management of shade and neighbor trees is a tool for the farmer to adjust the microclimate for the cocoa as well as the timing and quantity of nutrient transfer from tree to soil. Decaying organic matter on shaded farms hosts a diversity of organisms that aid in decomposition and nutrient cycling, notably beneficial fungal mycorrhizae [15].

The planting density and pruning practices of leguminous species will affect the amount of nitrogen fixed. Some planting schemes allow shade species grow freely while manage the shade species intensively for particular results [16]. Predictably soil is better conserved and erosion is less of a threat in shaded than in un-shaded cocoa systems [17]. This is particularly true during heavy rainstorms. However, the degree of soil conservation depends on the amount of shade tree resides allowed to sta1y on the farm, especially in form a mulch layer during the rainy season when erosion threat is at its highest. However, erosion can be prevented in no shade systems through mulching.

The habitat conservation potential of cocoa agro forests largely depends on the floristic and structural diversity of the tree canopies coupled with the surrounding land use composition. Diverse canopies provide important habitats, resources and niches for a variety of plants and animals [18]. Studies in Ondo state show that diverse cocoa farms can harbor high species richness equivalent to that of forest ecosystems. In some cases, managed cocoa farms can support higher richness and abundance of migrant and resident bird species [15]. Although, sampled forest plots had more diverse tree species. The canopy cover and height of the cocoa farms was sufficient, similar to preserve a high degree of habitat functions for avian populations.

In another view, cocoa agro-forests serves as shade in Nigeria to preserve habitat for other plants such as the ebony woods (*Genus Diospyros* and *Docryodes butteri),* avian species (*buceros*), black casqued hornbills- *Ceratogymna atrata)* and African gray parrots [15]. Diverse cocoa agro-forests will have the maximum habitat conservation value when established in concert with patches of protected forest and vegetative corridors between agricultural areas and protected areas [19]. Also, shaded cocoa farms provide more hydrologic benefits than other land uses such as annual food cropping systems. They are for example better at controlling sediment loads in local watersheds and water recharge systems. However, the extent of shaded farmed in the overall landscape is the determinant of the hydrologic benefits [14].

In South Western Nigeria, where weather pattern is predicted to introduce new precipitation regimes, [20] researched on the effects of rainfall pattern on soil moisture, soil temperature and plant growth in alfisol soil of the humid forest transition zone. That to simulate six precipitation regimes which cover the maximum range to be expected under climate, a portable irrigation system was designed to modify the frequent of monthly rainfall events with the constant delivery rate of water, while maintaining contemporary average precipitation consistent with the 10 year average rainfall for this location. Manipulating the number of precipitation events and inter-rainfall intervals, while maintaining monthly rainfall average affected plant growth. Even with monthly rainfall averages that are similar to contemporary monthly precipitation averages, decreasing the number of monthly rainfall events reduced plant growth through soil moisture deficits [20].

It is well established that cocoa is highly sensitive to changes in climate- from hours of sun, to rainfall and application of water, soil conditions and particularly to temperature due to effects on evapotranspiration [21]. Climate change could also alter stages and rates of development of coca pests and pathogens, modify host resistance and result in changes in the physiology of host-pathogen/pests interaction. The most likely consequences are shifts in the geographical distribution of host and pathogen/pests, altered crop yields and crop losses which, will impact socio-economic variables such as farm income, livelihood and farm-level decision making. Hence the need for an understanding of climate change impacts on cocoa production and the potential for adaptation to climate change [22].

There are speculations that climate change will increase ecosystem productivity, their results show a reduction in the number of monthly rainfall while maintaining monthly average influence moisture and temperature dynamics, which ultimately affect the plant growth [23]. Furthermore, changes in the mean condition, for most systems and communities, fall within the coping range, whereas, many systems such as agricultural, are particularly vulnerable to change in the spread, duration and intensity of extreme events outside the coping range. [24] documented that many social and economic systems including agriculture, forestry, water resource management, human health and transportation had many possible adaptation measures, initiatives or strategies with potential to moderate change impact if implemented. Such possible adaptation measures included the change of topography of land, the use of artificial systems to improve land, water availability against soil erosion, the change of farming practices, the change of timing of farming operation the use of different crop varieties, the use of government and institutional policies and programs and finally researching into new technologies.

Climate variation is the primary determinant of agricultural productivity. It is expected to influence crop and livestock production, hydrological balances and other components of agricultural systems. Crop and livestock yields are directly affected by changes in climatic factors such as temperature, precipitation and extreme events like drought, floods and windstorm. Climate variation is the significant and lasting variation in the statistical properties of the average weather system when considered over long period of time, regardless of cause [22].

Climate variation can be referred to as the variation in average weather which is attributed directly or indirectly to human activities in addition to natural events that alters the composition of the atmosphere over comparable time period. The term is sometimes used to refer specifically to climate variation caused by human activities, as opposed to earth's natural processes. Climate change is a long-term shift in the weather condition of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. It could be a shift in average weather conditions, or in the distribution of weather around the average conditions [22].

2.2 Study Area

The study area is located in Akoko region of Ondo State, Nigeria, which is one of the largest cocoa producers in the country. For instance, West Africa has one of the largest cocoa producing countries where Nigeria is the 4^{th} largest global producer of cocoa, which means they are literally behind the 3 first producing states which are Ivory Coast, Indonesia, and Ghana, and in terms of exportation, Nigeria is the 3rd largest African exporter, after Ivory Coast and Ghana. Cocoa has been the leading agricultural export of the country with the below-listed states as the cocoa producing States in Nigeria, namely; Edo, Oyo, Osun, Ondo, Ogun, Cross River, Akwa Ibom, Ekiti and Delta.

The location is the largest and ancient city of the region with a distance of 56 km away from Akure, the state capital of Ondo State. The study location is situated between latitudes 7°28’ and 7°0’ N of the equator and longitudes 5°44’ and 5°0’ E of Greenwich meridian. It is bounded by Ekiti State to the North, Akngba-Akoko to the South, while to the East and West by Akoko-Edo and Akoko Southwest, respectively (Figure 1).

The climate of the study area is equatorial with two peaks of rainfall. The first peak comes up between April and July while the second peak falls between late August and October. These two

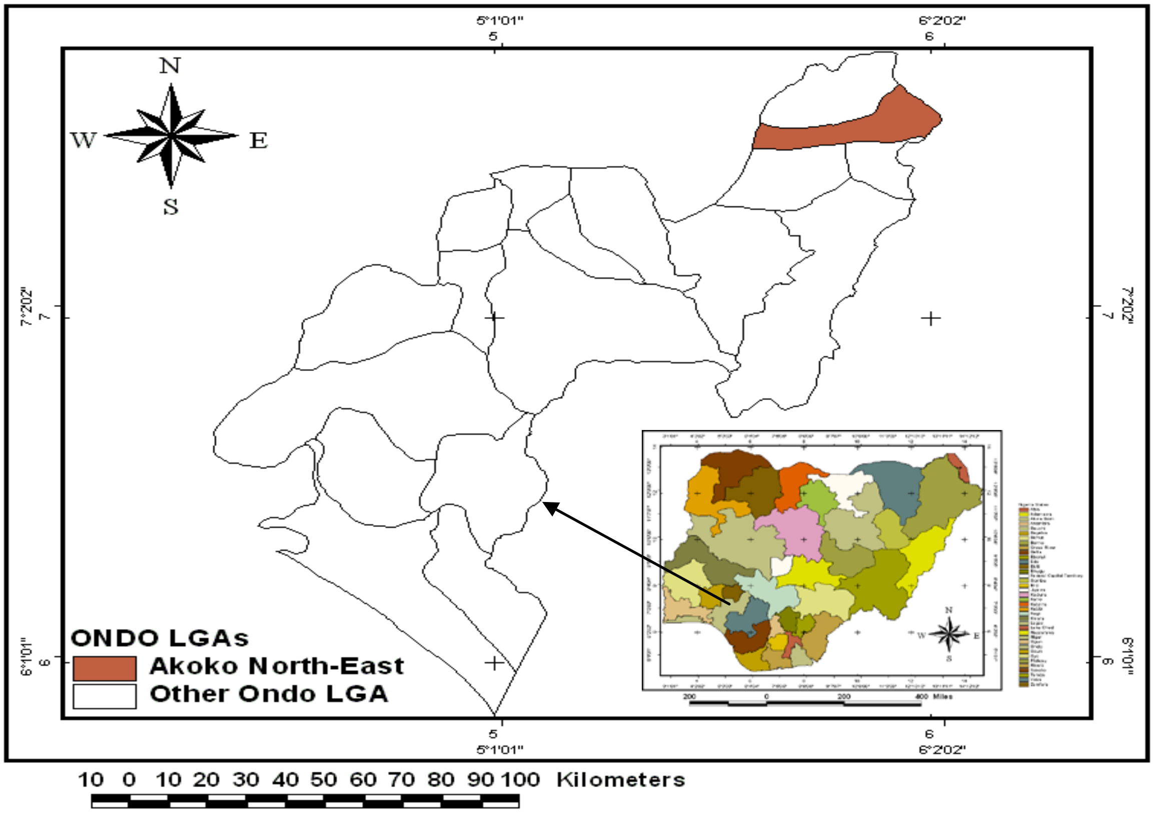

Figure 1: Study Area

Source: Ondo State Ministry of Lands and Housing, 2017

peaks are marked by heavy rainfall with the mean annual rainfall of 1500-2000 mm. The relative humidity of 75-95% results into severe cold condition in most cases. As observed by [25], the mean annual temperature is 23-26°C. The area under study is situated in the deciduous rainforest in southwestern part of Nigeria. It is dominated with ever-green vegetation. The vegetation type is described as rainforest and guinea savannah vegetation which is characterized by deferent plants and trees with height between 5 m and even more.

The state lies in the tropical rainforest, the state has a bimodal rainfall distribution but with less intensity. In Ondo state, there is lower layer vegetation mostly dense with abundance herbs, canopy and shrubs. The humidity and temperature are relatively high [26].

The state enjoys luxuriant vegetation with high forest zone (rain forest) in the south and sub-savannah forest in the northern fringe [27]. Ondo State is richly blessed with varied and favourable ecological and climatic conditions with vegetation ranging from mangrove swamps to the southern coastal riverine areas through the rainforest of the mid-lands to the derived savannah in the northern part of the state.

There are two distinct geological regions in Ondo State. First, is the region of sedimentary rocks in the south, and secondly, the region of Pre-Cambrian Basement Complex rocks in the north. Some few kilometres north of Aaye occurs the basement complex sedimentary rocks boundary. The sedimentary rocks are mainly of the post Cretaceous sediments and the Cretaceous Abeokuta Formation [28]. The basement complex is mainly of the medium grained gneisses. These are strongly foliated rocks frequently occurring as out crops. On the surface of these outcrops, severely contorted, alternating bands of dark and light coloured minerals can be seen. These bands of light coloured minerals are essentially feldspar and quartz, while the dark coloured bands contain abundant biotic mica. A small proportion of the state, especially to the northeast, overlies the coarse grained granites and gneisses, which are poor in dark ferromagnesian minerals.

Agricultural practice in the study area is restricted to small scale farm holdings with production of both food and cash crops as, maize, yams, cassava, vegetables, cocoa and palm tree. Cocoa has so many health benefits; while the cocoa bean seed is used to produce cocoa butter, the cocoa butter, in turn, is converted into chocolates which are regarded as the cocoa beverage when grounded. Also, people of the study area are preoccupied with industrial activities that include; traditional craft, trading, soap making, red-oil production, mechanic, educational, health and religion activities.

2.3 Materials and Methods

Data used in this study were obtained from secondary source and included; rainfall, minimum and maximum temperature and crop yield. The data were obtained from the Meteorology Department and the Department of Produce Services, Ministry of Natural Resources, Akure; covered a period of thirteen years (2003-2016). The period selected was based on the availability of both climate and yield data recorded over the years in the study area. Correlation analysis was used to establish inter-relationship among the crop yield and climate data. Coefficient of Variation (CV) examined the degree of variation in the climate data; while regression analysis established the existing influence of climate data on crop yield.

3. RESULTS AND DISCUSSION

3.1 Presentation of Climate and Cocoa Yield Data

Data on annual yield of cocoa, maximum and minimum temperature, and rainfall are presented in Table 1. It is revealed that recorded values of rainfall and temperature over the years determined to some extent cocoa yield produced by the farmers.

Table 1: Climate and cocoa yield data

Year	Annual rainfall (mm)	Temp Maximum (°C)	Temp Minimum (°C)	Yield (Tons/ha)
2003	40.66	373.98	232.27	1001.5
2004	1305.29	384.28	245.14	895.5
2005	1001.6	375.7	257.8	647
2006	1402.55	384.37	255.35	678.5
2007	77.2	397.3	238.5	399
2008	1096.53	395.3	258	312.5
2009	1314.6	401	257.8	368.5
2010	1912	389.9	254.4	143.5
2011	975.1	380.8	251.2	137
2012	1858.3	354.2	257.2	137.5
2013	1311.5	375.2	256.8	134
2014	1595.3	366.3	245.8	189.5
2015	989.6	356.4	250	320.5
2016	637	378.6	261	330.5

Source: Department of Produce Services, Ministry of Natural Resources, Akure, 2017

Trend analysis in Figure 2, shows a downward trends of cocoa yields over the selected period of the study. The trend maintained sharp fall from 2003 to 2010, while a bit balance in production was observed in 2010 to 2013. However, there was slit increased production in 2014 and 2016.

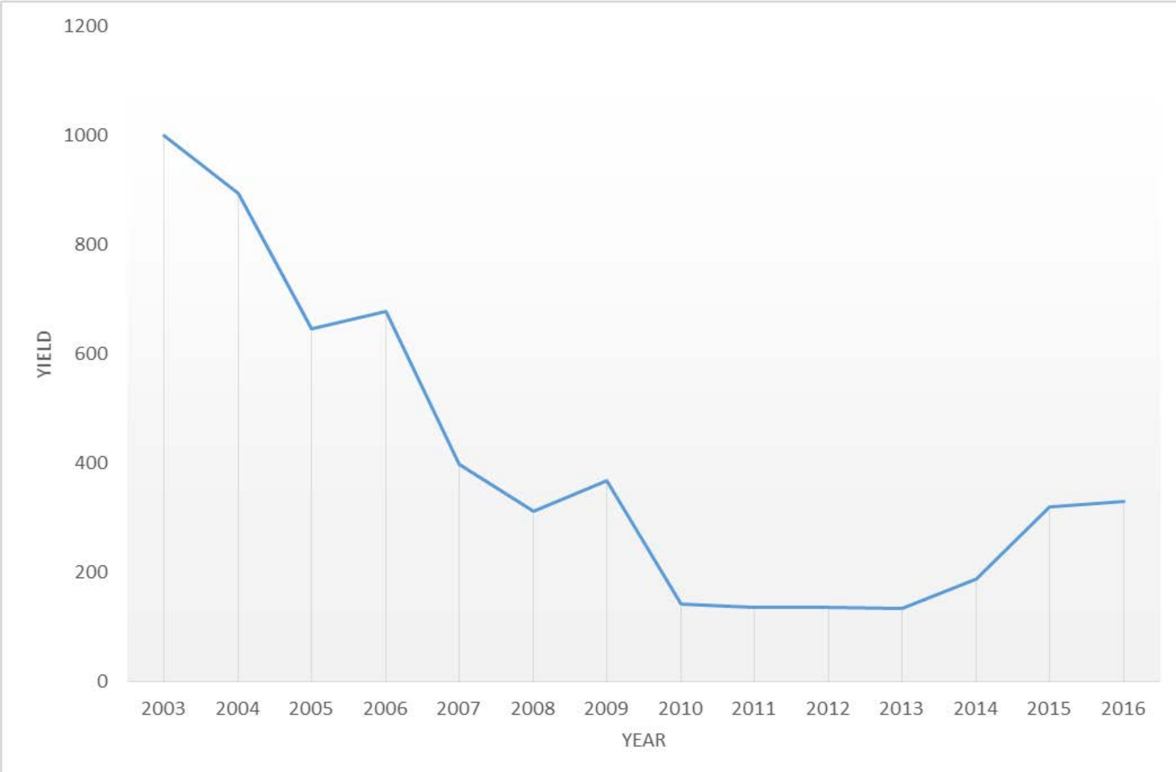

Figure 2: Trend of cocoa yield (tons/ha) in 2003 to 2016

Source: Department of Produce Services, Ministry of Natural Resources, Akure, 2017

However, Figure 3 presents a situation where improved yield of cocoa does not absolutely depend on rainfall and temperature but other factors of crop growth and development. For instance, in 2003, there were low amount of rainfall received in the year but appreciable cocoa yields were recorded. The appreciable yields recorded could be from other farming methods than climatic factor. Also, the increased yield might not be disconnected from coverage extent of the farmers in 2003. However, the increased yield of cocoa in 2006 production period indicates that increased rainfall (1402.55 mm) was responsible for appreciable yield of 678.5 t ha^{-1}.

In 2010, a downward trend of yield (143.5 t ha^{-1}) was recorded in view of increased rainfall of l912 mm. The effect of increased rainfall in 2010 resulted into low yield during the production period. In the recent times, between 2014 and 2016, there were improved yields as indicated by the upward trends, while both maximum and minimum temperature did not reflect any significant change over time. It should be noted further that rainfall values (1595.3 mm, 989.6 mm, and 637 mm) fall respectively in 2014, 2015 and 2016. Notwithstanding, the recorded yield values (189.5, 320.5 and 330.5 t ha^{-1}) for 2014, 2015, and 2016, respectively increased significantly.

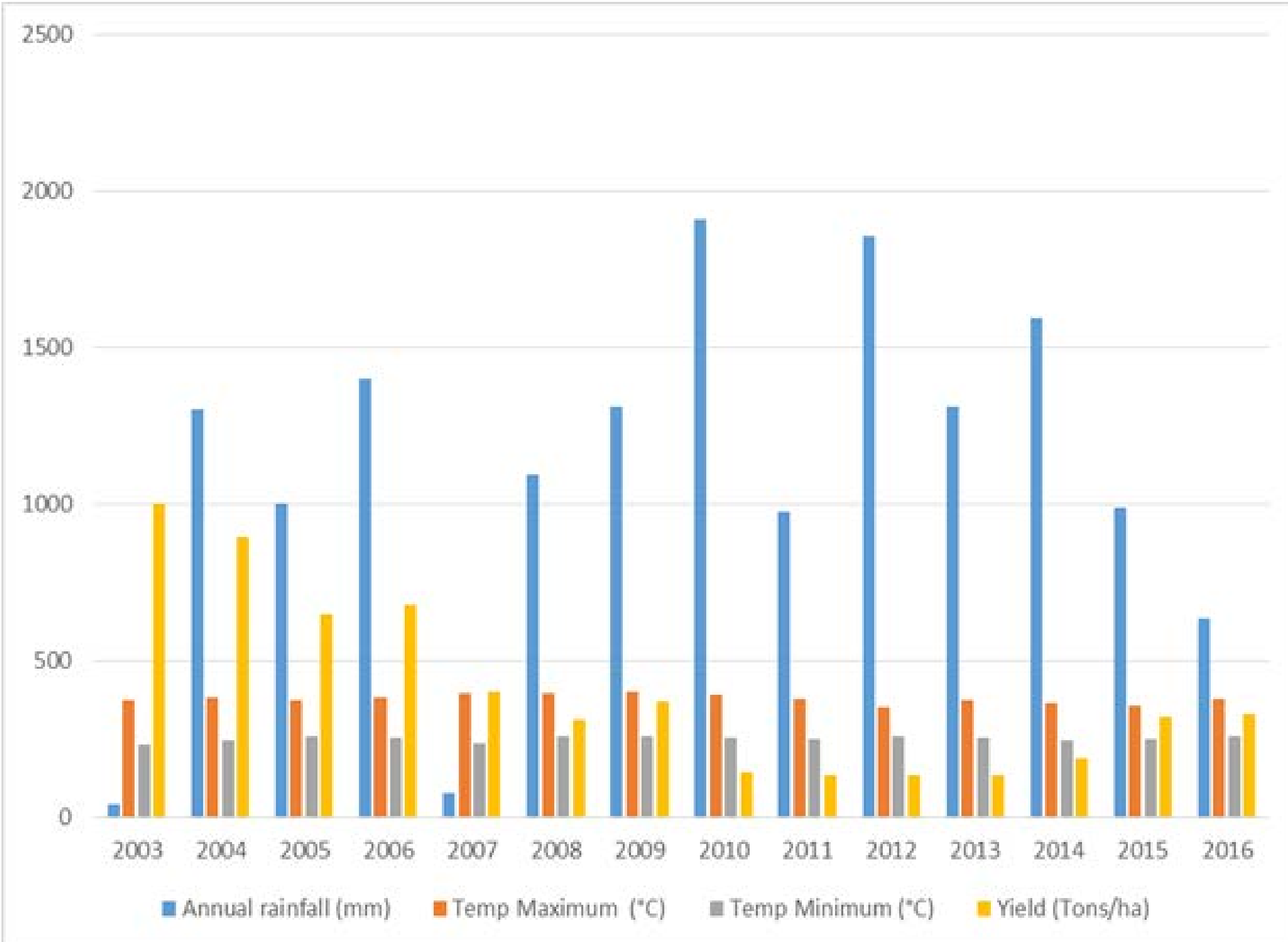

Figure 3: Cocoa yield, rainfall and temperature pattern between 2003 and 2016

3.2 Variation among Climate and Cocoa Yield Data

In this study, coefficient of variation (CV) was expressed in percentage (%) and applied to establish whether or not the climate parameters being considered vary during the production period in the study area. Variation only exists when CV is greater than 33% [25]. To compute the CV, the study presented the standard deviation of each climate variable and the crop yield as a percentage. This study revealed average mean values of 406.79, 1108.4, 379.5 and 251.5 for the cocoa yield, rainfall, maximum and minimum temperature, respectively (Table 2).

Table 2: Variation among the yield, temperature and rainfall data

Variable	Mean	Std. Deviation	CV
Yield (tons)	406.79	288.76	70.99*
Rainfall (mm)	1108.37	563.19	50.81*
Temperature (Max ^{0}c)	379.52	14.13	3.72
Temperature (Min ^{0}c)	251.52	8.37	3.33

The recorded coefficient of variation (CV) for the rainfall (70.99*) and cocoa yield (50.81*) simply suggests that rainfall and cocoa yield are significantly varied in the study area. That is, rainfall plays dominant role in cocoa production in the study area. The current trend was previously reported by [5] that production of cocoa crop heavily depends on rainfall. In another recent study, [29] reported that yearly variation in the yield of cocoa was affected more by rainfall than any other climatic factors. However, the CV revealed that maximum (3.72) and minimum (3.33) temperature have homogenous distribution in the study.

3.3 Interrelationship among Temperature, Rainfall and Cocoa Yield

The correlation matrix for the climatic parameters and crop yield (-0.46) indicates negative significant relationship between the rainfall and the yield of cocoa production in the study area (Table 3). However, the amount of rainfall received within the study period shows a positive relationship (0.57) with the observed minimum temperature. In another trend, negative relationship was established between the rainfall and maximum temperature (-0.19).

Table 3: Correlation analysis showing relationship between yield and climate parameters

Variables	Yield (tons)	Rainfall (mm)	Temperature Max (0^{c})	Temperature Min (0^{c})
Yield (tons)	1			
Rainfall (mm)	-0.46	1		
Temperature (Max 0^{c})	0.13	-0.19	1	
Temperature (Min 0^{c})	-0.50*	0.57*	0.03	1

* Correlation is significant at the 0.05 level .

The study further revealed existing positive relationship of maximum temperature (0.13) and crop yield in this study. This observed relationship implies that minimum temperature has dominant influence on rainfall availability over the years in the study area.

3.4 Climate Parameters and Cocoa Yield Regression Model (YRM)

In this study, YRM revealed the extent at which various climatic parameters has affected cocoa yield in the study area. The calculated values of the regression analysis are presented in Table 4. This contains the dependent variable (Cocoa yield) and independent variables (temperature and rainfall). The decision rule states that reject H_0 if $F_c > F_\alpha$ at V_1V_2 of 95% confidence level. The above statement shows that the calculated F value of 0.28 is significant at P= 0.05.

In addition, the R value (0.553[a]) indicates an existing strong relationship among the climatic parameters and the cocoa yield. It should be noted that these climatic parameters under consideration are significant to yield and rejection of any could impede cocoa growth and development in the study area and other related agro-ecologies. Also, the correlation coefficient of 0.31 signifies that both temperature and rainfall have 31% control over the yield of cocoa while the remaining 69% could be attributed to other factors of cocoa production in the study area.

Table 4: Summary of climate parameters and cocoa yield regression model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.553[a]	.305	.097	274.41278	.305	1.465	3	10	.282

a. Predictors: (Constant), Min Temperature, Max Temperature, Rainfall

4. CONCLUSIONS AND RECOMMENDATION

It concludes that; the temperature is homogenous all over the years while rainfall has heterogeneous distribution; the thread of heterogeneity of rainfall distribution influenced general yield of cocoa in this area; while minimum temperature has dominant influence on rainfall availability over the years. Based on these conclusions, the study recommends adoption of climate copping strategy for farming practices, as well as utilizing early warning of weather forecasting systems for sustainable cocoa production in the study area and other related environment.

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