Evidence of Climate Change on Derived Precipitation Effectiveness Indices and Anomalous Precipitaion Pattern of Jos South Local Government Area of Plateau State, Nigeria

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***Abstract:*-Fifty years' daily Precipitation data (1966-2015) for Jos south LGA were used to derive six important Precipitation Effectiveness Indices: onset, cessation and length of rainy season, annual rainfalland anomalous precipitation pattern as well as forecasted anomalous years within the study period (2016-2035).The derived indices were subjected to time series analysis to determine the trend in their occurrences in the face of the current global climate change.Trend lines and linear trend line equations for each of the parameters were fitted to show the direction of change. Results of analysis showed that mean onset date was 15th of April while mean cessation date was 25th of September. This implies that the rainy season starts early in recent times while cessation dates arrive late. Consequently, the length of rainy season is long. This showed that the trend of onset and cessation dates and length of rainy season are characterized by marked variability. Additionally,long term mean rainfall was 1266.54 mm. Maximum rainfall occurred in 1969 (1720.3 mm) while the minimum was 814 mm in 1995. Results revealed a decline in precipitation; its intensity, amount and duration in Jos South.The result of forecasting anomalous years for twenty years (2016-2035) showed a decreasing rainfall as signified by the negative trend line equation of y= -9.2709x + 1106.8. This implies a decline in precipitation; its intensity, amount and duration in Jos South. The highest forecasted rainfall was 1297.82mm in 2017 while the lowest was 833.76mm in 2022. The years below forecasted mean, indicates that rainfall anomalies were fluctuating drastically, which as a result, could increase periods of dry spells and drought occurrences in the study area. These are all indications of climate change syndrome. It can be recommended that continuous data acquisition should be encouraged in areas where none existed, public enlightenment on the impacts of climate change, adopting new hybrids of short-duration crop varieties in cases of fluctuating trends, early planting and establishment of dam sites will minimize impacts of these changes on livelihood.**

Keywords: **climate change, precipitation effectiveness and derived indices**

I. INTRODUCTION

A change in climate implies a change in the general circulation of the atmosphere on which climate ultimately depends (Ayoade, 1993). The Intergovernmental Panel on Climate Change (2007) defined climate change as a change in the statistical distribution of weather patterns when that change lasts for extended period of time (i.e. decades to millions of years). It is the variations in weather averages that persist for long periods. This includes shifts in the frequency and magnitude of sporadic weather events, rise in global surface temperature, and rise in sea level, continuous change in precipitation, evaporation and stratospheric ozone layer depletion.

Changes in precipitation effectiveness indices caused by climate change has affected productivity in terms of quantity and quality of crops. Sawa and Adebayo (2011) examined, using rainfall data of three decades (1976-2005), six derived indices: onset, cessation and length of rainy season, hydrologic ratio, seasonality index and occurrence of pentad dry spells. Results of their analysis show that the rains now start late but end early, length of rainy season is decreasing and also found that Northern Nigeria is becoming drier as the rainy season is now spread within fewer months. This is diminutive to agriculture, water resources and biodiversity in the tropics, which as a result could be a threat to food security and sustainable development.Sawa and Adebayo (2012) shows that northern Nigeria is getting drier and drier due to the impact of climate change on precipitation. The rains are starting late but are ending earlier than normal, thereby, shortening the duration of the rainy season. The higher degree of dryness, shortening of the spread of the rainy months and increased demand for water to avert drought; coupled with the late onset and early cessation are all manifestations of the impact of the current global climate change syndrome in the study area. Agriculture has remained the chief source of livelihood in Jos South Local Government Area of Plateau State and is the major means by which the teeming population of the community is fed. The schedule of agricultural activities, right from land preparation, through crop selection and planting, to the time of harvesting is rainfall dependent. Several studies have been conducted towards improving crop

yields in the study area by the National Root Crop Research Institute (NRCRI), Vom, Plateau State and other agricultural Research institutions in Nigeria through breeding of high yielding varieties, pest and disease resistant varieties, improved yield and cultural practices of weeding and fertilization (Solomon, Zemba and Jahknwa, 2013). Yet there is still declining crop yields per hectare in Jos South Local Government Area of Plateau State. This is mainly because of the effects of climate change on onset date of rains, cessation and length of the rainy season. This development has posed a great threat to sustainable agriculture and food security in the study area (Sawa and Adebayo, 2012; Solomon, Zemba and Jahknwa, 2013; Burton, 1989; Sale, 1973; Susnochi and Meir, 1978; Zaag and Burton, 1978; Wolfe, Fereres and Voss, 1983). A good knowledge of the present status of some of these rainfall attributes will not only inform farmers of when best to start planting and undertake the other vital processes of crop production but what type of crop to plant and where best to plant it. This paper examines the current status of the major precipitation effectiveness indices visa viz the present climate change phenomenon with a view to presenting some vital information to farmers about the changing onset and cessation dates, duration of the rainy season, the anomalous years (1966-2015) within the period of study and pattern of anomalous precipitation in twenty (20) years to come in the study area

The Study Area

Jos South Local Government Area lies within latitudes 9^0 37'and 9^0 54' N and between Longitudes 8^0 42' to 8^0 58' E (Figures 3.1 and 3.2). Jos South Local Government Area is one of the seventeen Local Government Areas in Plateau state. It is situated at the north western part of the state with its headquarters at Bukuru.JosSouthLocal Government is bounded to the north by Jos North to the north east by Jos East to the north westbyBassato the south byRiyom and to the south east byBarkinLadi Local Government Areas. It is made of four districts: Vwang, Du, Gyel and Kuru. The Local Government Area has total land area of about 1,037km^2. The following wards make up the four districts in the study area, which are Bukuru, Zawan, RafinMangu, Shen, Vom, Gero, Rayfield, TCNN, Udu, Du,Gyel, DogonaHawa,Mai-adiko, Wang, Turu, Kuru, Pasa Kai, SabonGida, Kirana, Dutsen Kato, BarkinNda, BarkinTintin and Anguldi.

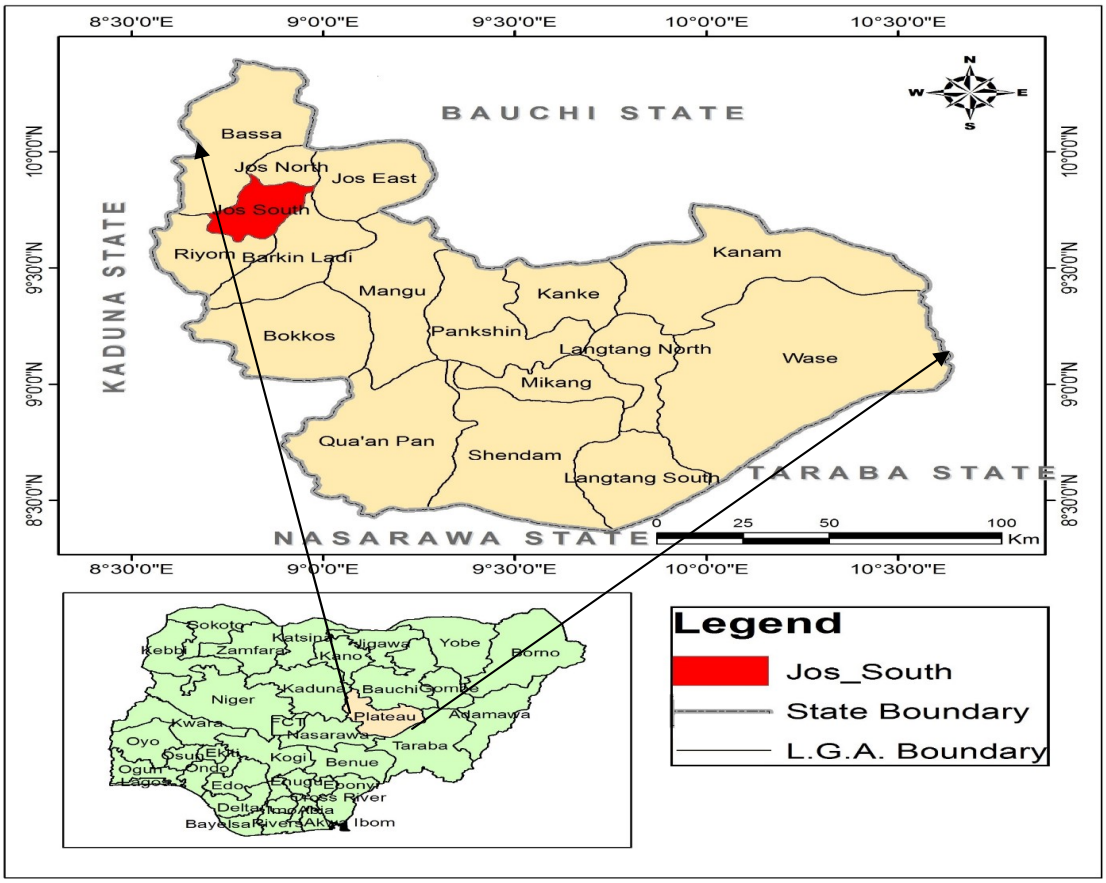

Figure 1.1: Jos South Local Government Area

Source: Adopted from Administrative Map of Plateau State (2012)

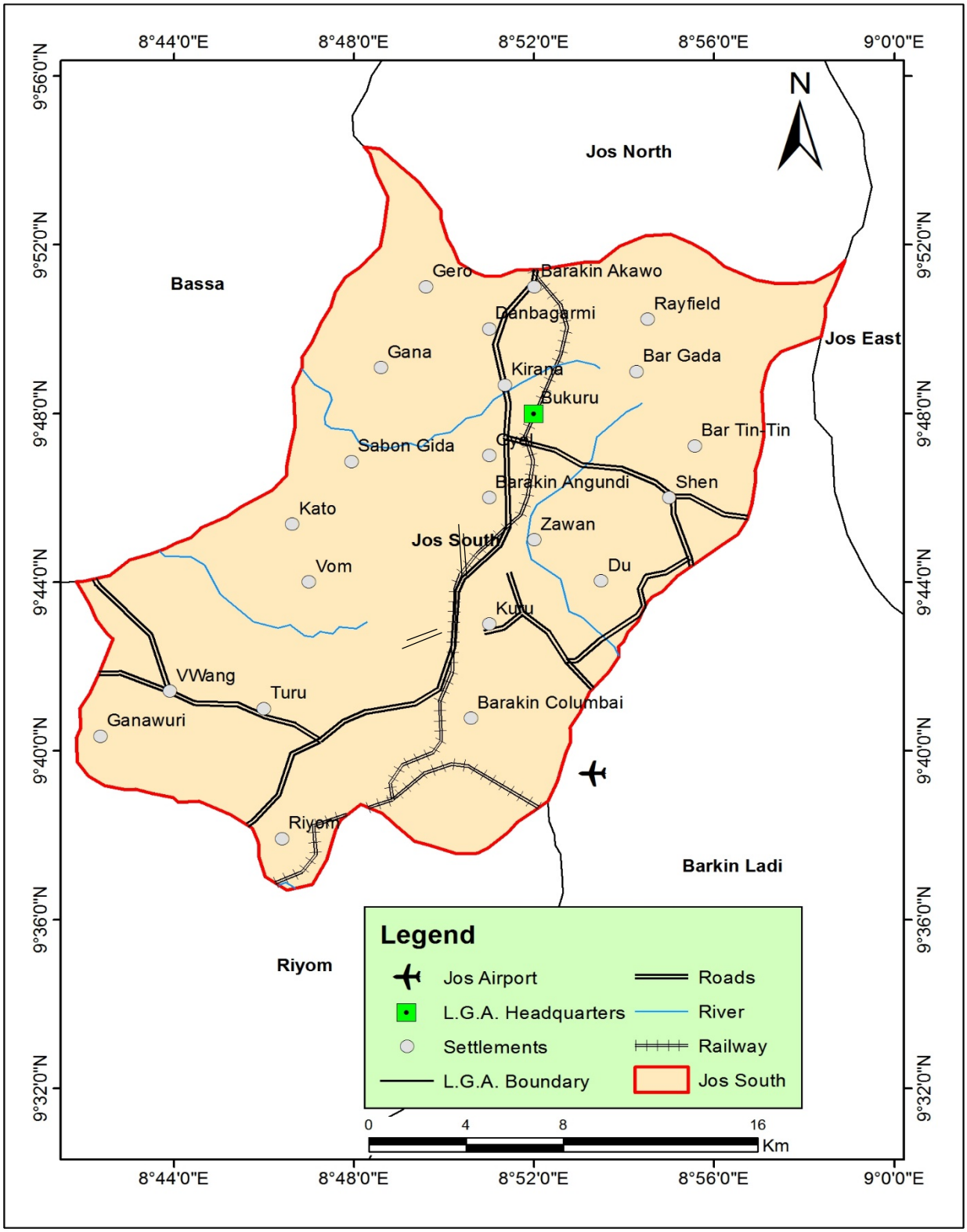

Figure 1.2: Jos South; the Study Area

Source: Adopted from Administrative map of Plateau State (2012)

The study area is characterized by alternating wet and dry seasons as tropical rainy (A_w) climate by Koppen (1918).The precipitation arises from both convectional and orographic sources, owing to the location of the city on the Plateau. Rainfall in the study area lasts between April and October, which has seven months' duration of rainy season. Rainfall is at its peak between July and August. The mean annual rainfall in Jos South varies from 1317.5mm in the southern part to 1460mm on the Plateau (Blench, Daniel and Hassan, 2003). In July, the precipitation reaches its peak with an average of 298mm, July and August are the months with the highest number of rainy days while the lowest number of rainy days occur in January, February, November and December. The greatest amount of rainfall is obtained in the southern and western margin of the high plateau than at the lowlands. Conversely, rainfall variabilities are higher on the lowlands of the State than on the high plateau. Rainfall variabilities are higher at the beginning and at the cessation of rains than in the middle of the rainy season. The pattern of rainfall distribution of Jos is explained partly by the movements and positions of the Intertropical Discontinuity (ITD) at various times of the year and partly by interplay direction of rain bearing south-westerly winds with the physiographic features in the State (Odumodu 2016). Precipitation is a very important resource in the study area as many human activities depend upon its availability (Buba,1995). Therefore, the amount and the distribution of rainfall are important factors in determining the ultimate productivity of crops under natural conditions (Bagulia, 2006). Precipitation is also considered as critical resources in the study area because its supply is confined to a season which coincides with the northern hemisphere summer (Ofuma and Nnodu 2005). Furthermore, the wet season is characterized by temporal and spatial variations, the magnitude of such variations with regard to the onset, distribution, cessation and length of the season are therefore important in planning for agricultural development and as well as for commercial planning and development. (Nieuwoit,1975). Since agricultural activities in Jos South are mostly rain fed, for a successful crop production, there is need to have reliable rainy season in each particular year (Dhameja, 2005).Jos South is situated in the tropical climate, with a higher altitude meaning that Plateau State has a near temperate climate with anaverage temperature between 18 and 22^0C,but mean monthly values vary between 19.4^0C in the coolest month of December when the area comes under the influence of the cool and dry desiccating north-easterly continental air mass (Harmattan) and 24.5^0C in the hottest month (April).The annual average maximum temperature is 28.3^0C, annual average low temperature is 16.9^0C and the average temperature is 22^0C.In the study area, temperatures are everywhere reduced by altitude (Eziashi, 2007).Jos enjoys a more temperate climate than much of the rest of Nigeria. Night-time temperature drops as low as 11^0C, resulting in chilly nights. Hail, sometimes falls during the rainy season, owing to the cool high altitude weather.

II. MATERIALS AND METHODS

Data used in this study was daily rainfall records from 1966-2015 for Jos South Local Government Area of Plateau State, Nigeria which was obtained from the achieves of the Nigerian Meteorological Agency, Oshodi, Lagos.

Derivation of Precipitation Effectiveness Indices Onset, cessation and length of the rainy season

Sawa and Adebayo (2011) in their research in Northern Nigeriasaw the definition of Onset and Cessation dates and Length of the rainy season as a problematic one due to the intermittent and patchy nature of rainfall in the tropical region. These three terms have been defined in various ways for different purposes. Various methods abound for the determination of onset and cessation dates and length of the rainy season, for example; Walter, 1967; Ilesanmi, 1972; Kowal and Knabe, 1972; Stern, Dennett and Dale, 1982b; Stern and Coe, 1982;Olaniran, 1984, 1988; Sivakumar, 1988 and Adefolalu, 1993.

Following the unreliable and patchy nature of rainfall in Northern Nigeria, Walter's (1967) method is most accurate (Sawa and Adebayo, 2011). On this premise, this method was employed by the researcher. Here, soil moisture index is related to monthly rainfall using 51mm as the benchmark for soil moisture level necessary for plants germination. Therefore, onset and cessation dates were derived considering months with rainfall greater than or equal to 51mm.

Annual rainfall, Long-term mean, standard deviation and Coefficient of Variation

This refers to the annual records of total rainfall received in a given year. The rainfall data obtained from the meteorological station for fifty years(1966–2015)was added for each of the years beginning from January to December. This gave the total annual rainfall received in Jos Southfor each of the fifty years (1966-2015). The long-term mean was determined by summing all annual rainfall records and dividing by the number of years. The standard deviation explains the measure of dispersion of rainfall values from the mean while coefficient of variation equals the standard deviation divided by long-tern mean multiplied by 100.

$$\mu=\frac{\sum AR}{Y}$$

where;

μ= Long term mean, AR= Annual Rainfall, Y= Years

Statistical Analyses

The derived station year onset, cessation dates and length of the rainy season, the length of growing season, annual rainfall,anomalous rainfall pattern of the specified lengths were all subjected to time series analysis. The year to year variability in each of these rainfall effectiveness indices were smoothened by the 5-year moving average. Linear trend lines

and best fit trend line equations were plotted for each rainfall parameter and presented graphically by means of EXCEL software of the computer.

III. RESULTS AND DISCUSSION

Characterization of Rainfall of the Study Area

The annual rainfall series for Jos South LGA from 1966 to 2015 were subjected to descriptive statistical analysis as shown in Table 4.1.

Table 3.1: General Statistics for Annual Rainfall in Jos South LGA (1966-2015)

Total amount (mm)	Mean (mm)	SD (mm)	CV (%)	Max (mm)	Min (mm)	Range (mm)	Mean Onset Date	Mean Cessation Date	Mean LRS
63327.2	1266.54	523.83	41.36	1720.3 (1969)	814 (1995)	906.3 (26 years)	15th April	25th Sept.	163 days

Source: Data Analysis for Jos South LGA (2017)

From the above table, the Jos South LGA experienced a very high total amount of rainfall with a long-term mean of 1266.54 for the entire period. However, the Standard Deviation (SD) from the mean was not significant enough judging from the low Coefficient of Variation (CV) which was less than 50%. The CV was arrived at by finding the percentage of dividing the Standard Deviation by the Long-term mean. The range of annual rainfall (906.3 mm), which calculated the difference between the maximum and minimum rainfall, was significant enough. The maximum rainfall was recorded in the year, 1969 while the minimum rainfall occurred in 1995. A significant difference of 26 years running close to three decades was calculated between the Maximum and Minimum values. The mean onset date is in mid-April while the mean cessation date is late September. This shows early onset and late cessation giving a lengthy growing season that averagely lasts for $5^{1}/_{2}$ months.

Trends in Rainfall Series

Trends in annual rainfall pattern

To specify the character of the rainfall during the period, the annual rainfall amount graph was plotted with consecutive five- year (pentad) and ten-year (decadal) running means (moving average) used to smoothen the rainfall series as presented in Figure 1.3.

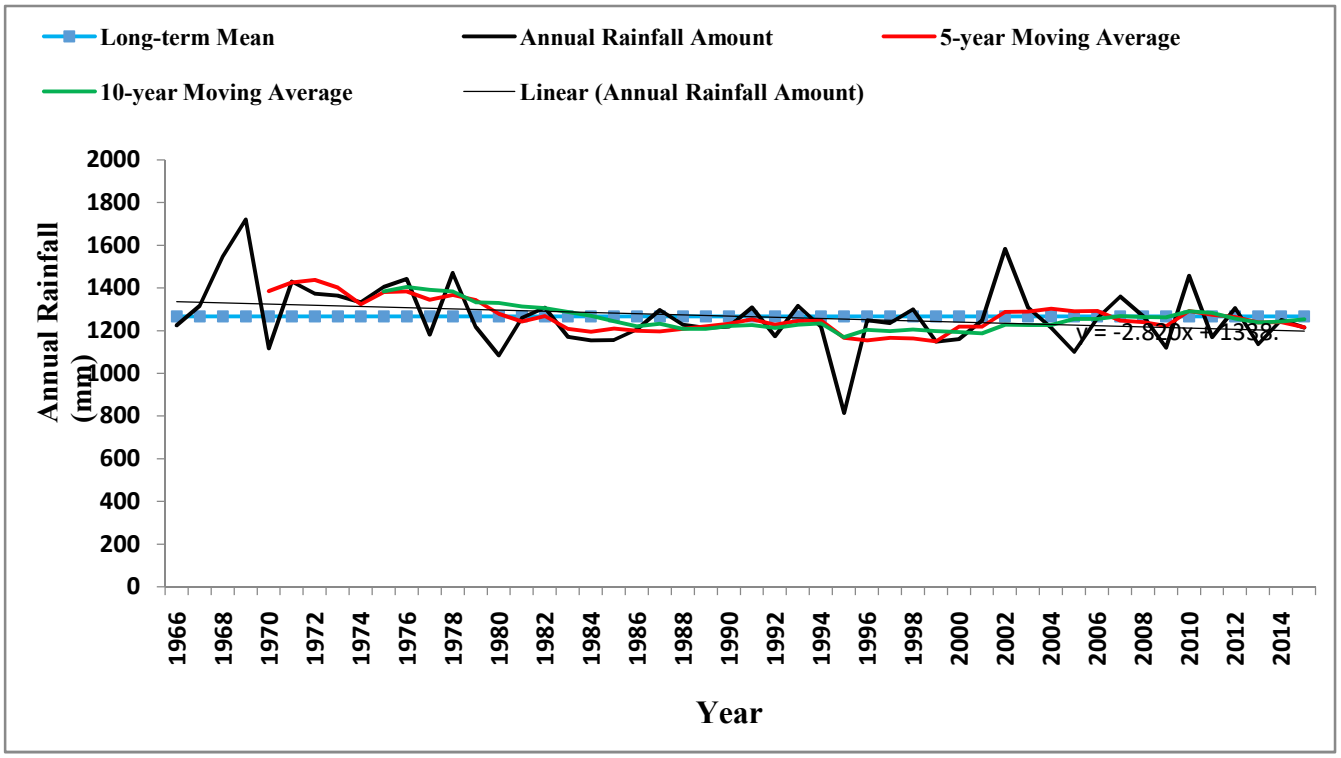

Figure 1.3 – Trends in Annual Rainfall in Jos South LGA, Plateau State, Nigeria(1966-2015)

Source: Data Analysis for Jos South LGA (2017)

The above figure shows annual rainfall totals coupled with the 5-year and 10-year running means. The 5-year running mean (or moving average) generally showed annual rainfall amounts significantly above normal (long-term mean) from the 1970 until 1981 when it declined below normal and fluctuated until 2002 to 2006 when an insignificant rise above the mean was experienced. Another partial rise occurred in 2010 and 2011. After that, annual rainfall declined below normal. The 10-year moving average also experienced significant rise from 1975 until 1984. After which it went below the mean from 1985 to 2006. However, in 2007, 2010 and 2011, rises occurred until 2008 when it fell below normal. Figure 1.3 reveals that from the mid-1960s to the early 1980s, annual rainfall amounts were appreciable above the long-term mean. However, from the mid-1980s to the early millennium, precipitation changes were experienced giving place for mild drought periods to set in (although not extreme) as compared to the normal. From year 2002 to 2015, the early periods were above normal but the later attempted to decline. The linear equation for the annual rainfall is y = -2.820x + 2338 showing a negative trend line which appears to be dropping below normal.

Trends in Onset Dates at Jos South LGA

Figure 1.4, clearly indicates an increasing trend line in the onset dates. The best fit line equation is positive (y= 0.034x + 42839). This means decreasing Julian days and implies that rainfall progressively starts early in recent times in the study area. The mean onset date is 15thApril which is early enough for farmers to start pre-sowing activities. Figure 1.4 indicates that in the study area, the rains start early (April 15), such reliable information on onset date is important for local farmers to purchase seeds on time to plant early thereby avoiding the tendency of the risk of crop failure and to ensure adequate and effective food production. It is well established that early planting produces higher yields than late planting. The primary reason to plant early is to avoid environmental stresses that could impedes agricultural production (residual nutrients in the soil) in the study area, as posited by Sawa and Adebayo (2011), that late onset and early cessation could be a threat to food security and sustainable development. Higher crop yields are usually obtained when crop is planted as early as weather conditions permit mainly because of reduced pest and disease pressure late in the season and better rainfall patterns and cooler soil moisture during crop silky. As a result of early planting crops enjoy more moisture stored in the soil for germination. Crops pollinating in late May and June will have better moisture index in most years than crops flowering in July and August. The effect of planting late could lead to increased pest and disease pressure during key growth stage especially in maize, irish potatoes, yam, cassava, cocoyam, soya bean and rice. This could also lead to less time for crops to dry down before harvest.

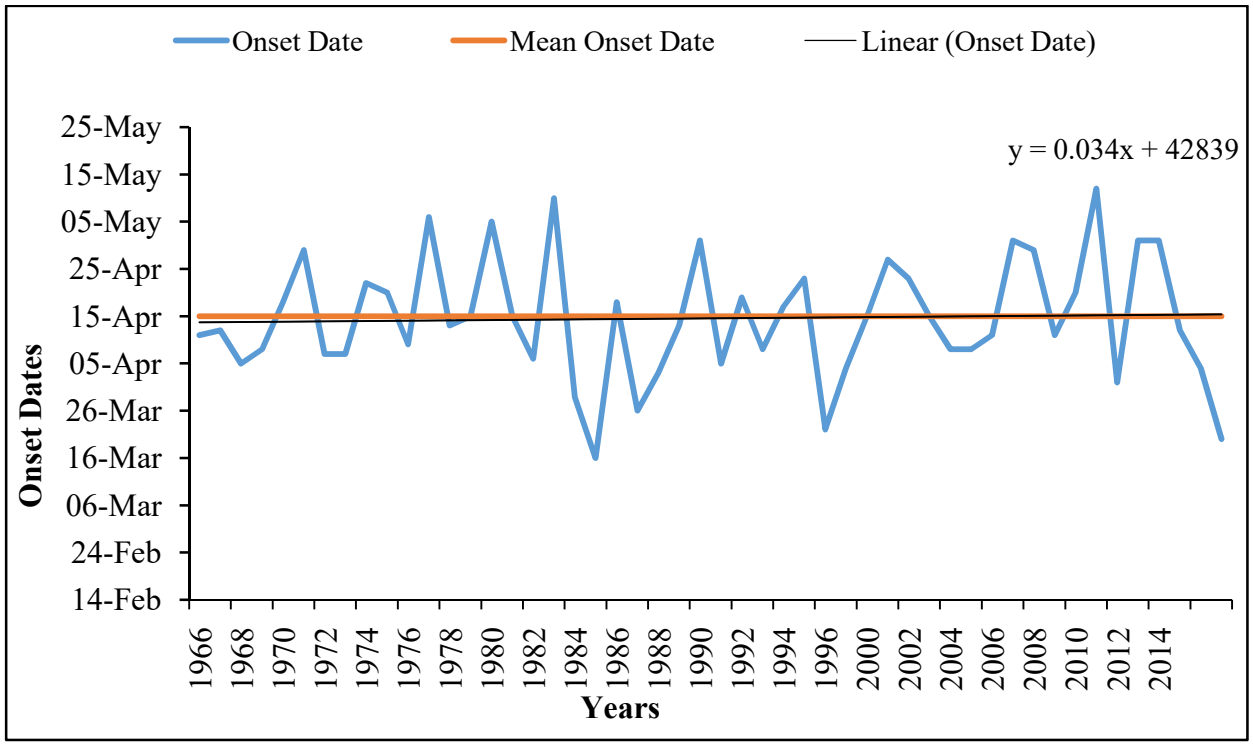

Figure 1.4: Trends in Onset dates of Rainfall in Jos South LGA, Plateau State (1966-2015)

Source: Author's Analysis (2017)

Trends in Cessation Dates at Jos South LGA

In Figure 1.5, the cessation dates of rainfall are characterized by marked 'noise' (variability) from year to year. The mean cessation date is 25thSeptember. The graph clearly indicates an increasing trend in cessation dates as the trend line equation (y = 0.7354x + 42984) is positive. This means that rainfall cessation date comes relatively later than usual, that is, there is a slight delay in rainfall cessation date. This is also good news to farmers in the study area as crops may have adequate moisture for later stage development and more time for crops to dry down before harvest, and since the early onset in the study area is experienced before the period of late cessation, crops enjoy more moisture stored in the soil for germination. This encourages adequate crop production due to available soil moisture as a result of long duration of rainy season, this also agreed with Sawa, Adebayo and Bwala (2014), that late onset and early cessation shorten the duration of hydrological growing season which poses a great threat to surface and underground water resources management and agriculture and sustainable food security as well as biodiversity in Kano and Nigeria at large.

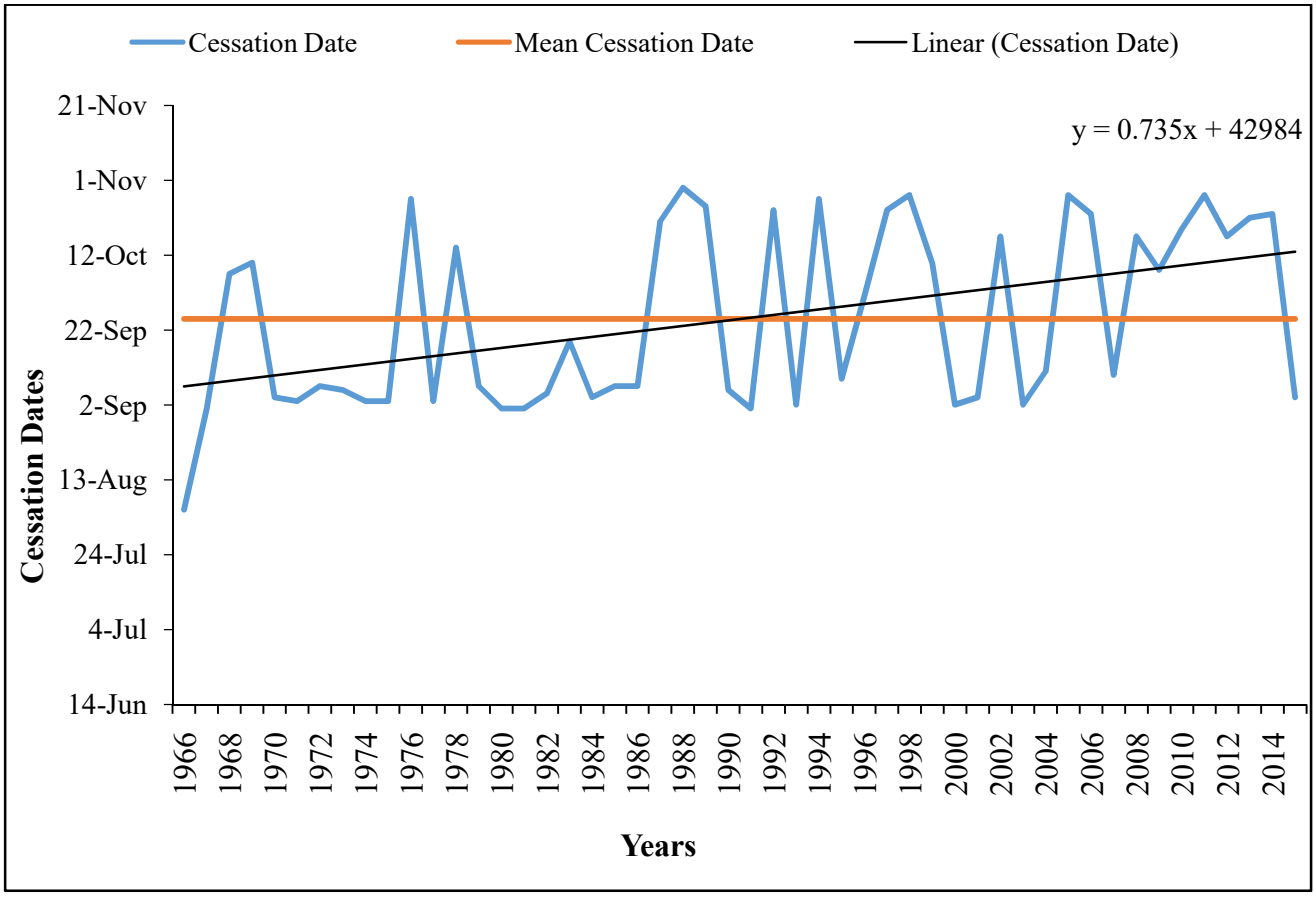

Figure 1.5: Trends in Cessation dates of Rainfall in Jos South LGA, Plateau State (1966-2015)

Source: Author's Analysis (2017)

Trends in Length of Rainy Season (LRS)

Figure 1.6 shows a positive trend line equation of y= 0.7644x+143.29, which indicates an increasing Length of Rainy Season. The mean length of rainy season was 163 days or about $5^{1}/_{2}$ months. However, this confirms to the marked yearly 'noises' on the trend line. For instance, in the year 1966, the LRS was as low as 116 days before shooting to a peak of 210 days in 1988 followed by 209 days in 1987 and dropping to 168 days in the year 2015 but still slightly above normal. The increasing length of rainy season is owing to the fact that the mean onset date is early (15th April) in recent times compared to earlier years while the mean cessation date is late (September 25th). Hence, the early onset dates and late cessation dates imply longer length of rainy season. Agriculturalists will find this very interesting because of long duration of rainfall, of about seven months, encourage available moisture stored in the soil for germination, growth and utilization by crops and long maturing crop varieties will thrive better in such environment.

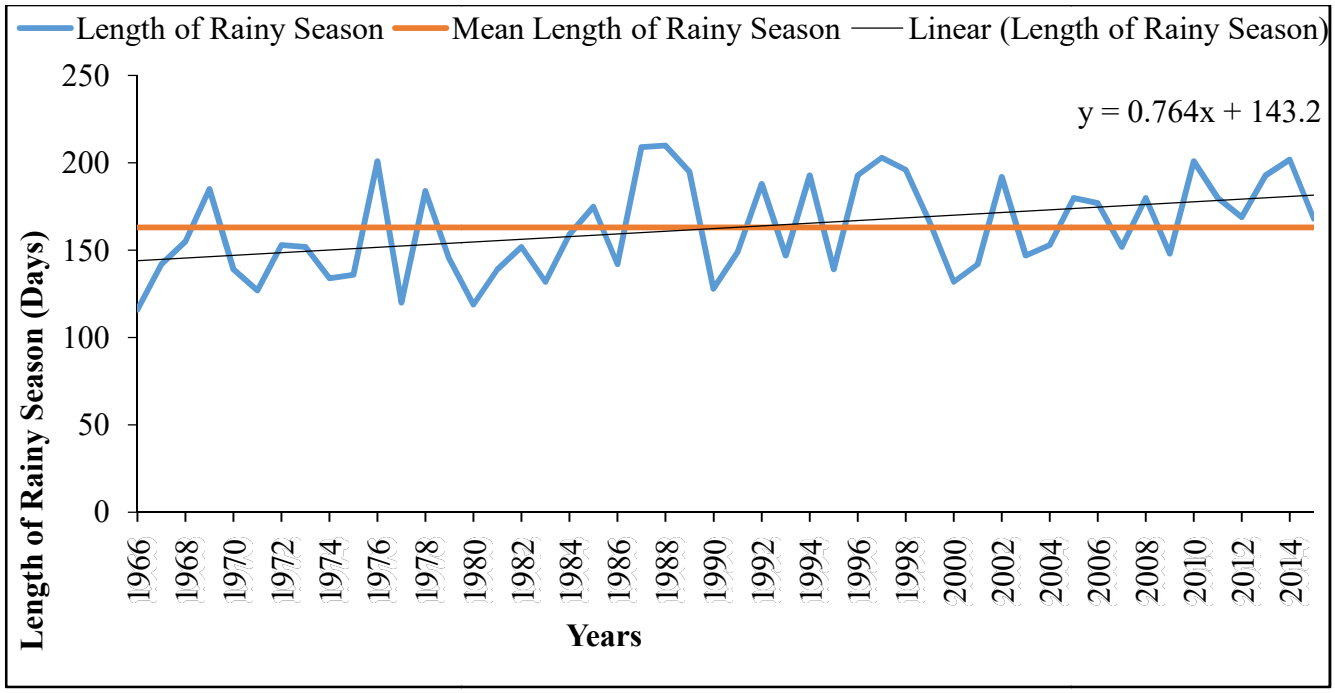

Figure 1.6: Trends in Length of Rainy Season in Jos South LGA, Plateau State (1966-2015)

Source: Author's Analysis (2017)

Rainfall Anomalies

The normal or mean annual rainfall of Jos South Local Government Area of Plateau State based on 1966 – 2015 rainfall data is 1266.5mm. Once this normal condition was established, any particular year was described in terms of its departure from this normal in the study area. In effect, 1225.2mm annual rainfall received at Jos South in 1966 can be described as 3.3% below normal (negative), while 1315.5mm annual rainfall received in the area in the year 1967 can be expressed as 3.9% above normal (positive). These departures are referred to as anomalies.

(A). Table 3.2: Rainfall Anomalies for Jos South LGA from 1966 to 2015

Year	Total Annual Rainfall	Annual Rainfall Minus Mean Annual Rainfall	Percentage Anomaly	Positive (above) and Negative (below) Mean
1966	1225.2	1225.2 -1266.5	3.3%	- 41.3
1967	1315.9	1315.9-1266.5	3.9%	+ 49.4
1968	1546.4	1546.4-1266.5	22.1%	+ 279.9
1969	1720.3	1720.3-1266.5	35.8%	+ 453.8
1970	1116.5	1116.5-1266.5	11.8%	-150
1971	1430	1430-1266.5	12.9%	+ 163.5
1972	1373.2	1373.2-1266.5	8.4%	+ 106.7
1973	1363.8	1363.8-1266.5	7.6%	+ 97.3
1974	1332.2	1332.2-1266.5	5.1%	+ 65.7
1975	1404.7	1404.7-1266.5	10.9%	+ 138.2
1976	1442.2	1442.2-1266.5	13.9%	+ 175.7
1977	1181.1	1181.1-1266.5	6.7%	-85.4
1978	1470.1	1470.1-1266.5	16.1%	+ 203.6
1979	1216.4	1216.4 -1266.5	4%	- 50.1

1980	1083.7	1083.7-1266.5	14.4%	-182.8
1981	1258.6	1258.6-1266.5	0.6%	-7.9
1982	1307.4	1307.4-1266.5	3.2%	+ 40.9
1983	1170.2	1170.2-1266.5	7.6%	-96.3
1984	1153.8	1153.8-1266.5	8.9%	-112.7
1985	1155.8	1155.8-1266.5	8.7%	-110.7
1986	1204.7	1204.7-1266.5	4.9%	-61.8
1987	1296.2	1296.2-1266.5	2.3%	+ 29.7
1988	1227.3	1227.3-1266.5	3.1%	-39.2
1989	1212	1212-1266.5	4.3%	-54.5
1990	1218.3	1218.3-1266.5	3.8%	- 48.2
1991	1307.6	1307.6-1266.5	3.2%	+ 41.1
1992	1173.1	1173.1-1266.5	7.4%	- 93.4
1993	1315.2	1315.2-1266.5	3.8%	+ 48.7
1994	1216.6	1216.6-1266.5	3.9%	- 49.9
1995	814.0	814.0-1266.5	35.7%	- 452.5
1996	1248.9	1248.9-1266.5	1.4%	- 17.6
1997	1235.1	1235.1-1266.5	2.5%	- 31.4
1998	1299.5	1299.5-1266.5	2.6%	+ 33
1999	1148.2	1148.2-1266.5	9.3%	- 118.3
2000	1160.0	1160.0-1266.5	8.4%	- 106.5
2001	1247.5	1247.5-1266.5	1.5%	- 19

Source: Author's Analysis (2017)

(B). Table 3.2: Rainfall Anomalies for Jos South LGA from 1966 to 2015

Year	Total Annual Rainfall	Annual Rainfall Minus Mean Annual Rainfall	Percentage Anomaly	Positive (above) and Negative (below) Mean
2002	1582.7	1582.7-1266.5	25%	+ 316.2
2003	1306.6	1306.6-1266.5	3.2%	+ 40.1
2004	1211.9	1211.9-1266.5	4.3%	- 54.6
2005	1100.5	1100.5-1266.5	13.1%	- 166
2006	1257.1	1257.1-1266.5	0.7%	- 9.4
2007	1359.0	1359.0-1266.5	7.3%	+ 92.5
2008	1265.7	1265.7-1266.5	0.1%	- 0.8
2009	1119.9	1119.9-1266.5	11.6%	- 146.6
2010	1457.2	1457.2-1266.5	15.1%	+ 190.7
2011	1169.4	1169.4-1266.5	7.7%	- 97.1
2012	1305.4	1305.4-1266.5	3.1%	+ 38.9
2013	1136.1	1136.1-1266.5	10.3%	- 130.4
2014	1249.7	1249.7-1266.5	1.3%	- 16.8
2015	1214.3	1214.3-1266.5	4.1%	- 52.2

Source: Author's Analysis (2017)

Trends in Rainfall Anomalies

From Figure 1.7, the trends in anomalous yearsof rainfall were fluctuating or departing above and below the normal or mean anomalous years. The mean of the anomalous years is 0.044mm. The best fit line equation is negative (y= -2.820x+71.96), implies a decline in anomalous years rainfall.This means a decrease from normal was experienced after the long-term mean was subtracted from the annual rainfall. The trend line from 1966 experienced a decline from the beginning of the period with the anomaly peak in 1968 to the positive and at the late 1980s. The trend line became negative and continued to fluctuate until the end of the period with the highest anomaly decline recorded in 1995. These constant fluctuations from normal or mean anomalous years is referred to as departures and these incessant departures from the normal constitutes anomalous records in the study area. The anomalous years include the late 1960s to late 1970s, 1995, 2002 to 2010, 2013 to 2015.The linear equation is also a proof of the effect of climate change according to Farmer and Wigley (1985) whose assumption stated that persistent climatic fluctuations for long periods constitutes climate change. In effect, it can be stated that Jos South LGA experiences climate change. Consequently, this implies a decline in precipitation; its intensity, amount and duration in the study area which could pose a great threat to sustainable agriculture. Sawa (2002) opined that the great drought periods of Northern Nigeria's states coincided with the above years, as most of these areas are becoming drier due to decreasing precipitation.

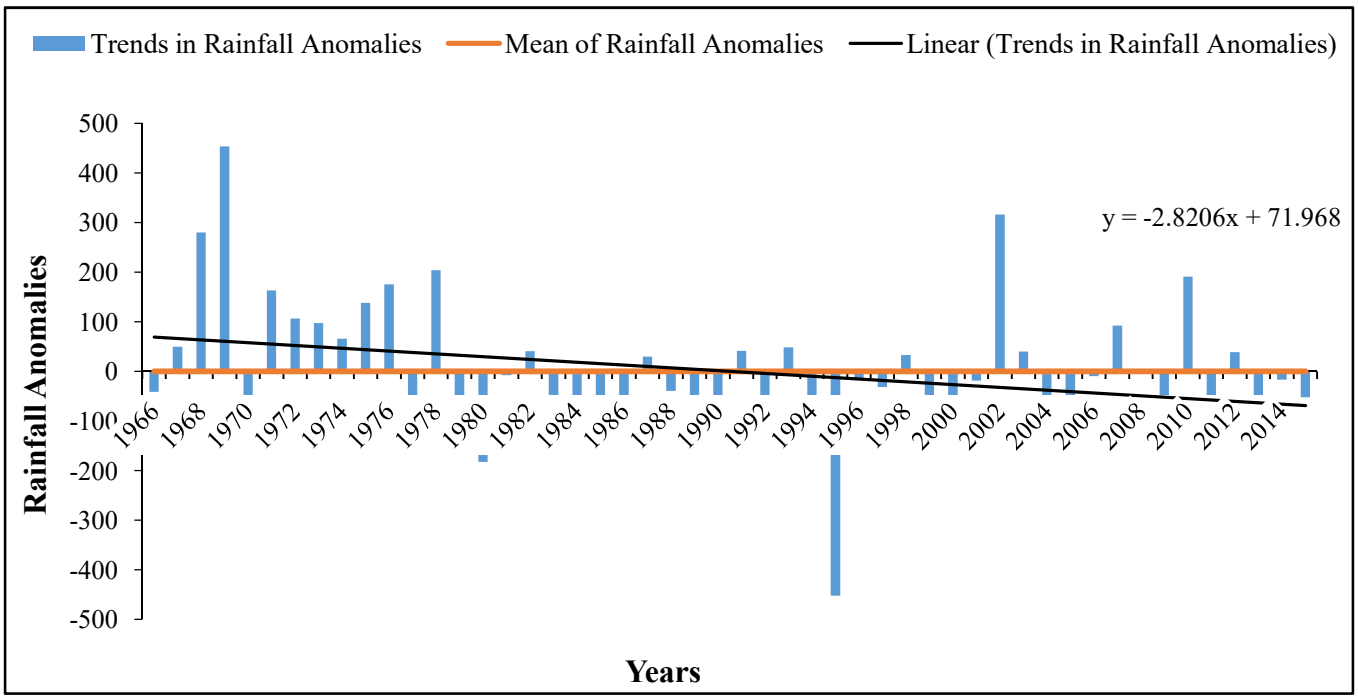

Figure 1.7: Trends in Rainfall Anomalies in Jos South LGA, Plateau State, Nigeria (1966-2015)

Source: Author's Analysis (2017)

Forecasting of Anomalous Rainfall Years

In figure 1.8, the best fit line equation is negative y= -9.270x +1106, which implies a decline in the anomalous rainfall years. The mean of forecasted rainfall was 1009.4mm. In the year 2016, the forecasted amount of rainfall was 1179.94mm; 2017 was 1297.82mm; 2018 was 1129.49mm; 2019 was 1260.85mm; 2020 was 1011.83mm; 2021 was 895.27mm; 2022 was 833.76mm; 2023 was 901.38mm; 2024 was 1029.65mm; 2025 was 935.03mm; 2026 was 867.24mm; 2027 was 949.97mm; 2028 was 959.75mm; 2029 was 1009.75mm; 2030 was 998.64mm; 2031 was 953.7mm; 2032 was 958.66mm; 2033 was 946.68mm; 2034 was 997.04mm and 2035 was 1071.82mm. In future, rainfall has been predicted to be high above normal between year 2016 and 2020 after which it will go below the mean until 2035 when it will rise until the end of the predicted period. The years above the mean are 2016, 2017, 2018, 2019, 2020, 2024, 2029 and 2035 and those below the mean are 2021, 2022, 2023, 2025, 2026, 2027, 2028, 2030, 2031, 2032, 2033 and 2034. It implies that rainfall anomalies are fluctuating but on a downward trend which could increase periods of dry spells and drought occurrences in the study area. The trend is an evidence of climate change, this fluctuation below the forecasted mean implies reduction of rainfall amount which makes agricultural productivity difficult, increasing incidence of pests and diseases and rising number of heat waves.

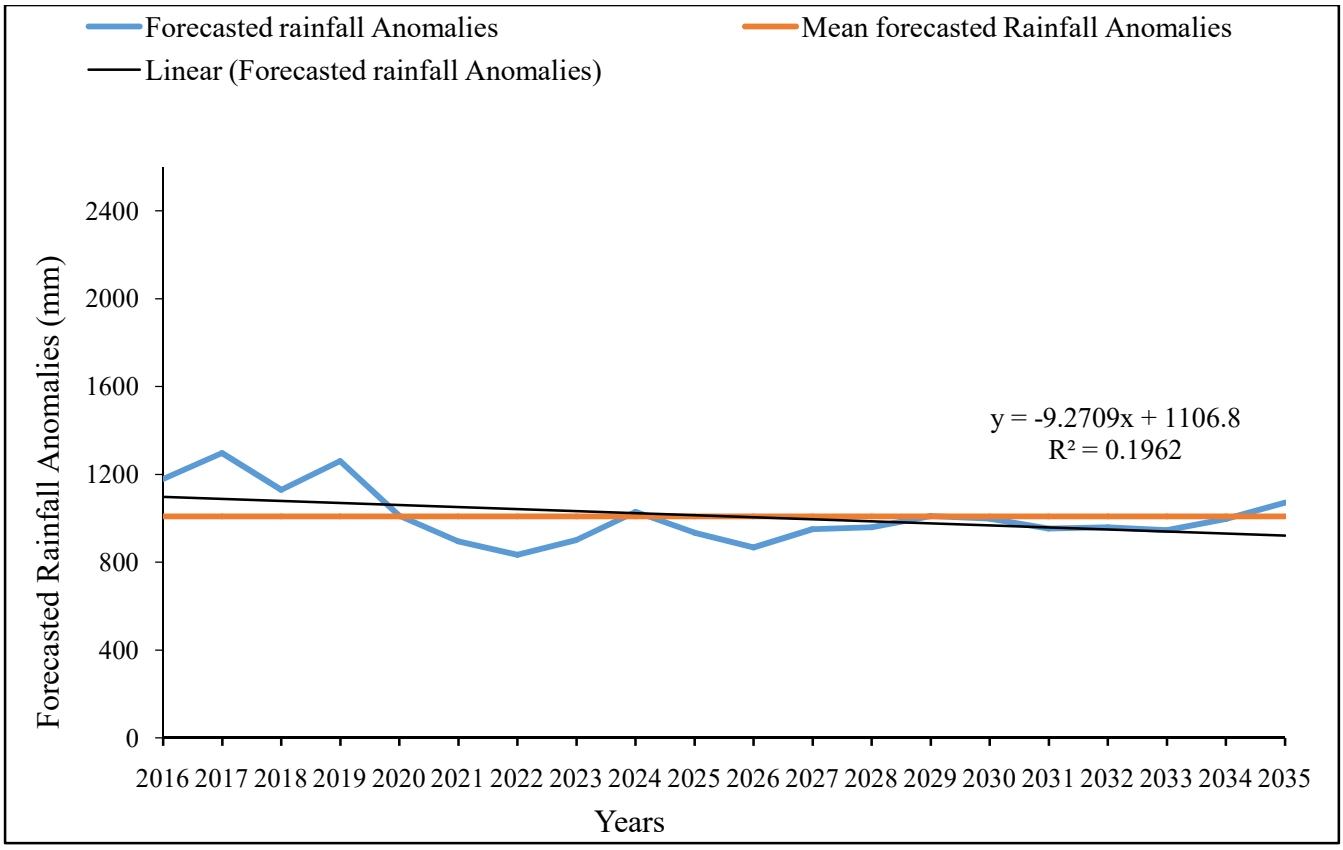

Figure 1.8: Trends in forecasted Anomalous rainfall in Jos South LGA, Plateau State (2016-2035)

Source: Author's Analysis (2017)

IV. SUMMARY

This study assessed the changes in precipitation effectiveness indices from 1966 to 2015 as evidence of climate change in Jos South Local Government Area of Plateau state, Nigeria. The study used daily rainfall records (mm) sourced from the Nigerian Meteorological Agency (NIMET), Jos Airport from 1966 to 2015. Furthermore, the Walter's 1967 method was used to derive selected precipitation effectiveness indices. Anomalous rainfall years was derived using descriptive statistical techniques. Farmer and Wigley (1985) method was used to show the evidence of climate change using the anomalous records years of the study area. The estimated parameters were subjected to time series analysis. Trend lines and linear trend line equations for each of the parameters were fitted to show the direction of change. while the forecast of anomalous years was derived using time series analysis where linear trend lines and trend line equations were developed to forecast its occurrence.

V. CONCLUSION AND RECOMMENDATIONS

The major source of water available either for agricultural or human consumption is precipitation. This is the reality in the study area where the ultimate productivity of crops under natural conditions are determined by the amount, distribution and variability of rainfall.Rainfall distribution and variability occurs as a result of climate changes and these changes will impact on agriculture in Jos South LGA. The Precipitation effectiveness indices analysed showed that there is an indication that there are more early onset of rainfall and late cessation in the study area. This development has increased the length of the rainy season. Result also showed decreased total annual rainfall and decreased in forecasted anomalous years, all these are evidences of climate change gradually occurring in the study area, which in turn could pose a great threat to sustainable agriculture. This study therefore acknowledges that the changes in precipitation effectiveness indices is as a result of the effect of climate change which indeed is a reality in the study area and with time, its effects, if not properly managed by employing effective adaptation strategies, would be felt severely on water resources, agriculture and other living conditions and occupation of the populace in the area.

Based on the findings of this research, the following recommendations are proposed:

1. Since the characteristics of onset dates and cessation dates, length of rainy season, total annual rainfall, hydrological growing season and anomalous years are inconsistent and variable in the study area, it is

therefore, recommended that land preparation and planting of crops can be done from 15th of April, which is the established mean onset date of rainy season in the study area. This is to allow the crop that do not require amount of rainfall to mature early enough to avert the danger of incidence of pest and disease and high rainfall which characterized the month of August. This is because this high rainfall is unhealthy to the tuberous of the crops depending upon the crops e.g. long maturing rice variety like WITA 4, SIPPI, FARO 140

2. Executing the best soil conservation practices for farming such as crop rotation, shifting cultivation, terracing, use of seed-dressing fungicides and insects' treatments which would
help to reduce pests attack.
3. Since there is a decreased in total annual rainfall and forecasted anomalous years which may lead to incidence of dry spells in the study area, farmers should introduce other crops and seed varieties of high yield that can tolerate short dry spells in order to boost crop production in the study area. Examples of such crops include Irish Potato (Solanum Tuberosum), maize (Zea mays) and cowpea.
4. More weather stations should be established in areas where none existed so as to facilitate generating climatic data all over the area to provide information for long term planning and development of agriculture generally in the study area. Research works need to be conducted in other areas like cultural practices on the farm, soil factors so as to understand the contribution of each of these factors

REFERENCES

[1]. Adefolalu, D. O. (1993).World Meteorological Organization. Lecture Series 1: 1-4.
[2]. Adefolalu, D. O. (1998). Precipitation, Evapotranspiration and the Ecological Zones in Nigeria. *Theoretical and Applied Climatology*. 39: 81-89.
[3]. Ayoade, J. O. (1993).*Introduction to Climatology for the Tropics.* Spectrum Book Limited, Ibadan.
[4]. Bello, N. J. (1995). On the Reliability of Methods of Predicting the Onset and Cessation of the Rains in a Tropical Wet-and-Dry Climate: A Case Study of Ondo. *Journal of the Nigeria Meteorological Society*, 1:41-55.
[5]. Bello, D. (2008). Precipitation Effectiveness Indices and Millet Yield in Two Local Government Areas of Kano State, Nigeria. Department of Geography, Ahmadu Bello University, Zaria.(Unpublished Thesis).
[6]. Benoit, P. (1977). The Start of the Growing Season in Northern Nigeria. *Agric. Met.*, 18: 91-99.
[7]. Blench, R. M., Daniel, P. and Hassan, R. (2003). *Traditional Livestock Breeds: Geographical Distribution and Dynamics in Relation to the Ecology of Nigeria*. ODI Working Paper 122. London: Overseas Development Institute. Available inAcrobat format at: http://www.oneworld.org/odi/publications/wp122.pdf
[8]. Buba, L.F. (1995). Drought Occurrence and Utilization of Rainfall for Agriculture in NorthernNigeria. In Falola, J.A, Ahmed, K, Liman, M.A, Maiwada, A (eds). *Issues in LandAdministration and Development in Northern Nigerian*, Geography Department BayeroUniversity Kano.
[9]. Burton, W. G. (1989). The Potato Veenman and Zonen, Wageningen.Netherlands.p382.
[10]. Dezfuli, A. K and Nicholson, S. E. (2011). A Note on Long-term Variations of the Afrrican Easterly Jet. *International Journal of Climatology,* 31: 2049-2054.Dhameja, S.K. (2005). Environmental Studies, Delhi: S.K Kataria and sons.
[11]. Dorman, J. M. and Gyuse, U. (1979). *Problem of Soil Erosion on the Jos Plateau, in Ajaegbu*. H. I. and Morgan, (Eds.), Geographers and Planning in Nigeria Proc. 21 Annual Conference
[12]. Eziashi, A. C. (2007). Finding Solutions to Environmental Problems: *Challenges of the Nigerian Geographer in the Twenty-first Century*. Department of Geography and Planning, University of Jos (Unpublished).
[13]. Farmer, G. and Wigley, T. M. (1985).*Climatic Trends for Tropical Africa.*A Research Report for the Overseas Development Administration.136 pp.
[14]. Forbes, J. C. and Watson, R. D. (1992).*Plants in Agriculture*. New York: Press Syndicate of the Cambridge University Press.
[15]. Hess, T. M., Stephens, W. and Maryah, U. M. (1995). Rainfall Trends in the North East Arid Zone of Nigeria 1961–1990. *Agricultural and Forest Meteorology* 74: 87–97
[16]. Intergovernmental Panel on Climate Change, (2001).*Climate Change.* The IPCC Third Assessment Report, Vol. I, the Scientific Basis, II-Impacts, Adaptation and Vulnerability, III Mitigation, Cambridge University Press: Cambridge and New York.
[17]. Intergovernmental Panel on Climate Change, (2007).*Climate Change 2007:* Climate Change Impacts, Adaptation and Vulnerability, Working Group II Contribution to theIntergovernmental Panel on Climate Change – Fourth AssessmentReport Summary for Policy makers.
[18]. Intergovernmental Panel on Climate Change, (2011).Workshop Report of the Intergovernmental Panel on Climate Change. Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems by Field, C. B., V. Barros, T.F. Stocker, D. Qin, K.J. Mach, G.-K. Plattner, M.D. Mastrandrea, M. Tignor.
[19]. Odumodu, L. O. (2016). Rainfall Distribution, Variability and Probability in Plateau State. *International Journal of Climatology*. 3(4). Royal Meteorological Society. John Wiley and Sons, inc.
[20]. Olaniran, O. J. (1984). The Onset of Rains and the Start of the Growing Season in Nigeria.
[21]. Nieuwoit, S. (1975). An Introduction to the Climates of the low latitudes. Nairobi: John Willey and sons.
[22]. Sale, P. J. (1973). Production of Vegetable Crops in a Region of High Solar Inputs, *Australian Journal of Agriculture,* Irish Potato, Research*,* 24: 733-744
[23]. Sawa, B.A. (2010). *The Occurrence and Persistence of Dry Spells and Its Implications for Crops Yield in the Sudano-Sahelian Regions of Northern Nigeria*.An Unpublished Ph. D Thesis, Dept. of Geography Modibo Adamawa University of Technology, Yola.
[24]. Sawa, B. A. and Adebayo, A. A. (2011).The Impact of Climate Change on Precipitation Effectiveness Indices in Northern Nigeria.*Research Journal of Environmental and Earth Sciences* 3(5): 481-486, 2011.
[25]. Sawa, B. A. and Adebayo, A. A. (2012).Derived Rainfall Effectiveness Indices as Evidence of Climate Change in Northern Nigeria and Implications for Food Security.*Journal of Agriculture and Biodiversity Research ©2015 Online Research Journals.*Available Online at http://www.onlineresearchjournals.org/JABR.
[26]. Sawa, B. A. Adebayo, A. A. and Bwala, A. A (2014). Dynamics of Hydrological Growing Season at Kano as evidence of Climate Change. *Asian Journal of Agricultural Sciences* 6(2): 75-78, 2014. ISSN: 2041-3882. Maxwell Scientific Organisation, 2014
[27]. Wolfe, D. W., Fereres, E. and Voss, R. E. (1983). Growth and Yield Response of Two Irish Potato Cultivars to Various Levels of Applied Water, *Irrigation Science Journal, 3*: *211-222.*
[28]. Zaag, D. E. and Burton, W. G. (1978). Potential Yield of Irish Potato Crop and its Limitations, *Survey paper, 7th Triennial conference of the European Assoc.* For Irish Potato Research, Warsaw, Poland, 7-22.

APPENDIX I

JULIANDATECALENDARPERPETUAL

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct	Nov	Dec.	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

FORLEAPYEARUSEREVERSESIDE