Effects of Length of Monsoon Drought on the Annual Yield of Cocoa in Akure, Southwestern Nigeria

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Received: 27-APRIL-2024; Reviewed: 12-SEPT-2024; Accepted: 21-SEPT-2024
https://dx.doi.org/10.4314/fuoyejet.v9i3.24

ORIGINAL RESEARCH

Abstract— The period of drought during monsoon months (June-September) sometimes known as “August Break” usually provides opportunities for harvesting and other farm-level processing activities in the humid and sub-humid agro-ecological zones of Nigeria. This is particularly so for cocoa, a major crop grown in Akure, Ondo State, Nigeria. Thus, the aim of the present study was to evaluate the impacts of length of monsoon drought on the annual yield of cocoa in Akure. Daily rainfall data and annual yield of cocoa covering the period 2004-2018 were obtained from the Ondo State Ministry of Agriculture, Akure and analysed. Results showed that rainfall was highest in July, contributing about 28%, while December contributed the least (<1%). Moreover, highest annual cocoa yield was recorded in the year 2004 (7998 tons) and the least (1506 tons) was in 2017, while the longest and shortest of monsoon drought were 28 and 3 days in 2005 and 2008, respectively. There was high variability and declining trends in both annual yield of cocoa and length of monsoon drought during the period under study. Given the slope of the regression equation and the R^2 values (172.16 and 0.48, respectively) obtained, it was concluded that length of monsoon drought was a major factor determining the annual yield of cocoa in Akure. Consequently, for increasing yield, optimum use of the period of monsoon drought for important cultural practices, including application of fungicides to reduce the spread of black pod diseases, timely pod harvesting and bean processing, amongst others, are recommended.

Keywords— Monsoon, Drought, Season, Harvesting, Processing, Cocoa, Productivity.

1 INTRODUCTION

A monsoon is a seasonal change in the direction of the prevailing or strongest winds of a region (Kumar et al., 2013; Mishra et al., 2016). Monsoons cause wet and dry seasons throughout much of the tropics, including Nigeria and this is always obvious along the coastal regions of the country. In the southwestern Nigeria where over 70% of the annual rainfall is concentrated in the rainy season (June-September), the monsoon is a dominating factor (CLIVAR, 2015). However, there is increasing year to year variability in the monsoon seasonal rainfall such that can have large impacts on water resources and agriculture. This may also lead to extreme rainfall events such as floods and droughts. For example, because of large variability, monsoon droughts had disastrous effects on agriculture, water resources, food security, economy and social life in India (Kumar et al., 2013). According to Salerno (2015), the agro-industry is severely affected by drought as vegetation and plants suffer the deficiency of water in the air and soil due to evapotranspiration. Moreover, the prevailing climate change may further exacerbate changes in the hydrological cycle by affecting precipitation and evaporation, causing further variability during the monsoon (Yu et al., 2013).

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Section E- CIVIL ENGINEERING & RELATED SCIENCES
Can be cited as:
Oloruntade A.J., Oguntunde P.G, and Alao J (2023). Effects of Length of Monsoon Drought on the Annual Yield of Cocoa in Akure, Southwestern Nigeria, FUOYE Journal of Engineering and Technology (FUOYE**JET), 9(3), 525-529.** https://dx.doi.org/10.4314/fuoyejet.v9i3.24

Therefore, given the rain-fed agriculture that is commonly practiced amongst cocoa farmers in the West African sub-region, Nigeria and Akure, adequate understanding of the seasonal changes in the monsoon may be of great benefit to both farmers and other critical stakeholders in the cocoa industry.

Although cocoa is highly sensitive to climate change (Oyekale et al., 2009, Longe and Oyekale, 2013; Omosuyi et al., 2021), however, studies have also shown that the crop is more resilient to heat stress caused by elevated temperature than water stress due to drought (Schroth et al., 2016; Kotei, 2020). Consequently, several studies have investigated the effects of climate change and drought on cocoa with diverse results. For instance, Hutchins et al. (2015) reported that as a result of rainfall variability, planning for cultural practices, harvesting and farm-level processing of cocoa were made difficult, leading to reduced yield and poor bean quality in Ghana. Moreover, extreme rainfall events have been adduced for the alteration in the development stages and rates of pests and diseases related to cocoa, decrease in the incubation periods and development of harmful organisms, and high ease of introduction of invasive species as well as changes in their geographical distribution (Schroth et al., 2016). In Ghana, Kotei (2020) assessed the response of cocoa to drought length and revealed a significant negative influence of drought lengths on all the yield parameters of the crop.

Within the Nigeria context and particularly in the southwestern part of the country where cocoa production predominates, Oyekale et al. (2009) assessed the vulnerability and effects of climate change on cocoa production and reported high susceptibility of the crop to drought. Similarly, while climate change has been described as a major factor posing serious threats to sustainable cocoa production in Nigeria (Longe and Oyekale, 2013), Oguntunde et al. (2014) further investigated the trends and association between climatic variables and cocoa yield in Ondo State and reported a significant correlation between crop yield on one part and, rainfall and temperature on the other part. Omosuyi et al. (2021) studied the effects of climate variability on cocoa production in Ondo State and also observed an inverse relationship between rainfall and cocoa output but increasing output with both humidity and temperature.

Despite the significant number of studies on the effects of climate change and, particularly, drought on the production and yield of cocoa across the world, information is scarce regarding the effects of monsoon drought on the crop. Meanwhile, significant fluctuations at the decadal time series of West African monsoon rainfall have been severally reported (Adejuwon and Odekunle 2006; Salako, 2008). Regrettably, such fluctuations may lead to extreme rainfall events in forms of droughts and floods, as water deficit due to drought causes significant yield reductions both for rain-fed and irrigated crops (Ray et al., 2018). Yet, given that cocoa is more sensitive to annual rainfall distribution than amounts (Longe and Oyekale, 2013; Olabode, 2020), future global cocoa yield and output may be negatively affected as global climate models have shown further fluxes in the spatial and temporal distribution of precipitation, with decreasing climatic suitability projected in many cocoa origins (Bunn et al., 2017). Therefore, under rain-fed agriculture, fluctuations in rainfall distribution may have significant effects on general crop yield and impact the means of livelihood of most of the populace, including cocoa farmers.

Ondo State is one of the leading cocoa producing states in Nigeria of which Akure is a major town within the cocoa producing zone of the state. Studies have shown fluctuations in the annual yield of cocoa in the state (Omosuyi et al., 2021), with a projected mid-century decline of about 9,334 tonnes/yr by 2050 and a long-term future decrease of 13,504 tonnes/yr of cocoa by 2100 (Omotayo et al., 2019), because of climate change. However, the period of monsoon drought (August Break) usually provides a window of opportunity for the application of fungicides and, ripening, harvesting and sun-drying of cocoa in Akure. In this regard, there is a growing suspicion amongst scientists that the short break in rainfall also commonly known as short/little dry season (Asadu, 2002; Adeniyi and Oladiran, 2006) may have significant contribution to the yearly yield of cocoa, thus requiring further investigation. Therefore, the main objective of the present study was to assess the effects of monsoon drought on the annual yield of cocoa in Akure, Nigeria.

2. MATERIALS AND METHODS

2.1 THE STUDY AREA

The study area is Akure the capital city of Ondo State, Nigeria (Figure 1). Akure lies within the Latitude 7.25° N and Longitude 5.2° E, with a population of about 484,798 covering about 991 km² (Ayeni, 2011). Most of the inhabitants live within the metropolis. The area is characterized by heavy rainfall with climate following the usual tropical pattern. The climate is humid with a rainy season which normally starts in March/April and ends around October/November, while a short dry season earlier described as 'August Break' or monsoon drought occurs between the month of July/August and the long dry season is from November to February or March. Mean annual rainfall and temperature are 2378 mm and 26.7 °C, respectively, while relative humidity is about 58% (Balogun et al., 2011). The driest month is usually December, but in September, precipitation reaches its peak, with an average of 405 mm. The warmest month of the year is March, with an average temperature of 28.1 °C, while at 25.2 °C on average, July is the coldest month of the year. The difference in precipitation between the driest month and the wettest month is 386 mm. The variation in annual temperature is around 2.9 °C. Food crops such as cocoyam, tomato, maize, plantain, and cash crops including cocoa, kola nut and timber are commonly grown in Akure (Omosuyi et al., 2021).

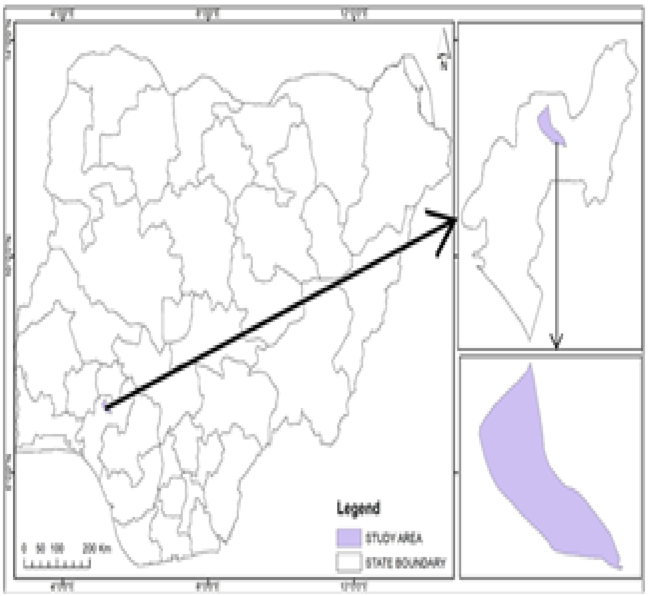

Figure 1: Location of Akure in Ondo State, Nigeria

2.2 DATA COLLECTION

The study relied mainly on secondary data of annual cocoa yield and daily rainfall of Akure covering the period 2004 to 2018. The annual yield data used for this study were collected from the Ondo State Agricultural Development Project, Ministry of Agriculture, Akure, while the daily rainfall data were obtained from the archive of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. The Agency is affiliated to the World Meteorological Organization (WMO), a specialized agency of the United Nations.

2.3 Data Analysis

Preliminary Data Analysis

The preliminary data analysis (PDA) is useful to gain an insight into the direction and mode of change in hydro-climatic variables. It uses graphical tools such as time series and scatter plots, and it is intended to ensure

http://dx.doi.org/10.46792/fuoyejet.v9i3.24 engineering.fuoye.edu.ng/journal

improved understanding of the existing data and the fundamental processes involved in its changes. In addition, simple descriptive statistics which include the mean $(\overline{X})$, standard deviation (SD) and coefficient of variation (CV), minimum and maximum values were also calculated to obtain an initial understanding of the data.

To achieve the foregoing, the daily rainfall data were aggregated into monthly and annual time series after which time series plots were made and descriptive statistics computed. Similar analysis was extended to the annual yield of cocoa and length of monsoon drought after its computation. For all the analysis, the Microsoft Excel package, 2013 was used.

2.4 Definition and Computation of Length of Monsoon Drought

In this work, length of monsoon drought is defined as the period from the 3rd week of July to the end of August during which daily precipitation (p) is less than 0.3 mm $(P < 0.3)$ for at least three (3) consecutive days (Adejuwon and Odekunle, 2006; Chineke et al., 2010; Ayanlade et al., 2018). However, it ends when precipitation is equal or greater than 0.3 mm $(P \geq 0.3)$ for another consecutive three (3) days.

3 Results and Discussion

Descriptive Statistics of Monthly Rainfall in Akure

The results of the PDA showed that July contributed the highest rainfall (6268.15 mm) throughout the research period and December contributed the least (142.22 mm) (Table 1). Maximum rainfall was recorded also in the month of July (647 mm) and December had the lowest. The highest range was also in July (482.34 mm) which may be an indication of high rainfall variability in the month, while February recorded the least (88.68 mm); July was also the month with the highest mean (417.88 mm) and the lowest mean was recorded in the month of December (9.48 mm). Moreover, July had the highest standard deviation of 142.23 mm and December with the lowest (23.65 mm), while December and September had the highest and lowest coefficient of variation (249.43%) and (27.42%), respectively, compared to other months. These results are not unexpected as Akure enjoys tropical climate where rainfall is generally high and reaching its initial peak in July (Odekunle, 2006; Babatolu et al. 2014). The results further suggest that rainfall in the months of September during the period under study was more stable and predictable than in the other months. In addition, the mean annual rainfall in August (139.42 mm) is the lowest amongst the monsoon months (June-September). This may not be unconnected with the fact that the greater number of days of the annual little dry season usually spans through August.

Table 1: Descriptive statistics of monthly rainfall time series of Akure

Month	Total	Max	Min	Range	Mean	SD	CV
January	354.37	108.78	0.00	108.78	23.62	36.99	**156.57**
February	513.57	**89.40**	0.72	88.68	34.24	27.26	79.61
March	1229.73	144.71	16.92	127.79	81.98	42.74	52.13
April	1722.98	187.87	58.32	129.55	114.87	41.02	35.71
May	1950.43	244.19	37.55	206.64	130.03	63.05	48.49
June	2192.58	391.16	66.97	324.19	146.17	78.54	53.73
July	**6268.15**	**647.00**	**164.66**	**482.34**	**417.88**	**142.23**	34.04
August	2091.24	261.82	44.00	217.82	139.42	65.00	46.63
September	3457.95	352.10	80.66	271.44	230.53	63.22	**27.42**
October	2022.09	227.33	51.05	176.28	134.81	46.54	34.52
November	629.89	121.97	8.67	113.30	41.99	32.40	77.16
December	**142.22**	93.59	**0.00**	**93.59**	**9.48**	**23.65**	249.43

SD = standard deviation; CV = coefficient of variation, while bold figures represent the maximum and minimum values for each of the statistics

Descriptive Statistics of Annual Cocoa Yield and Length of Monsoon Drought in Akure

PDA also showed that the highest annual cocoa yield (7998 tons) and length of monsoon drought (28 days) were recorded in the years 2004 and 2005, respectively (Table 2). Moreover, while the lowest annual cocoa yield (1506 tons) was in 2017, the shortest length of monsoon drought (3 days) was in 2008. Mean annual cocoa yield for the period under study was 5682 tons, while the mean length of monsoon drought was 11.47 days. Variability was high for both the annual cocoa yield and length of monsoon drought given the high coefficient of variability (CV) of 31% and 62% obtained for the two parameters, respectively. Previous studies have also shown the variability of the monsoon drought, with significant effects on annual crop production (Kumar et al., 2013; Mishra et al., 2015; Ayanlade et al., 2018). High variability in annual yield of cocoa may have negative impact on farmers' income, particularly for those without alternative sources of income.

The monsoon drought hovered between the first and third weeks of August in about 53% of data duration whereas it fell between the last week of July and third week of August in about 25% of the period. Generally, for the whole length of data, monsoon drought did not commence until the last week of July in any year, while it only delayed till the second week of August in the year 2004. The results show that the monsoon has always waited till August before its annual break in Akure in most of the years under consideration. This is similar to the results of Chineke et al. (2010) in which slight break in rainfall commencing from the third week of July or late July to early August was observed over the southern part of Nigeria.

Table 2: Descriptive statistics of annual cocoa yield and length of monsoon drought

Year	Cocoa Yield (tons)	Length of Monsoon Drought (Days)	Dates
2004	7998	9	14 - 24, August
2005	7863	28	27, July -23, August
2006	5116	17	05 - 21, August
2007	3707	4	03 - 06, August
2008	4469	3	09 - 11, August
2009	5747	12	02- 13, August
2010	5331	9	28, July - 05, August
2011	7044	10	23, July - 01, August
2012	6198	8	05 - 13, August
2013	7499	22	30, July - 20, August
2014	5345	9	09 - 17, August
2015	5684	19	29, July - 16, August
2016	7224	12	30, July - 10, August
2017	1506	4	07 - 10, August
2018	4501	6	03 - 08, August
Maximum	7998	28	
Minimum	1506	3	
Mean	5681.90	11.47	
SD	1746.16	7.16	
CV	0.31	0.62	

Trends of Annual Yield of Cocoa and Length of Monsoon Drought in Akure

Annual yield of cocoa shows decreasing trend from 2004 (7998 tons) reaching its minimum (3707 tons) in 2007 (Figure 2a). Thereafter, it rose through 2008 to 2016 before it finally got to its least (1506 tons) in 2017, after a decade. This suggests that annual yield of cocoa may be following a decadal pattern. Thus, considering the likely negative effects of the fluctuating pattern on the contribution of cocoa to the GDP of the country, there may the need for more intensive and extensive studies into its causes with a view to averting future reoccurrence.

In the same vein, length of monsoon drought shows a general decreasing trend over the period of study (Figure 2b). Although, it rose from 9 days in 2004 reaching its peak (28 days) in 2005, it thereafter displayed decreasing trend until 2008 when it slightly recovered till 2013. However, since 2015, the length of monsoon drought has been on decreasing trend. These results may suggest that cocoa farmers might have been faced with the challenge of finding the appropriate timing for the spraying of fungicides to possibly reduce black pod disease of cocoa. This is because, the longer the period of monsoon drought, the more the effects of fungicides stay on cocoa trees. In addition, as some cocoa pods become ripe and harvested during this period, sun-drying the harvested beans may become very difficult under short period of monsoon drought and high humidity. Generally, there is a good agreement in the pattern of decreasing trend between the annual yield of cocoa and length of monsoon drought in Akure. This result may not be unconnected with the fact that shorter monsoon drought implies high relative humidity and reduction in sunlight hours which may lead to premature shedding of flowers and decreased pod formation, high rate of diseases attack and ineffective drying of cocoa beans (Longe and Oyekale, 2013; Lawal and Omonona, 2014; Olabode, 2020).

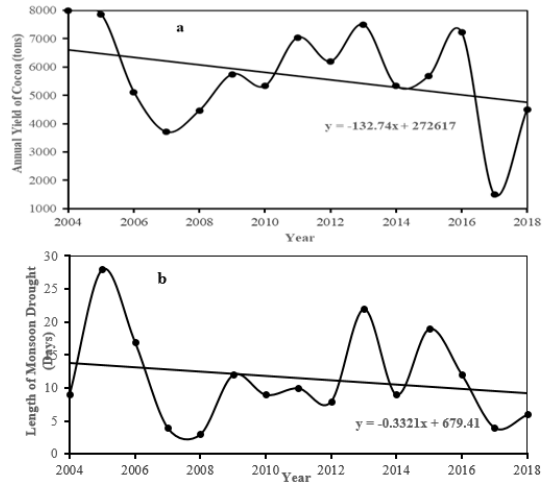

Figure 2: Trends of (a) Annual yield of cocoa and (b) Length of monsoon drought in Akure

Further plot of annual yield of cocoa with the length of monsoon drought shows a positive relationship (Figure 3). This further helps to confirm the earlier suggestion of a good agreement in the trend patterns of annual yield of cocoa and length of monsoon drought in Akure. Moreover, given the R^2 of 0.4808, it can be inferred that length of monsoon drought is responsible for about 48% of the factors affecting the annual yield of cocoa in Akure. The possible implications of this may include the fact that cocoa output may be higher in the years with longer monsoon drought such that farmers should ensure maximum use of the opportunity provided during this period for various cultural practices on the farm, including harvesting and farm-level processing of cocoa for increased productivity.

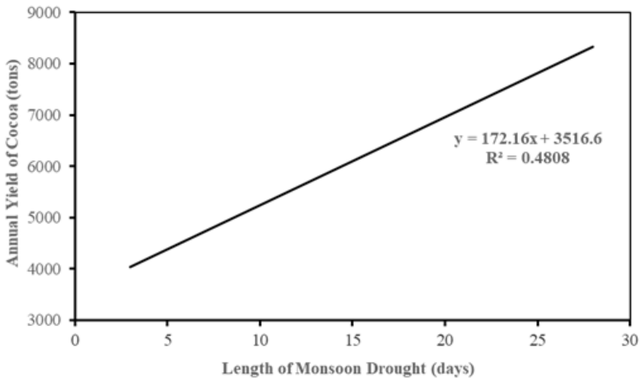

Figure 3: Variation of annual yield of cocoa with length of monsoon drought

8 Conclusion and Recommendations

There was high variability in both annual yield of cocoa and length of monsoon drought in Akure and the mutual agreement in the patterns of the decreasing trends for the two parameters. Consequently, it can be concluded that the length of monsoon drought is a major factor determining the annual yield of cocoa in Akure. Hence, the following recommendations:

(i) farmers should maximize the use of the period of annual monsoon drought for harvesting, fermentation and sun-drying of cocoa for possible improvement on the annual cocoa output.
(ii) cocoa farmers in Akure should ensure timely application of appropriate fungicides and other chemicals in their cocoa farms, to reduce the spread of black pod diseases.
(iii) similar study should be extended to other notable cocoa producing towns in the state and Nigeria, most especially, with longer data durations.

ACKNOWLEDGMENT

The authors wish to thank the authorities of Ondo State Agricultural Development Project, Ministry of Agriculture, Akure, Nigeria for releasing the cocoa data used in this study.

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