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RAINFALL VARIABILITY AND THE IMPACT ON MAIZE AND RICE YIELDS IN NORTH – CENTRAL NIGERIA

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ABSTRACT

Rainfall variability in terms of amount, distribution (spatial, seasonal and diurnal), intensity and frequency of rainy days influence crop production and yield. This paper examined rainfall temporal trend inter-annual and spatial distribution and the implication of mean annual rainfall on maize and rice yield in North – Central Geopolitical Region of Nigeria. Daily rainfall records of thirty years period (1987 – 2016) at six stations in the region, namely; Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna were obtained from the archive of the Nigerian Meteorological Agency (NiMet), Abuja and maize and rice yield for the period 1994 – 2016 obtained from the Bureau of Statistics of Nigeria were used for the study. The rainfall data were subjected to statistical analysis using descriptive analysis. Mann-Kendal test and Kriging method were used for the spatio–temporal rainfall distribution while the impact of rainfall amount on maize and rice yields was investigated using regression analysis. The annual rainfall amount experienced in study area was between 1100 mm and 1700 mm. Out of the six stations studied; only Abuja indicated statistically significant increased trend while the other five stations in the region showed no significant trend. Rainfall distribution in the region is largely influence by the Jos Plateau rather than Latitudes or Longitude. Generally, rainfall influences maize and rice yield positively but at varying degree from station to station

Key Words: Rainfall variability, Trend, Distribution, Impact

INTRODUCTION

Rainfall is a climatic parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive (Obot & Onyenkwu, 2010). It has always been captivating when suddenly the bare surface of the earth begins to wear green look at the onset of the wet (rainy season) with grasses springing up and plants, shrubs and trees bud and flourish with green leaves all over. All of these are in response of the earth to the rains it receives. Ayoade, (2004) observed that Rainfall is the most variable of tropical climate. It is a vital climatic factor that determines vulnerability level of crop production in Nigeria.

Rain has some characteristics which are of practical implication, such as its amount, intensity, duration, seasonal and diurnal distribution, frequency of rainy days and variability. The amount of moisture (soil water) available to crops depends on rainfall onset, length, and cessation which influence the success or failure of a cropping season. Inter–annual and seasonal rainfall variability are key factors in the success of agricultural production, particularly where it is rain-fed (Ngetich *et al*, 2014). It is not within man's ability to influence the occurrence (timing), distribution and amount of rainfall (Stroosnyder, 2008), however, the knowledge of their frequency for a variety of durations is necessary, if they are to be well managed (Nunez *et al*, 2011) for efficient crop production.

The impact of rainfall variability/climate change on agriculture among other sectors of the economy has been a global concern. IPCC (2013) observed that changes in precipitation across the globe will not be uniform and that by the mid-21st century and beyond, for wheat, rice and maize in tropical and temperate regions, climate change without adaptation would negatively impact production. Similarly, Schubert, (2012), the Communication Officer (Climate Change, Agriculture and Food Security – CCAFS) of the CGIAR maintained that climate change had reduced food production between 1–5% per decade across the globe. For tropical cereal crops such as maize and rice, usually grown in already vulnerable regions in South and Central America, sub–Saharan Africa and Asia, will be negatively affected. West African countries in or near the Sahel were to be most negatively impacted with 70% decreases in suitable areas for crop production. The fact that Climate change or variability is taking its toll on regions of the globe raised concern because communities in the North - Central region of Nigeria, as in most parts of Sub–Saharan Africa, are vulnerable to climate variability and farmers depend mostly on rain-fed agriculture.

Several empirical studies have been carried out on rainfall variability and the implication of rainfall on crop production. Oguntunde *et al* (2011) evaluated changes in the spatial and temporal patterns of rainfall with a view to improving water management strategies in regions of Nigeria. Rainfall trend was analysed for the period 1901 to 2000 using standard test to examine the existence of trend in monthly and annual rainfall in Nigeria. Rainfall variability was estimated as standard rainfall departure while auto-correlation spectral analysis was used to obtain the periodicities inherent therein. Results obtained showed that rainfall spatial distribution was highly Latitudinal dependent ($r^2 > 0.09$) and had no clearly linear relationship with the Longitude.

Akinsanola and Ogunjobi (2014) analysed rainfall and temperature variations in Nigeria for 25 synoptic stations from 1971 – 2000 (30 years period) employing statistical approach. Valuable insight on the spatial and temporal patterns of rainfall and temperature were revealed. There was significant increase in temperature within the year under reviewed. Rainfall anomaly occurred over all the stations which showed that there was a composite nature in which some of dry years were mixed with wet years and vice versa. A decrease in rainfall observed and was attributed to failure of rain – producing mechanisms such as Intra-tropical Discontinuity (ITD), African easterly Jet (AEJ), Tropical Easterly Jet (TEJ), to organised thunderstorms, squall line that are responsible for over 70% of the total annual precipitation.

Agada, Obi and Ali (2016) evaluated rainfall characteristics at Makurdi, North–Central Nigeria for the period 1985 – 1987. Rainfall intensity, amount, duration, drop size, distribution, terminal velocity and slope angle, and kinetic energy were analyzed to quantify the key physical characteristics of rainfall in Makurdi in order to provide information on the erosive nature of rains. The study utilized auto recording data for 3 – years to characterize rainfall erosivity and found out that storm intensities were high and frequent. Storm less than 20mm per rain event were very frequent and complemented with exceptional storms as high as 71 mm per rain event. Rainfall erosivity is high in Makurdi with multiple rainfall erosivity peaks during the rainy season. The implication on crop production was not considered.

Orfega, (2014) analysed the variability of daily rainfall Intensity in Middle Belt region of Nigeria in context of Climate change for a period of 46 years (1961 – 2006). The result was that the spatial variations and pattern of daily rainfall intensity generally indicated three (3) enclaves centring on the Jos Plateau; Light rains were increasing on the Jos Plateau and on the Western axis Heavy Rain were also increasing. There are implications from risk of Surface Run off and flooding as well as changing conditions for crop production.

Adamgbe and Ujoh, (2013) investigated the effect of variability in Rainfall Characteristics on Maize Yield in Gboko, Nigeria. Data on rainfall and maize yield were analyzed using mean, correlation and regression analysis to establish cause and effect relationship between rainfall characteristics and maize yield at the study area. Rain days and rainfall amount had strong positive relationship ($r = 0.747$ and $r = 0.599$, respectively) with maize yield. It was also observed that the rainfall characteristics jointly contributed 67.4% in explaining the variations in the yield of maize per hectare.

Aondoakaa, (2012) used simple regression, correlation and multiple regression model to correlate the relationship among temperature rainfall and crop yield and found out that a correlation between the climatic data (rainfall and temperature) and crop yield existed. Regression value for the crops investigated were: maize 0.11, rice 0.67, cassava 0.14, ground nut 0.37 and garden egg 0.57. It was positively significant though weak and showed that rainfall and temperature influence crop yield in the FCT. The study recommended that other environmental factors (soil fertility, soil type among others) should be considered.

Most of the works on rainfall variability focus more on the individual states with less emphasis on North – Central Nigeria as a region and the implication on crop production. This study examined the pattern of rainfall variability and its implication on maize and rice yield in the study area. The specific objectives were:

i. examined the temporal rainfall trend in the study area

ii. analyzed the spatial distribution of rainfall in the study area, and

iii. investigated the impact of rainfall amount on maize and crop yields, the information obtained can be useful in enhancing crop production through proper planning and policy formulation with mitigation and adaptation strategies incorporated in the agricultural practice.

THE STUDY AREA

North–Central Region is a geo-political entity of Nigeria which comprises of six states namely, Plateau states (Jos), Benue State (Makurdi), Nasarawa State (Lafia), the Federal Capital Territory (Abuja), Kogi (Lokoja), Kwara state (Ilorin) and Niger State (Minna). These states lie within the Guinea Savannah, and experience two seasons; the dry season and wet/rainy season. The climate is controlled by the meridional oscillation of the Inter-Tropical Discontinuity (ITD). The ITD is a zone of separation between two air masses, Northeast (NE) trade Winds and South-westerly (SW) Winds. These trade winds prevail over the region and over West Africa in general. In January when the ITD attain its southernmost position at latitude 6^0 N, the region and virtually the entire country is under the influence of NE trade winds. The weather then is dry, cold and hazy, normally referred to as dust haze or the dry season. The SW maritime winds, however, predominates over the region/country with the northward retreating of the ITD attaining its northernmost position at about latitude 22^0 N in August. The region experiences rainy season also known as the summer period.

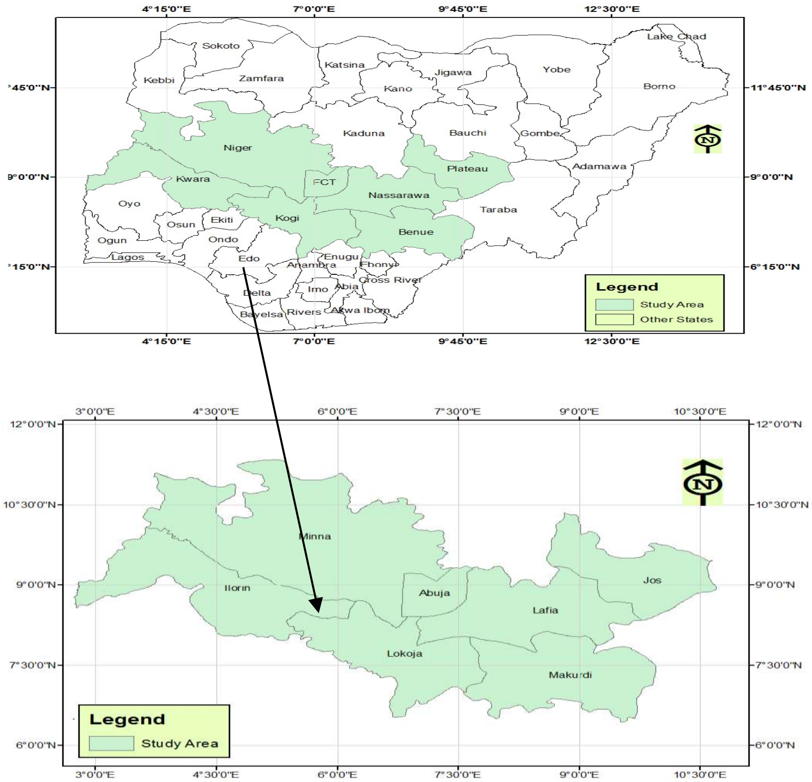


Figure 1.0: North – Central Geo-Political Region of Nigeria

Source: Author's work, 2017

MATERIALS AND METHODS

Daily rainfall data from seven stations in the study area: Jos, Makurdi, Abuja, Lokoja, Ilorin, and Minna for a period of 30 years (1987 – 2016), were obtained from the archives of the Nigerian Meteorological Agency (NiMet). Data on maize and rice yields from 1004 – 2016 obtained from Bureau of Statistice of Nigeria were also employed for the study. Rainfall monthly and annual totals were computed from the daily rainfall data through cumulative analysis (summation). Other statistical methods employed were the descriptive statistics (mean, standard deviation, and coefficient of variation) were.

Trend in the annual rainfall was examined using Mann – Kendall rank correlation (MK) non–parametric test statistics. The MK rank correlation method was employed at a significance level of 5% to study the temporal trends of annual rainfall amount and its coefficient of variability (CV).

Given a rainfall data set of size ($n \geq 10$), mean of zero (0) and a standard deviation of unity (1), and assuming that time series is independent, then MK statistic S, expressed mathematically as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n-1} Sign(X_j - X_i) \quad (1)$$

$$\text{Where } Sign(X_j - X_i) = \begin{cases} 1 \ if \ X_j - X_i > 0 \\ 0 \ if \ X_j - X_i = 0 \\ -1 \ if \ X_j - X_i < 0 \end{cases} \quad (2)$$

X_i and X_j are sequential data for the i^{th} and j^{th} terms

$$Var\ (S) = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

For situation where ties may occur, the $Var\ (S)$ is extended to the form:

$$Var(S) = \left[n(n-1)(2n-5) - \sum_{p=1}^{q} t_p(t_p-1)2(t_p-5)\right]/18 \quad (4)$$

Where q = the number of tied groups; T_p = the number of data values in the P^{th} group

$$Z = \frac{S-1}{\sqrt{VAR\ (S)}} \text{ if } S > 0;\ Z = 0 \text{ if } S = 0 \text{ and } Z = \frac{S+1}{\sqrt{VA\ \ (S)}} \quad (5)$$

The null hypothesis H_0 for a two-sided test is rejected when $|Z| \geq Z_{\alpha/2}$ at a level of significance.

If Z is positive, then the trend is increasing and if Z is negative, then the trend is decreasing

Spatial rainfall distribution: The Spatial pattern of the correlations and trends across the region were examined using ordinary Kriging Interpolation method (Miras-Avalos et al., 2007; Yang et al. 2010). ASurfer software was employed for the analysis. The 30 years rainfall amount at each station of the study area (Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna) were categorized into three subdivision of 10 years (1987 – 1996, 1997 – 2006 & 2007 – 2016) where the decadal spatial distribution was examined and the 30 years period also was considered.

RESULTS AND DISCUSSION

Rainfall pattern: The pattern of rainfall in the study area as revealed by descriptive statistical analysis is given in Table 1. The result indicated that the annual rainfall received in the North–Central Region of Nigeria ranges from 1181.4mm to 1610.7 mm. the highest annual rainfall was recorded at Abuja and the lowest at Makurdi. Generally, in the region, the rainfall showed moderate inter-annual variability; Ilorin having the highest variability (CV = 30.3%) and Jos the lowest (CV = 11.31%).

Table 1.0 The Annual rainfall total, maximum and minimum, mean, standard deviation and coefficient of variation in Rainfall in North – Central Region of Nigeria

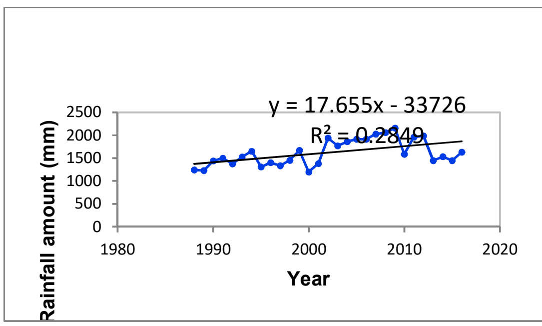
Variable	Abuja	Ilorin	Jos	Lokoja	Makurdi	Minna
Cumulative Rainfall (1987 – 2016)	48320.4mm	38378.3mm	37045.2mm	37842.2mm	35441.4mm	36774.0mm
Maximum Rainfall	1198.3mm	2552.6mm	1582.7mm	1767.1mm	1617.1mm	1547.4mm
Minimum Rainfall	2157.6mm	727.7mm	814.7mm	931.5mm	761.5mm	818.4mm
Mean ($\bar{x}$)	1610.7mm	1279.6mm	1234.8mm	1261.4mm	1181.4mm	1225.8mm
Standard Deviation	279.8	393.4	141.6	233.1	206.5	156.6
Coefficient.of Variation (CV)	17.1%	30.3%	11.3%	18.5%	18.5%	12.6%

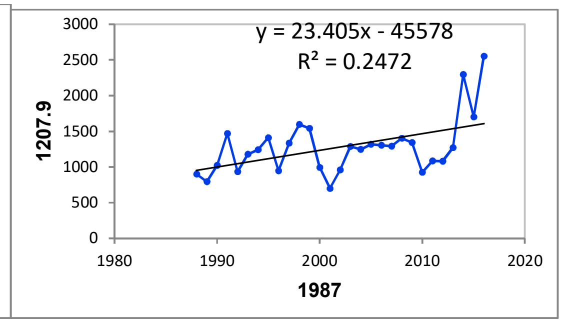
Temporal trend: The Temporal trend of rainfall amount in the study area was examined using the Mann–Kendall's test, based on rank correlation. The results (Table 2 and Figure 1) showed variation in rainfall trend in the study area. Two stations (Abuja and Ilorin) indicated an increase in trend, however only Abuja is statistically significant. If this trend should be sustained over time it would on one hand improve agricultural production and meant good for water resource management. On the other hand, increased severity in rainfall could pose serious dangers such as flooding. The other four stations (Jos, Lokoja, Makurdi and Minna) indicated no significant change in rainfall trend; however, there is tendency for Lokoja to experience a decreasing trend in rainfall (R = - 0.015; the Sen;s slope is also negative: - 1.049).

Table 2.0 Mann-Kendall's trend test (α = 0.05)

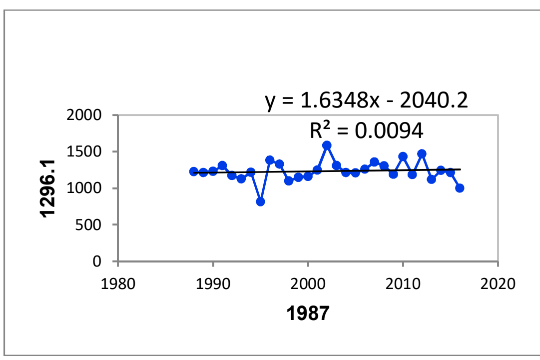
	Abuja	Ilorin	Jos	Lokoja	Makurdi	Minna
Kendall's tau	0.409	0.300	0.030	- 0.015	0.138	0.030
S	163.000	122.000	12.000	- 6.000	56.000	12.000
p-value (Two-tailed)	0.002	0.023	0.837	0.925	0.302	0.837
Sen's slope	21.503	16.118	0.737	- 1.049	5.281	0.653

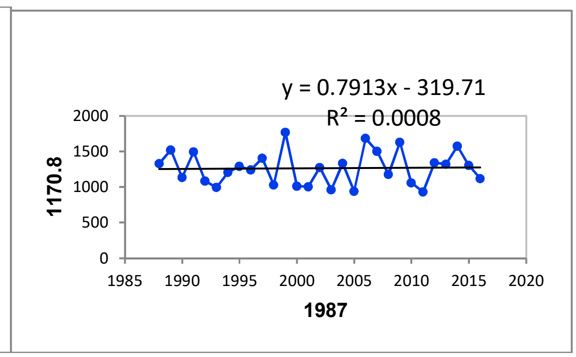
Figure 1: Temporal Trend in annual rainfall for Abuja (a), Jos (b), Makurdi (c), Ilorin (d), Lokoja (e) and Minna (f) stations in the study area for 30 years period (1987 – 2016)



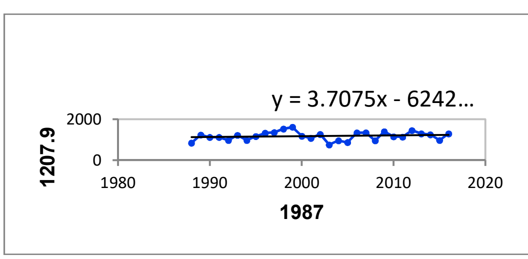


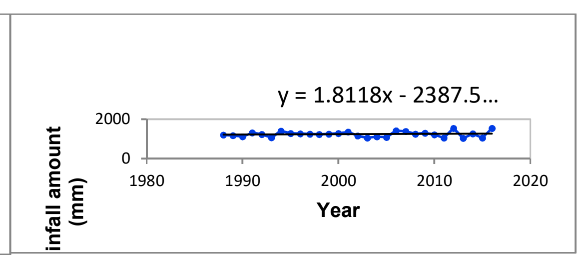
a. Abuja **d. Ilorin**





b. Jos **e. Lokoja**

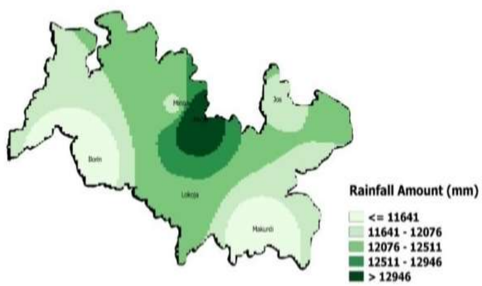




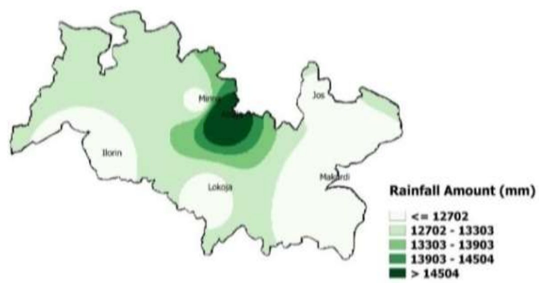
c. Makurdi **f. Minna**

Spatial Rainfall Distribution: The results from the analysis are given in figures 2.0. The first 10 years (1987 – 1996) showed that Abuja station recorded the highest rainfall in the region (> 12946mm) while Makurdi, Minna and Ilorin recorded the least rainfall amount (< 11641mm). The second 10 years period from 1997 – 2006 showed similar trend to the first decade. Abuja received the higher rainfall amount (> 14504mm) while the other five stations (Ilorin, Jos, Makurdi and Minna) received rainfall below 12702mm. similarly, the last ten years period (1997 – 2006) also shows Abuja station having higher record of rainfall amount (> 15213mm), Ilorin received rainfall between 14485 – 15213mm while Jos, Makurdi and Minna received rainfall below 13030mm. Generally, the rainfall distribution pattern in the study area is typically influenced by the Jos Plateau which altered the latitudinal dependence of rainfall distribution known for regions of Nigeria as observed by (north – central region of Nigeria). Stations at higher latitude received high rainfall than stations at lower latituudes. For instance, Minna station (09.39^0 N 06.28^0 E) located to the West of the Jos Plateau recorded 1225.8mm mean annual rainfall which is quite higher than the mean annual rainfall (1181.4mm) recorded at Makurdi station which is at a lower Latitude (7.25^0 N 8.43^0 E), located to the east and Leeward of the Jos Plateau.

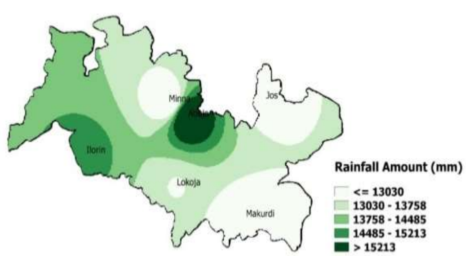
Fig 2: Spatial distribution of rainfall at 10 years interval (a – c) and 30 years period (d) in the study area from1987 – 1996



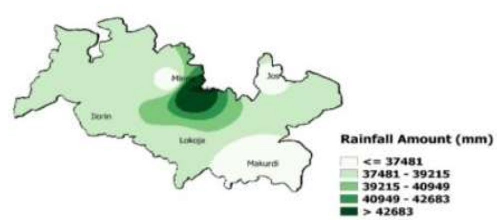
a. 1st Ten years (1987 – 1996)



b. 2nd Ten years (1997 – 2006)



c. 3rd Ten years (2007 – 2016)



d the 30 years period from 1987 – 2016

Crop Yield and Rainfall Amount Relationship

Tables 3.0 and 4.0 give the result of the analysis. The result of the regression of maize, rice and yam yields on rainfall amount at Abuja station from 1994 – 2016. The results indicate that the regression value (R^2) for maize and rice were 0.284 and 0.240 respectively. The positive regression values, although weak, for the two crops show significant relationship between maize and rice yam yields and rainfall amount at Abuja. This result seems to agree with a related finding by Aondoakaa (2012) who established regression values for crops in Federal capital Territory (FCT), where the regression values maize and rice were 0.11 and 0.67 respectively. Rainfall amount influences maize, rice and yam yields in Abuja. At Ilorin station, results indicate positive regression coefficients for the three crops. The relationship between maize yield and rainfall amount is statistically significant ($R^2 = 0.610$); rice shows a weak relationship ($R^2 = 0.245$) and yam, a very weak relationship ($R^2 = 0.014$). This implies that rainfall has great influence on maize yield and has influence also on rice yield and very weak influence on yam yield at Ilorin. High rainfall at Ilorin will therefore favours maize cultivation at Ilorin. At Jos station, the regression coefficients for the three crops were positive; maize had a significant relationship ($R^2 = 0.748$) while that of, rice was weak ($R^2 = 0.245$). Thus, rainfall influences maize and rice yields but the impact was more on maize. The same situation was same at Lokoja; the result indicated statistically significant relationship between maize ($R^2 = 0.470$) yields and rainfall amount while rice ($R^2 = 0.064$) a weak relationship. At Makurdi, the regression values for the two crops were positive, however, statistically an insignificant relationship exist between maize yield and rainfall ($R^2 = 0.020$); and a weak relationship for rice yield ($R^2 = 0.353$). This result seems to contrast with an earlier study by Adamgbe and Ujoh (2013 who used correlation and regression analysis to examine the impact of rain days and ranfall amount on maize yield in Gboko and found a strong positive relationship (r = 0.559) for the regression coefficient. At Minna, the results indicate weak relationship for both maize ($R^2 = 0.384$) and rice ($R^2 = 0.276$). Generally, the results show that rainfall influences maize and rice production in North – Central Region of Nigeria at various degree from station to station. The influence of rainfall on crop yield depends on the type of crops as demonstrated by the varying regression coefficient of the two crops examined (maize, rice and yam) for all the six stations (Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna) in the region. This is similar to a position maintained by Eregha, Babatolu and Akinnubi (2014), who examined the effect of climatic variables on crop production in Nigeria and opined that the effect varies depending on the type of crop and seasonal properties and length of days of the crop.

Table 3: Regression of rainfall amount on maize and rice yields at Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna for the period 1994 – 2016

		ABUJA	ILORIN	JOS	LOKOJA	MAKURDI	MINNA
MAIZE	R^2	0.284	0.610	0.748	0.470	0.020	0.384
	Adjusted R^2	0.250	0.592	0.736	0.445	-0.027	0.354
	PC	0.852	0.464	0.300	0.631	1.167	0.734
RICE	R^2	0.240	0.245	0.412	0.064	0.356	0.276
	Adjusted R^2	0.204	0.209	0.384	0.019	0.325	0.241
	PC	0.905	0.898	0.700	1.115	0.767	0.862

Table 4: Analysis of Variance (ANOVA) of rainfall amount on maize, rice and yam yields at Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna for the period 1994 - 2016

CROP	PARAMETER	ABUJA	ILORIN	JOS	LOKOJA	MAKURDI	MINNA
MAIZE	DF	1	1	1	1	1	1
	F	8.326	32.897	62.269	18.618	0.426	13.071
	Fr > F	0.009	< 0.0001	< 0.0001	0.000	0.521	0.002
RICE	DF	1	1	1	1	1	1
	F	6.633	6.826	14.740	1.429	11.589	7.997
	Fr > F	0.018	0.016	0.001	0.245	0.003	0.010

CONCLUSION AND RECOMMENDATIONS

The trend in annual rainfall in the north – central region of Nigeria in the last three decades vary from place to place. Three stations: Abuja indicated a statistically significant increased trend in the annual rainfall amount. However, the mean annual rainfall received at the region was generally between the range of 1181.7mm (Makurdi) and 1610.4mm (Abuja). Generally, in the region, the rainfall showed moderate inter-annual variability; Ilorin having the highest variability (CV = 30.3%) and Jos the lowest (CV = 11.31%), which could be suitable for crop production. The Jos Plateau play significant role in rainfall distribution within the north – central region of Nigeria with high rainfall recorded at the windward side of the Plateau. Rainfall influences maize and rice production. The influence of rainfall on crop yield depends on the type of crops as demonstrated by the varying regression coefficient of the three crops examined (maize, rice and yam) for all the six stations (Abuja, Ilorin, Jos, Lokoja, Makurdi and Minna) in the region. Farmers in the North – Central Region of Nigeria should be advised to take into account yearly rainfall forecast from relevant agencies such as Nigerian Meteorological Agency for effective planning to maximize crop production given the seasonal and annual rainfall variation and distribution in the region.

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