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VARIABILITY IN SOME SELECTED RAINFALL CHARACTERISTICS AND YAM PRODUCTION IN MAKURDI AND GBOKO, BENUE STATE, NIGERIA.

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ABSTRACT

This study examined the variability of five relevant rainfall characteristics: annual rainfall total, number of rainy days, length of the growing season, onset dates and cessation dates of rainfall, and their implications on Yam production in Makurdi and Gboko Benue State, Nigeria. Daily rainfall data from 1980 to 2015 was obtained from the Nigeria Meteorological Agency (NiMet), Makurdi, and Agro-Meteorological Station Yandev, Gboko, while yam production data from 1986 to 2011 was obtained from Benue State Agricultural and Rural Development Authority (BNARDA), Makurdi. The data were analyzed using trend, correlation, and regression analyses. In both Gboko and Makurdi, the results showed a variation and fluctuating tendency in rainfall characteristics of different degrees over time and space with the anomaly tilted toward a negative pattern. On the other hand, the results of the correlation and regression analyses between rainfall characteristics and yam production revealed insignificant positive and negative associations under the period under consideration except for Gboko where rainfall and rainy days were significant. We highlight the necessity for farmers in the study areas to plant early-maturing yam seedlings and pay attention to other factors of agricultural production in order to address the variability in rainfall characteristics especially the length of growing seasons (LGS).

Keywords: Crop production, Rainfall variability, Growing season, Food security, Nigeria

INTRODUCTION

Yam is a stem tuber crop that is widely grown in Nigeria's north-central and southern regions. According to Aighewi et al. (2021), yam production plays a number of essential roles in the Nigerian economy. First, in terms of food security and health benefits, the yam tuber is a rich source of energy and an excellent source of B-complex vitamin, an important pharmacologically active substance containing dioscorine, medicinally used as a heart stimulant (Obidiegwu, Lyons, & Chilaka, 2020). Second, the yam value chain operations that lead to its production, distribution, and consumption offer revenue to millions of Nigerian agricultural households and food and transportation vendors in both the food and transportation industries (Aighewi et al., 2021). As a result, Nigeria is the world's biggest yam grower, accounting for about 67.4% of the total worldwide, ahead of Ghana (11.1%) and Côte d'Ivoire (10.3%) (Akinola, Oke, Adesiyan, & Famuyini, 2019; Obidiegwu et al., 2020).

Despite the yam's culinary, health, and economic benefits for Nigeria, research shows a decline in yam production in the country's north-central regions, such as Benue State, where the majority of yams are grown (Aighewi et al., 2021; Apu et al., 2020). The decline in production is mostly owing to its sensitivity to climatic conditions, particularly moisture, as a result of variations in rainfall onset and cessation over time and space, rather than other environmental or edaphic factors. (Atedhor, 2020; Eruola, Bello, Ufogbunex, & Makinde1, 2012; Okongor, Njoku, Essoka, & Efiong, 2021). This is because an optimal yield requires a balanced water supply during the critical and active growth periods of vine and leaf development, tuber initiation, and bulking, but this is not always the case as yam is grown under a rain-fed system, which cannot guarantee consistent moisture availability throughout the growing season (Eruola et al., 2012).

As a result of the uncertainty in water supply requirements caused by variations in the onset, cessation, and duration of rainfall, seedlings typically rot and, even if they sprout, perish after several days of dry spells, resulting in poor production. Millions of households rely on yam farming for their livelihoods, and this has harmed their food security and income. Hence, it is necessary to examine the rainfall onset and cessation dates of individual years to generate time series to increase understanding of its implications on yam production, verifying the rainfall onset and cessation dates forecasts of individual years, and, most importantly, boosting yam farmers' confidence in its production (Akinola, Oke, Adesiyan, & Famuyini, 2019; Obidiegwu et al., 2020). Since such an understanding is key to helping farmers in the study area reduce the risk of crop failure, and poor crop yields owing, and reduce food insecurity and poverty in the state.

Accordingly, this study aims to examine the nature of onset, cessation, and their implications on yam production in Benue State from 1986 to 2011. Thus, in so doing, the study seeks to provide answers to the following research questions: (i) What is the trend in the onset and cessation of rainfall in Benue State?; (ii) What is the relationship between onset and cessation of rainfall, and yam production in Benue state?; and (iii) What are the implications of the variability in onset and cessation of rainfall on yam production in Benue state?

The study is expected to contribute to studies on global environmental change and food security in a low-income region of Nigeria in that the study is expected to shed light on the impacts of climate change on a popular local staple food

METHODOLOGY

Study Area

Geographically, Benue State lies between latitudes 6 0 25’ N and 80 8’ N of the equator, and between longitudes 70 47’ E and 100 00’ E of the Greenwich meridian (Figure 1). The state has a total land area of 30,800 sq. km (National Bureau of Statistics, 2010).

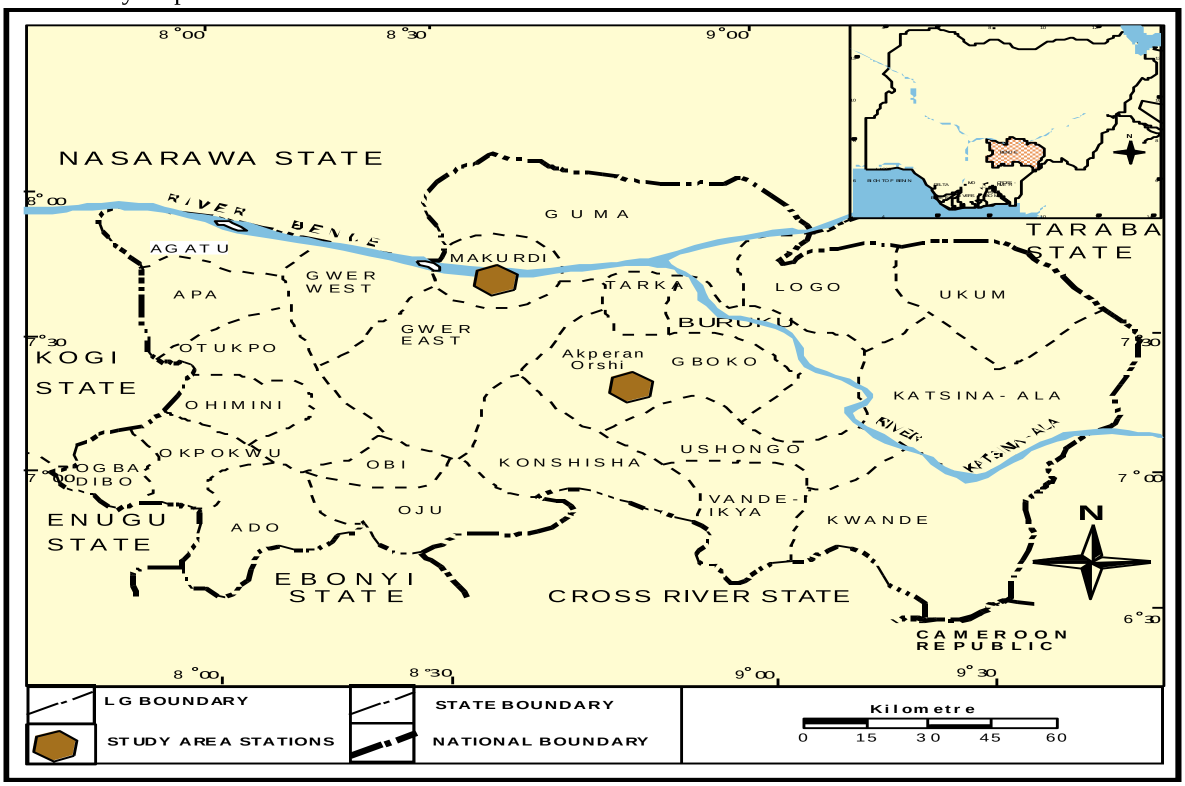

Figure 1: Map of Benue State showing the Study Area Stations
Source: Adapted from Benue State Ministry of Lands and Survey (2016)

The climate of Benue State is wet sub-humid tropical, with distinct wet/dry seasons.

The monthly rainfall distribution in Benue state is bimodal (Ojanuga & Ekwoanya, 1995) and varies dramatically from north to south, with an annual total of 1200 to 1400 mm (Ogungbenro & Morakinyo, 2014). The weather is hot all year, with average temperatures ranging from 230°C to 320°C (Abiodun, et al., 2013). The state's vegetation is characteristic of the southern Guinea Savannah biome, which is central Nigeria's primary vegetation area. According to Hulu (2010), the vegetation is currently characterized by scanty grasses and various heterogonous species of dispersed trees that have been over-exploited due to illicit lumbering and fuel wood collecting, as well as a lack of conservation work.

Yam production

Although yam is grown widely in Nigeria, the area where it is grown most is Benue (land area of 802,295 km²) one of the states in the Benue valley of Nigeria where the labour-intensive practices are still the norm and the land holdings are small. In Benue State, Yams are grown by planting pieces of the tuber, or small whole tubers seed saved from the previous season. Small-scale farmers, the majority of producers, often intercrop yams with cereals and vegetables. After clearing the first fallow, yam is grown on free-draining, sandy-loam and fertile soil. The land is prepared in the shape of a 1 metre (3 ft 3 in) high mound, ridge, or heap.

Methods of data collection

Data needs and sources

Two data sets are required to meet the study's objectives. Yearly records of rainfall characteristics from 1981 to 2015, including (i) daily rainfall total in mm/year; (ii) monthly rainfall total in mm/yea and (iii) annual rainfall total in mm/year. Second, production data for yams production (tons/year) from 1986 to 2011. However, monthly rainfall data was not accessed due to quality issues resulting from poor storage and mar handling.

These data sets came from the two research areas- Makurdi and Gboko, which were purposively selected owing to availability of functional Meteorological stations and consistent production of yam in the area. The Nigeria Meteorological Agency in Makurdi ($7^0\ 44^1\ 0^{11}$N, $8^0\ 32^1\ 0^{11}$E) and the Agro-Meteorological Station at Yandev in Gboko ($7^0\ 26^1\ 0^{11}$N, $10^0\ 6^1\ 0^{11}$E) provided rainfall data, while the Ministry of Agriculture and the Benue State Agricultural and Rural Development Authority (BNARDA) in Makurdi provided annual yam production data respectively.

Data Analysis

Descriptive statistics were used to analyse rainfall characteristics and yam production for the period under investigation. A linear regression model was used to determine the trends of rainfall characteristics: annual rainfall total, number of rainy days, length of the growing season, onset dates and cessation dates of rainfall, and yam production. The equation for the linear regression is given as:

$$y = a + bx \quad \text{……………………….……… equation (1)}$$

where a the intercept of the regression line on the y-axis; b is the slope of the regression line. The values of a *and* b are obtained from the following equations:

$$a = \frac{\sum y - b\left(\sum x\right)}{n} \quad \text{………………..…. equation (2)}$$

$$b = \frac{n\left(\sum xy\right) - \left(\sum x\right)\left(\sum y\right)}{n\left(\sum x^2\right) - \left(\sum x\right)^2} \quad \text{………equation (3)}$$

The Standardized Anomaly Index (SAI) was used to determine years of positive and negative anomalies.

$$Z = \frac{X - \bar{X}}{S} \text{……………………………. equation (4)}$$

X= Actual value

$\frac{\sum \bar{X}}{n}$ = Mean

S = Standard Deviation

The relationship between rainfall characteristics and yam production for the study areas was tested using Pearson's Product Moment (PPM) correlation coefficient. This is computed as:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2}\sqrt{\sum (y - \bar{y})^2}} \text{ ….. equation (5)}$$

Where: r = correlation coefficient

x and *y* = individual observations of dependent and independent variables respectively

$\bar{x}$ *and* $\bar{y}$ = mean of dependent *(x)* and independent *(y)* variables respectively.

The yam production values were used as dependent variables while rainfall characteristics values as the independent variable.

Multiple regression was used to measure the effects of the independent variables (Rainfall characteristics) ($X_1 - X_5$) on a single dependent variable (y).

The regression model is specified as:

$Y = a + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_nX_n$ ……. ……………………………….. equation (6)

Where: Y = the dependent variable (yam production); β_1, β_2, bβ_3, β_4, β_5 = regression coefficients; X_1, X_2, X_3, X_4, X_5 = the independent variables (Annual rainfall total, number of rainy days, Length of the Growing Season (LGS), onset dates and cessation dates of rainfall);

A = y intercept; e = error term

Walter, (1967) method of determining onset, cessation dates and Length of the Growing Season (LGS). This method was adopted because is the most accurate among other methods. The formula is as follows:

Days in the month $\{\left(\frac{51-\text{Accumulated rainfall of previous month}}{\text{Total Rainfall for the month}}\right)\}$

For the onset dates, the accumulated total rainfall is in excess of 51mm, in the case of cessation dates the formula is applied in a reverse order from December.

RESULTS

This section begins by providing descriptive statistics on rainfall characteristics and yam production in Makurdi and Gboko. This is followed by the presentation of results on trends in onset and cessation dates, and anomalies of rainfall. Then, the results on the relationship between rainfall characteristics and yam production are presented in next section. Lastly, the impact of rainfall characteristics on yam production are presented.

Descriptive Statistics on Rainfall Characteristics and Yam Production

Table 1: Descriptive Statistics on Rainfall Characteristics and Yam Production in Makurdi and Gboko

Locations	Variables	Mean	Std. Deviation	Minimum	Maximum
	Rainfall (mm)	1190.9	448.2	734.4	3028.7
Makurdi	Rainy Days (Days)	76.0	7.2	59.00	95.00
	LGS (Days)	244.7	35.3	185.0	334.0
	Yam Production (Ton)	14.3	1.0	11.84	15.40
	Rainfall (mm)	1306.1	217.2	903.6	1893.6
Gboko	Rainy Days (Days)	72.0	9.9	51.0	92.0
	LGS (Days)	246.6	32.1	185.0	308.0
	Yam Production (Ton)	9.5634	0.69951	7.9	10.2

Table 1 shows the descriptive data for the rainfall characteristics for the two research areas (Makurdi and Gboko), including rainfall totals, rainy days, LGS, and yam production. The result reveals that the average rainfall for Makurdi station is 1190.9 mm, the standard deviation is 448.2 mm, and the maximum and minimum rainfall amounts are 3028.7 mm and 734.4 mm, respectively. For the Gboko station, the average, standard deviation, maximum, and minimum values were (1306.1, 217.2, 1893.6, and 903.6 mm), respectively.

The maximum number of rainy days in Makurdi was 95 days, compared to 92 days in Gboko, the minimum number of rainy days in Makurdi was 59 days, and the mean number of rainy days was 76 days in Makurdi and 72 days in Gboko. The maximum LGS in Makurdi is 334 days and 308 days in Gboko, on average the rainy day for Makurdi is 245 days and 247 days in Gboko. The maximum yam production in Makurdi was 15.4 (ton) while 10.2 (ton) in Gboko. This implies that rainfall is received in Makurdi than Gboko and more yam production in Makurdi than Gboko.

Trends in Onset and Cessation Dates of Rainfall, and Anomalies of Rainfall

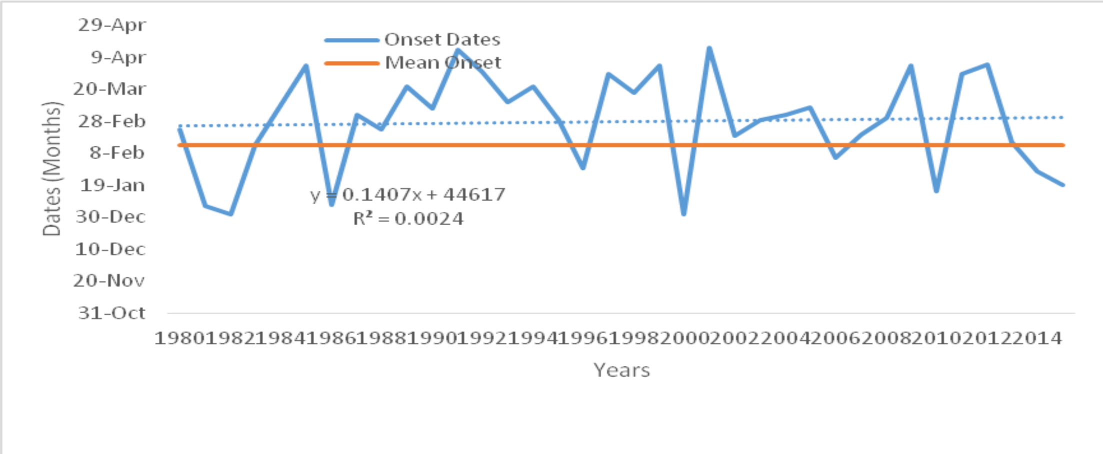

Figure 2. Trend of Onset Date of Rainfall in Gboko

From the start of the rainy season to its end, Figure 2 represents a fluctuating pattern of the season's onset. The early onset date was January 1st, the late onset date was April 15th, and the medium onset date over the duration of this study was February 13th. This suggests that farmers in Gboko may begin planting their crops on February 13th. The best-fit equation (y= 0.1407x + 44617) reveals that the onset days are decreasing in Gboko, and the trend line points in a positive direction.

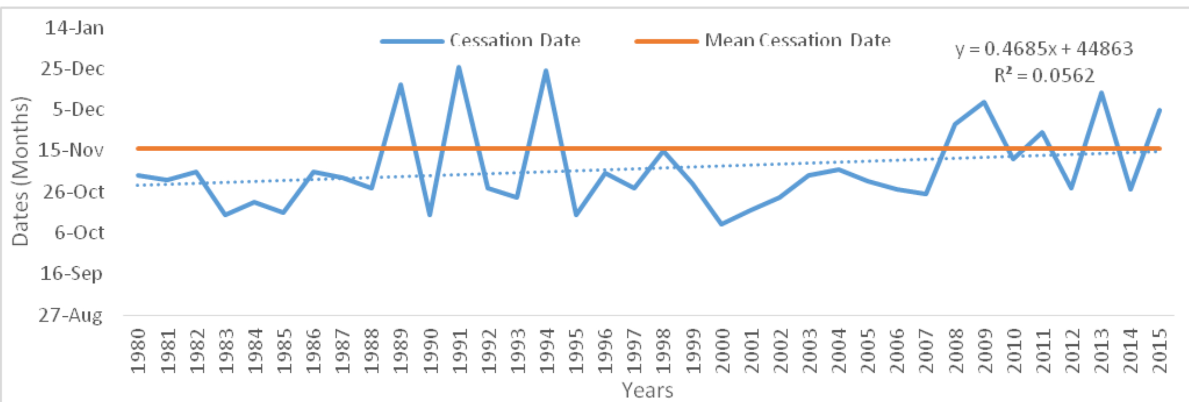

Figure 3. Trent of Cessation Date of Rainfall in Gboko

Figure 3 demonstrates how the pattern of the end date of the rainy seasons changes throughout the course of the study period. The rainy season officially ceased on 10 October 2000, two years earlier than when it officially ended on 26 December 1991. During the study period, the average rainy season cessation date is on November 16th. The trend line shows a pattern with the best-fit equation, which suggests that the cessation days are getting longer in Gboko (y= 0.4685x + 44863).

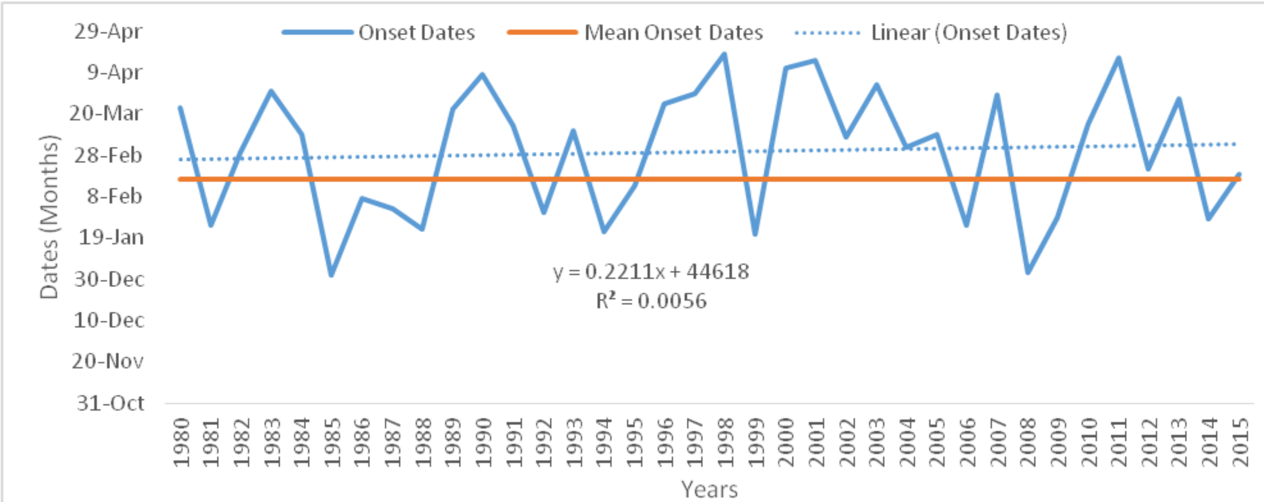

Figure 4. Trend of Onset Date of Rainfall in Makurdi

Figure 4 displays the onset date distribution pattern for Makurdi. The early onset date of the rainy season during the study period was 1st January 1985 while the late-onset date was 18th April 1998 and the mean onset date was 16th February. This indicates that onset days are supposedly getting shorter according to the line of the best-fit equation (y= 0.2211x + 44618).

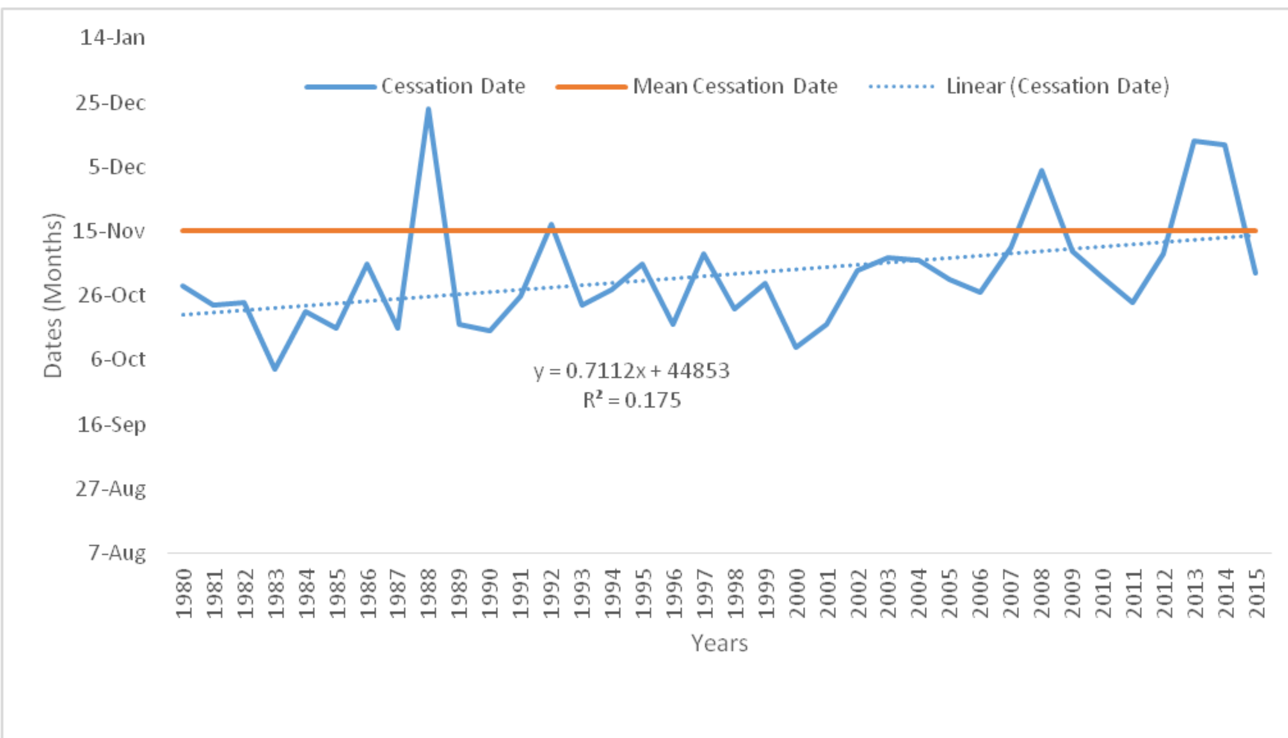

Figure 5: Trend of Cessation Date of Rainfall in Makurdi

Figure 5 presents the cessation pattern of rainfall in Makurdi. The early cessation date of the rainy season was 3rd October 1983, the late cessation date of the rainy season was 23rd December 1988 and the mean cessation date was 15th November during the study period. The line of the best-fit equation (y= 0.7112x + 44853) implies that the cessation days are increasing.

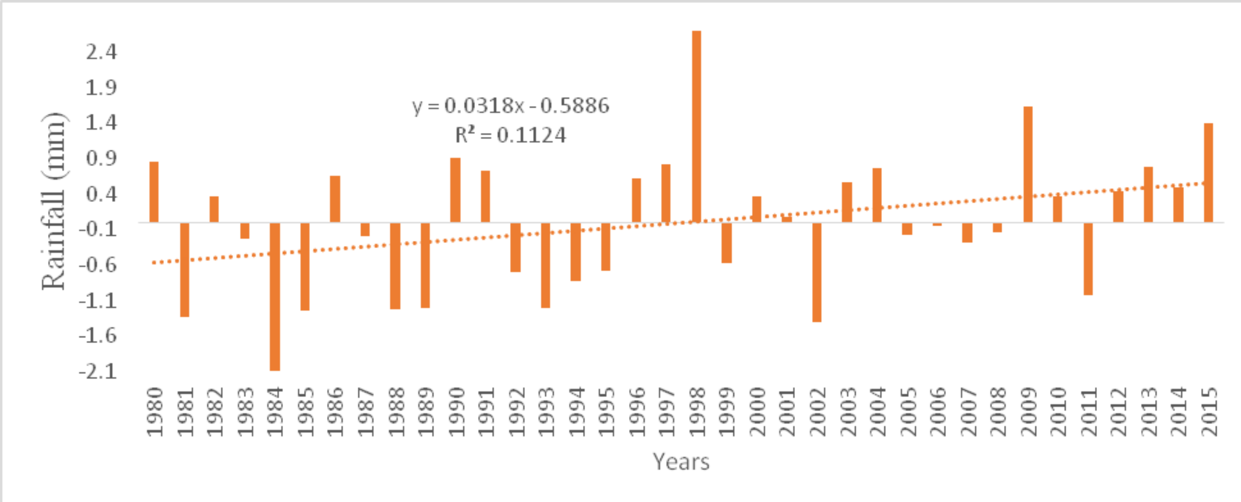

Figure 7: Rainfall Anomaly in Gboko

Figure 7 displays Gboko's rainfall anomalies. There were 18 years of positive anomalies, which made up 50% of the total, and 18 years of negative anomalies, which made up 50% of the total. With the line of the best-fit equation (y= 0.0318x-0.5886), the pattern of rainfall at Gboko showed an upward trend, indicating that rainfall is rising at a rate of 3.18mm-[1].

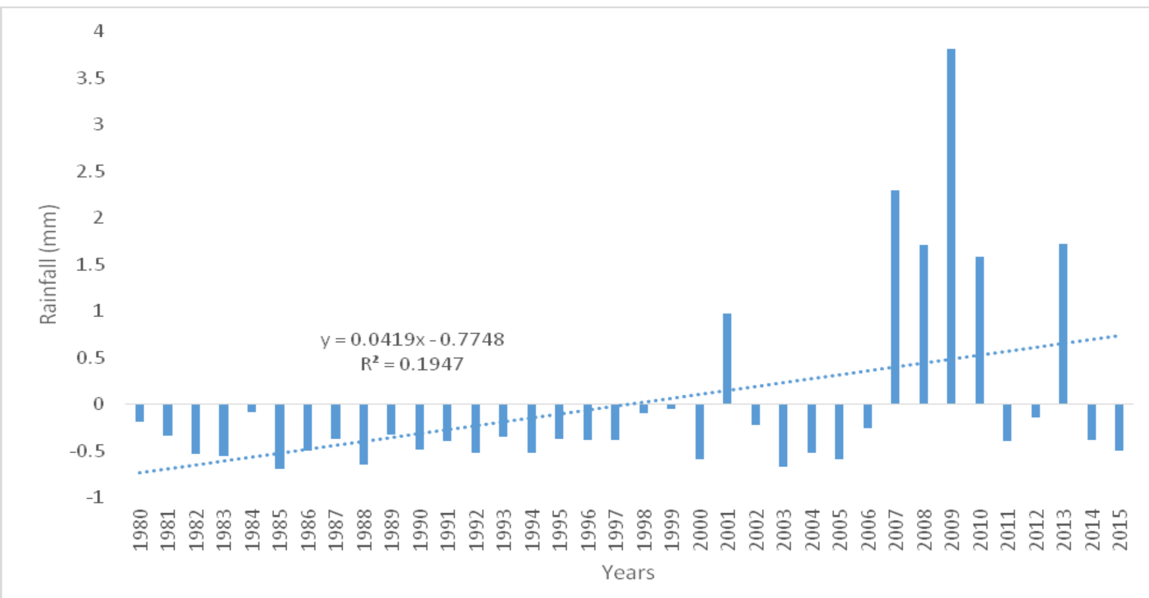

Figure 6: Rainfall Anomaly in Makurdi.

Positive and negative anomalies can be found in the rainfall patterns (Figure 6). Six (6) years of positive anomalies make up 17% of the total, while 30 years of negative anomalies make up the remainder (83%). The line of the best-fit equation (y=0.0419x-0.7748) shows an increasing pattern in Makurdi's rainfall trend. This suggests that rainfall is rising at a pace of 4.19mm per year.

Relationship between Rainfall Characteristics and Yam Production

Table 2: Relationship between Rainfall Characteristics and Yam Production in Gboko

		Rainfall	Rainy Days	LGS	Onset	Cessation
Yam	Pearson Correlation	0.288	-0.371	-0.253	-0.196	-0.252
	Sig. (2-tailed)	0.154	0.062	0.212	0.336	0.214
	N	26	26	26	26	26

According to Table 2's findings, there is a non-significant positive association between annual rainfall totals and yam production in Gboko (r= 0.288, p= 0.154 at a 5% significance level). Inferring that the land will produce more yam the more adequate rains receives. On the other hand, the results showed a negative relationship (r= -0.371) with a p-value of 0.062, which is significant at 10%, between the number of rainy days and yam production.

Additionally, the findings showed a weak and insignificant negative correlation between the LGS (r=-0.253), beginning (-0.196), and cessation (-0.252) dates of rainfall with the corresponding p-values of (0.212, 0.336, and 0.214) at the P-Value of 5%. The production of yam in Gboko is thus decreased by any shortening of the duration of these variables.

Table 3: Relationship between Rainfall Characteristics and Yam Production in Makurdi

		Rainfall	Rainy Days	LGS	Onset	Cessation
Yam	Pearson Correlation	0.196	-0.098	-0.220	-0.042	0.072
	Sig. (2-tailed)	0.337	0.633	0.280	0.837	0.727
	N	26	26	26	26	26

According to Table 3's findings, rainfall and yam production have a positive but not statistically significant association (r= 0.196) at 5% in Makurdi. This implies that the region will produce more yam the more adequate the rainfall that is received. The production of yam in Makurdi will fall when any of these variables declines, as shown by the negative relationships between rainy days, LGS, and the onset of rainy seasons (r=-0.098, -0.220, and -0.042, respectively), all of which are not statistically significant at 5%. Additionally, the results showed a positive but insignificant relationship between the cessation of the rainy season and the production of yams (r= 0.072, p > 0.05). This implies that any extension of the end of the rainy season will boost yield in Makurdi.

Impact of Rainfall Characteristics on Yam Production

Table 4: Impact of Rainfall Characteristics on Yam Production in Gboko

R= 0.604 | R^2 = 0.365 | Adjusted R^2= 0.206

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	
		B	Std. Error	Beta			Remark
1	(Constant)	11.304	1.313		8.610	0.000	
	Rainfall	0.001	0.001	0.392	2.109	0.048	S
	Rainy Days	-0.027	0.014	-0.388	-2.025	0.056	S
	LGS	-0.005	0.004	-0.211	-1.150	0.264	NS
	Onset	-0.008	0.013	-0.115	-0.628	0.537	NS
	Cessation	-.010	.015	-.129	-0.703	0.490	NS

a. Dependent Variable: Yam production, *S=Significant; NS=Not Significant*

According to the findings in Table 4, the influence of rainfall totals, rainy days, LGS, onset, and cessation together account for 36.5% (R^2) of the variation in yam yield in Gboko. With a p-value of (0.048) and a beta (β) coefficient of (0.392), both of which are significant at 5%, rainfall is implied to have a positive effect on yam production in Gboko.

Rainy days, on the other hand, have a negative effect on the production of yams, as indicated by a Beta (β) coefficient of (-2.025) and a p-value of (0.056), which is significant at 5%. With negative Beta (β) coefficients of (-1.150, -0.628, and-0.703) and corresponding p-values of (0.264, 0.537, and 0.490), which were not statistically significant at 5%, the effects of LGS, the onset and cessation dates of rainfall, and yam production are all negatively correlated. This indicates that an additional 63.5% of the total variation in yam production may have been accounted for by other production factors and processes such as temperature, soil, sunshine, humidity, inputs, market access, and the rest that were not included in the model.

Table 5: Impact of Rainfall Characteristics on Yam Production in Makurdi

R= 0.321 ; R^2 = 0.103							Adjusted R^2= -0.122
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	
		B	Std. Error	Beta			Remark
1	(Constant)	16.156	2.599		6.215	0.000	
	Rainfall	0.000	0.001	0.173	0.770	0.450	NS
	Rainy Days	-0.014	0.036	-0.095	-0.381	0.707	NS
	LGS	-0.006	0.007	-0.189	-0.783	0.443	NS
	Onset	-0.012	0.025	-0.116	-0.497	0.624	NS
	Cessation	0.019	0.026	0.180	0.735	0.471	NS

a. Dependent Variable: Yam; S=Significant; NS=Not Significant

Results shown in Table 5 showed that the variance in yam production in Makurdi was accounted for by the combined influence of rainfall, wet days, LGS, onset, and cessation (R^2=10.3%). The impact of rainfall on yam production in Makurdi is positive with a Beta (β) coefficient of **(**0.173) and a p-value of (0.450) which is not significant at 5%. The impacts of rainy days, LGS, onset, and yam production were negative with the following Beta (β) coefficients of **(**-0.095, -0.189, and -0.116) and their p-values were (0.707, 0.443, and 0.624) respectively and they are not significant at 5%. The impact of the cessation date of rainfall on yam production is positive with a Beta (β) coefficient of **(**0.180) and a p-value of (0.471) which is not significant at 5%. About 89.7 % may be accounted for other factors not considered in this study.

DISCUSSION

While other studies frequently analyse the impacts of rainfall or precipitation on crop production on a regional scale, particularly by looking at the entire state (see Adamgbe & Ujoh, 2012; Iornongo, Yahaya, Ojoye, & Tsado, 2019; Patrick, Emmanuel, & Obadiah, 2019) or a specific region of the country (Atedhor, 2020; Eruola et al., 2012; Ntat, Ojoy, & Suleiman, 2018), this study tries to downscale the analysis even further. It does this by focusing on two local government areas, Gboko and Makurdi, as separate geographic areas or entities, thereby unmasking or making visible geographic variations in rainfall characteristics , such as annual rainfall totals, rainfall onset and cessation dates, and LGS within the state, that were previously hidden in other studies.

The results on the pattern and trend of rainfall in the two study sites, Gboko and Makurdi, as shown by the anomalies (see Figures 2-7), demonstrate a rising trend in yearly rainfall totals in the two geographic locations examined by this study. This finding contrasts with that of Adamgbe & Ujoh (2012) and Ntat (Ntat, et al, 2018) who reported a declining trend in rainfall amount and are in agreement with Terdoo et al. (2020), Msheliza, and Bello (2016) and the 4th AR of the IPCC (see Niang et al., 2014), both of which anticipated rising precipitation in the region.

While Patrick et al. (2019) and Adamgbe & Ujoh (2012) found a positive correlation between climatic factors and yam production in Benue State, the findings of the correlation and regression analyses of this study partially concur and differ in that this study did not find a statistically significant relationship for the rest of the rainfall characteristics except for Gboko where rainfall and rainy days were significant. Negative associations were instead shown to be unimportant consequently suggesting that the effects of rainfall characteristics such as annual rainfall total, number of wet days, length of the growing season, start dates, and cessation dates of rainfall were less pronounced in Makurdi than Gboko.

CONCLUSION

In this study, the relationship between the variability of the following rainfall characteristics —annual rainfall total, number of rainy days, length of the growing season, onset and cessation dates of the precipitation—and yam production—was studied. In both Gboko and Makurdi, the analysis revealed the analysis showed a variation and fluctuating tendency of varied degree over time and space, with the anomaly of rainfall tilting towards a negative pattern. Furthermore, both negligible positive and negative connections between precipitation factors and yam production over the study period were found by the results of the correlation and regression analyses.

According to the study's findings, yam production in the studied areas is less affected by rainfall characteristics. Based on this, this study suggests that future research should take into account how other agricultural production factors affects yam production in Benue State, Nigeria. The results of this study equally highlight the necessity for farmers in the study areas to plant early-maturing yam seeds and to pay attention to other aspects of agricultural production variables, such as inputs, high-quality yam seedlings or cultivars, fertilizers applications, climatic variables among others, may have been crucial in determining the production of yam production in the research area. As this may be helpful to address the variability in rainfall characteristics, especially the LGS.

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