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Effect Of Climate Change On Hydrological Growing Season In Jos South Local Governement Area, Plateau State, Nigeria

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Abstract
The study examines the effects of climate change on the hydrological of growing season (HGS) in Jos South LGA, Plateau State. Monthly and annual rainfall data of 40 years (1979-2018) was obtained from the meteorological station of National Root and Crop Research Institute, Vom, Jos South LGA. Plateau State and crop yield (2005-2014) from same institute. Appropriate statistical techniques were used in calculating each index. The results obtained shows that Jos South has been experiencing progressive increase in rainfall amount by 5.01mm in recent times in Jos South Local Government Area (1979-2018). R^2 *= 0.162 shows that Jos South Local Government Area has been recording 16% increase in annual rainfall from (1979-2018). The average onset date of rain is 110 days (20th April) with deviation of 15 days.The mean rainfall cessation 91 days (1st October) with deviation of 10 days.Findings of HGS result shows that average HGS is 168 days with deviation of ± 20days. The shortest period recorded was 129 days in 1983 while the longest period is 217 in 2002. Correlation coefficient (r= 0.05) shows there is no significant relationship that exist between HGS and yield of potato in Jos South Local Government Area. The research concludes that this variability in rainfall characteristics shows evidence of climate change. Therefore, there is need to enlighten people especially farmers who rely on rain-fed agriculture on the negative effect of climate change.*

Keywords: *Climate change, Rainfall Variability, Onset, Cessation and Hydrological Growing Season*

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I. Introduction

Climate is an important factor of agricultural production; therefore, a change in the mean value of climatic elements will equally exert a proportional change in agriculture. Climate change effect on agriculture will differ across the world (Audu et al 2012). Determining how climate change will affect agriculture is complex because varieties of effects are likely to occur. The Inter Government Panel on Climate Change reported that by 2020, agricultural production including access to food in many African countries will be compromised by climate change. In addition, there may be changes in rainfall patterns with some areas of the world receiving more rainfall than they currently do receive, while others will receive considerably less rainfall. In general, agricultural production activities of all the sectors are the most sensitive and vulnerable to climate change (IPCC, 2007). Thus, climate change has and is still altering the global rainfall regime. Extremes of this climatic parameter are on the increase in some areas while its average is on the decrease at some. Similarly, a shift in the average climatic conditions of an area would, therefore, lead to a shift in the pattern of agricultural activities in the area (Sawa, Adebayo and Bwala, 2014).

Rainfall is the most variable of all climatic elements and determines the growing season in developing countries like Nigeria where agriculture is predominantly rain-fed. Growing season is the period during which rainfall distribution characteristics are appropriate for crop germination, establishment, growth and ripening. Hence, the onset and cessation of rainfall are of special importance in rain fed agriculture growing season. The combination of these two determines the length of the growing season (Lemma et al., 2016). The growing season often determines which crops can be grown in an area, as some crops require long growing seasons, while others mature rapidly. Growing season length is limited by many different factors. Depending on the region and the climate, the growing season is influenced by air temperatures, frost days, rainfall, or daylight hours (EPA, 2016).

Changes in the length of the growing season can have both positive and negative effects on the yield and prices of particular crops. A longer growing season could allow farmers to diversify crops or have multiple harvests from the same plot. However, it could also limit the types of crops grown, encourage invasive species or weed growth, or increase demand for irrigation. A longer growing season could also disrupt the function and

structure of a region's ecosystems and could, for example, alter the range and types of animal species in the area.

It has been observed that in Nigeria like in many other parts of the tropics, the hydrological growing season varies not only spatially but also temporarily (NIMET, 2008). The length of the rainy season varies between 250-290 days in the southern states of Nigeria to 90-130 days in the northern extremes especially states such as Borno, Katsina, Kano and Sokoto (NIMET, 2008; Walter, 1968). This no doubt brings about wide difference on the types of crops that are grown in the northern extremes and those favourable to the south. While south grows those crops with higher crop requirement and longer water requirement and longer life cycle of 120-270 days; the north with very short hydrological growing season grows grains whose life cycles are completed between 90-120 days (Adefolalu, 1981). This makes it difficult to grow crops that are not acclimatized to the environment whose length of rainy season is either too long for them or is in essence too short for them to do well. This explains why root crops are dominant in the south and grain crops in the north.

The problems associated with poor sustainable agriculture in a developing country like Nigeria could be attributed to the high variability in the onset and cessation of the rainy season. Reliable prediction of onset time will greatly assist on-time preparation of farmlands, mobilization of seeds; crops, manpower and equipment and will also reduce the risks involved in planting: sowing too early or too late (Omotosho, Balogun&Ogunjobi, 2000). Therefore, the influence of climate change on hydrological growing season in Jos south LGA, Plateau State is worth investigating with actual data in order to have reliable knowledge.

II. Materials And Methodology

The Study Area

Jos South LGA is located between Latitude $9^{o}35'00"N$ and $9^{o}55'00"$ N and Longitude $8^{o}37'00"E$ and $8^{o}57'00"E$ (Plateau Choice, 2019). It is bounded by Barkin –Ladi Local government to the South, Riyom Local government to the South West, Jos-East Local government to the East and Bassa Local government to the West with an average land area of 1, 037km^2 (Zemba, Wuyep, Adebayo &Jahknwa, 2013).The local government has a mean annual temperature ranging from $14^{o}C$ – $27^{o}C$ and annual rainfall ranges from 1000mm - 1650mm (NRCRI, 2014).

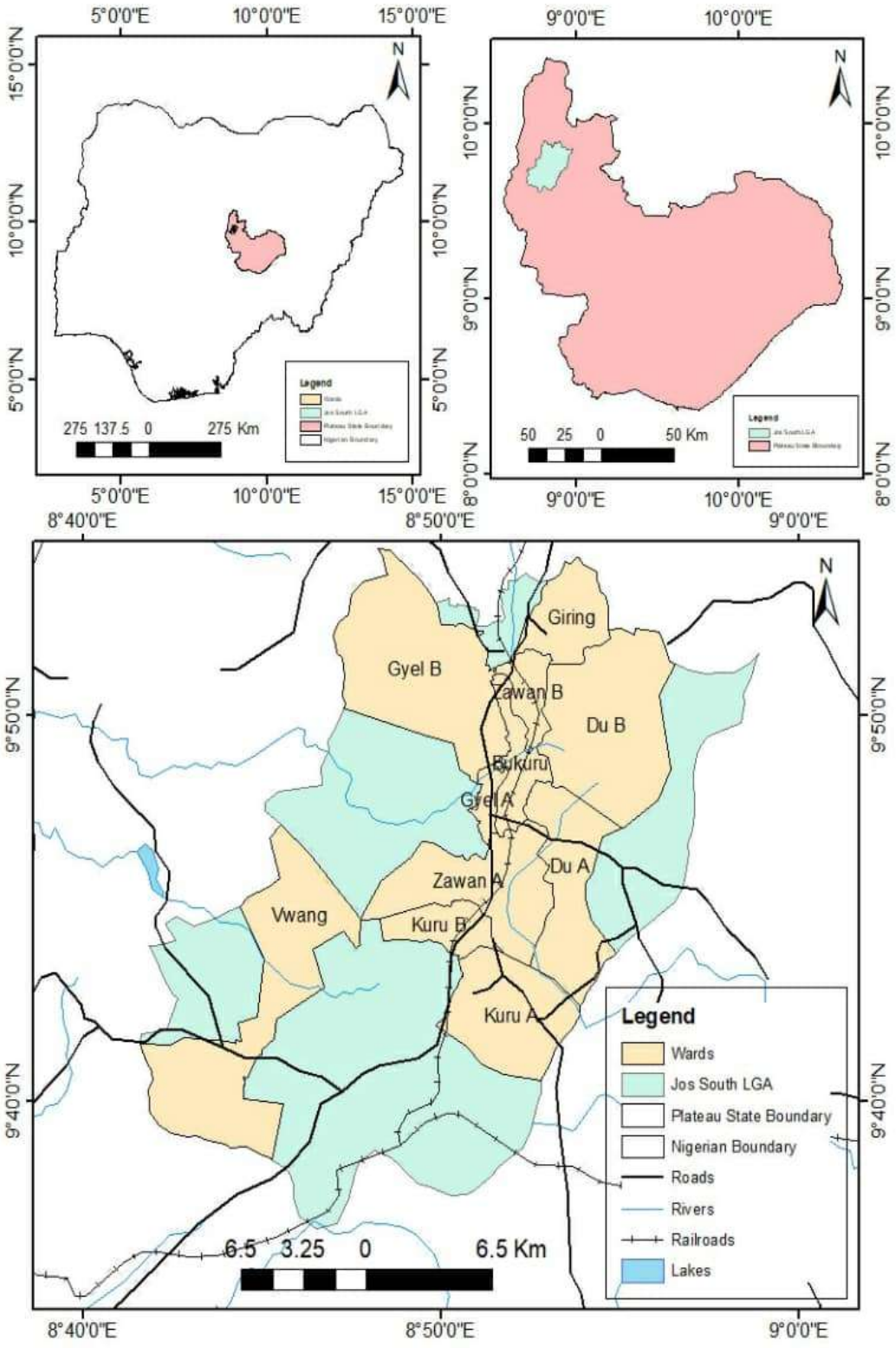

Fig 1: Jos South Local Government Area, Districts showing wards
Source: Unijos, GIS Lab

Data Collection

The data used for this study was purely secondary data that was collected from the National Roots Crop Research Institute (NRCRI), Vom, Jos South Local Government, Plateau State.The data collected was on monthly and annual basis according to the meteorological station and spans for 40years from 1979-2018.Crop (Irish Potato) yield data was collected from the same institute. The crop yield data spanned for 10 years (2005-2014) for the purpose of analysis.

Data Analysis

The rainfall data collected was subjected to descriptive statistics of mean and standard deviation. The mean monthly and annual rainfall is the summation of all rainfall values occurring within the study period, divided by the number of years or months as the case maybe. This is expressed as:

$$x = \frac{\sum X}{N} \quad (1)$$

The standard deviation measures the dispersion about the mean of the variable; it is simply the square root of the variance. It is expressed as

$$\sigma = \frac{\sqrt{\sum(x-x)2}}{N} \quad (2)$$

Rainfall Anomaly index (RAI) measures the variability in monthly and annual rainfall amount. This is expressed as:

$$RAI = \frac{\sum(X-\overline{X})}{S} \quad (3)$$

The annual rainfall amount was plotted against each year. To further examine the nature of the trends in the rainfall series, linear trend lines was auto fitted using Microsoft Excel statistical tool to take care of the extreme values and comparison was made with the long term mean totals.The major rainfall characteristics considered for this study are; Annual rainfall amount, Onset, Cessation of rainfall and hydrological growing season.

Rainfall Onset and Cessation

Onset is also known as the start of the growing season. It refers to the time a place receive an accumulated amount of rainfall sufficient for growing of crops. It is not the first day the rain falls. On the other hand, cessation means the termination of the effective rainy season. It does not imply the last day rain falls but when rains can no more be assured (Binbol and Zemba, 2007). Its calculation is done in reverse order of onset i.e. rainfall values are accumulated from December backwards and the same formula applied. Walter (1967) computed the onset dates of rains as follows:

$$\text{Date of Onset/Cessation} = DM \times \frac{51 - A}{TM} \quad (4)$$

Where;
DM = the number of days in the month containing the date of Onset/End;
A = the accumulated total rainfall of the previous months;
TM = the total rainfall for the month
51 mm = the threshold of rainfall for both Onset/End month (Where the month under reference is that in which the accumulated total of rainfall is in excess of 51mm). This method was adopted for this research because of accuracy and easy computation.
To determine length of rainy season i.e. the difference between the cessation date and onset date. Duration of the rainy season was derived by counting the number of rain days between the onset-date and the end-date of the rains in a given year.
The Pearson product moment correlation method was used to establish the relationship between hydrological growing season and selected crop. Similarly, relationship between hydrological growing and annual rainfall was also established with interval of 10years (decade) as well as the relationship between annual rainfall and crop yield for 10 years.

III. Results And Discussion

Annual Rainfall Variability in Jos South LGA

Standardized rainfall anomaly index (RAI) shows the result of rainfall variability from 1979-2018 in Table 1. Findings from table 1 revealed that annual rainfall variability fluctuates from year to year. This fluctuation shows significant levels of variation. Annual rainfall variability in Jos South ranges from +2.03 in 2017 to -1.73 in 2005 as shown in table 1. Thus, variability maybe due to internal or external variables that affect climate as explained by Odjugo (2010). Similarly, the annual rainfall ranges from 1017.9mm in 1995 which is the year with the lowest total amount of annual rainfall to 1634.4mm in 2017 the climax year with total amount of annual rainfall in Jos South Local Government Area within the period of study (from 1979-2018) as seen in table 1. The mean annual rainfall in the study area is 1235.8 mm with standard deviation of 145.6mm as shown in table 1. This supported the findings of Tiamiyu et al. (2015) that rainfall average is between 1020-1485mm in guinea savanna where Jos South Local Government Area is also found.

The extent of fluctuation determines the rate of excess rainfall or insufficient rainfall which may trigger incidence of drought, soil erosion or flood that may constitute a major threat. Therefore, this research ascertain that the deviation in rainfall over Jos South Local Government Area within the period under study shows some evidence of climate variations and change in the climate of Jos South Local Government Area.

Table 1: Rainfall Characteristics for Jos South LGA from 1979-2018

YEAR	AMOUNT	HGS	RAI	YIELD	ONSET DATES	ONSET DAYS	CESSATION DATES	CESSATION DAYS
1979	1169.9	166	-1.16	0	03-May	123	16-Oct	76
1980	1350.5	152	0.08	0	05-May	125	04-Oct	88
1981	1213.25	166	-0.86	0	15-Apr	105	28-Sep	94
1982	1312.1	175	-0.18	0	12-Apr	102	04-Oct	88
1983	1163.6	129	-1.2	0	06-May	126	12-Sep	110
1984	1193.4	190	-1	0	29-Mar	88	05-Oct	87
1985	1350.5	133	0.08	0	10-May	130	20-Sep	102
1986	1324.2	153	-0.1	0	21-Apr	111	21-Sep	101
1987	1264.4	137	-0.51	0	31-May	151	14-Oct	78
1988	1137.6	175	-1.38	0	04-Apr	94	26-Sep	96
1989	1404.6	174	0.45	0	08-Apr	98	29-Sep	93
1990	1394.1	152	0.38	0	30-Apr	120	28-Sep	94
1991	1378.8	173	0.62	0	07-Apr	97	27-Sep	95
1992	1346.8	167	0.06	0	15-Apr	105	29-Sep	93
1993	1358.5	157	0.14	0	22-Apr	112	26-Sep	96
1994	1387.4	174	0.34	0	11-Apr	101	02-Oct	90
1995	1017.9	163	-2.2	0	15-Apr	105	25-Sep	97
1996	1530.7	182	1.32	0	03-Apr	93	02-Oct	90
1997	1336.4	184	-0.02	0	25-Mar	84	25-Sep	97
1998	1376.6	162	0.26	0	25-Apr	115	04-Oct	88
1999	1325.5	184	-0.09	0	17-Apr	107	18-Oct	74
2000	1611.5	156	1.88	0	24-Apr	114	27-Sep	95
2001	1171.8	153	-1.15	0	22-Apr	112	22-Sep	100
2002	1418.6	217	0.92	0	11-Apr	101	14-Oct	78
2003	1231.4	157	-0.74	0	23-Apr	103	27-Sep	95
2004	1408.4	171	0.48	0	06-Apr	96	24-Sep	98
2005	1086.9	157	-1.73	15.32	02-May	122	06-Oct	86
2006	1143.3	132	-1.34	40.4	19-May	139	28-Sep	94
2007	1187.6	163	-1.04	22.8	06-Apr	96	16-Sep	106
2008	1293.4	159	-0.31	70.4	03-May	123	09-Oct	83
2009	1376.3	199	0.26	41.1	09-Apr	99	25-Oct	67
2010	1342.55	193	0.03	30.5	04-Apr	94	14-Oct	78
2011	1253.75	140	-0.58	57.2	11-May	131	28-Sep	94
2012	1436.1	190	0.67	30.7	16-Apr	106	23-Oct	99
2013	1580.3	186	1.66	101.4	11-Apr	101	14-Oct	78
2014	1585.5	184	1.7	47.15	09-Apr	99	10-Oct	82
2015	1468.9	152	0.9	0	06-May	126	05-Oct	87
2016	1442.2	190	0.71	0	16-Apr	106	23-Oct	99
2017	1634.4	188	2.03	0	18-Apr	108	23-Oct	99
2018	1427.45	165	0.61	0	03-May	123	15-Oct	77

MEAN	1235	168	170.3	110	91
SD	145.6	20		15	10

Source: Author's Computation (2020)

Annual Rainfall Trends in Jos South LGA

The trend analysis of annual rainfall in Jos South Local Government Area was determined by using trend analysis and trend line was auto fitted to smoothen the extremes 'variability' as well as to beget linear equation. Fig 2 indicates that annual rainfall amount has fluctuates from 1979-2018 in the study area. Peaks were noticed in the year 2000 and 2017 while dips were observed in 1995 and 2005. The peaks in 2000 and 2017 maybe as a result of favourable rainfall during the rainy season in that year as shown in Fig 2. The dips in 1995 and 2005 maybe accounted for as a result of unfavourable rainfall during the rainy season in the same period as seen in Fig 2.

The trend line equation for annual rainfall in Jos South Local Government Area as shown in Fig. 2, it is obvious that annual rainfall is characterized by marked 'seasonality' (variability) from year to year. Fig 2 vividly indicates an increasing trend line in annual rainfall. The best fit line equation is positive ($y = 5.010x + 1235.8$). This implies that rainfall amount increase progressively by 5.01mm in recent times in Jos South Local Government Area. This increase may be as a result of climate variability and change. This corroborated the findings of Labiru et al. (2020) in similar study conducted on the Jos Plateau, Plateau State. Nigeria.

From the findings shown in Fig 2, $R^2 = 0.162$ which is the coefficient of determination, shows the contribution of the variable (rainfall) to Jos South Local Government Area. This means that Jos South Local Government Area has been recording 16% increase in annual rainfall from 1979-2018. This is against the findings of Abaje et al. (2010) where he noted decline in annual rainfall was predominant in North Central Nigeria.

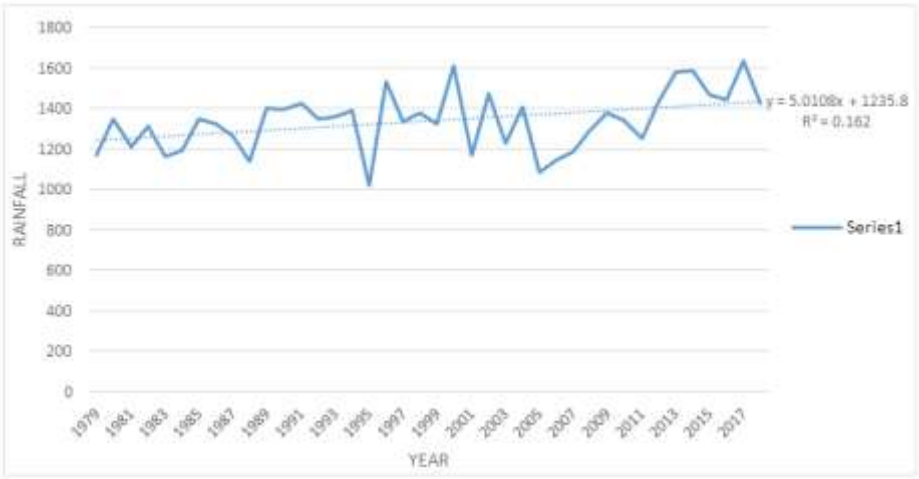

Fig. 2: Annual Rainfall trend from 1979 – 2018

Rainfall Onset

Onset date of rain refers to the time a place receives an accumulated amount of rainfall sufficient for growing of crops. It doesn't actually refer to the first day rain fell. Result in table 1 shows that over a period of 40 years (1979-2018) the average onset date of rain in Jos South Local Government Area is 110 days (20th April) with deviation of 15 days. The year with early start of effective rainfall is 1997 with 84 days (25th March) and 1987 had delay in onset with 151 days (31st May).

Fig 3 shows the onset dates of the rainy season in Jos South Local Government Area. From Fig 3, it is obvious that the start of effective rainfall is predominant in April in Jos South Local Government Area. This agrees with the findings of Okorie (2015) and Audu (2012) in a similar study conducted in Lokoja, North Central part of Nigeria. In the same vein, the onset is characterized by more marked irregularity 'variations' from year to year in Jos South Local Government Area. Variations in onset dates lead to peaks and dips being noticed in Jos South Local Government Area over the period of study (1979-2018). Dominant peaks were in 1987 and 2006 while prominent dips were seen in 1984 and 1997 as shown in Fig 3. The shifts and variability in rainfall onsets over Jos South Local Government Area within the period under study show some evidence of climate variations and change in the climate of the area.

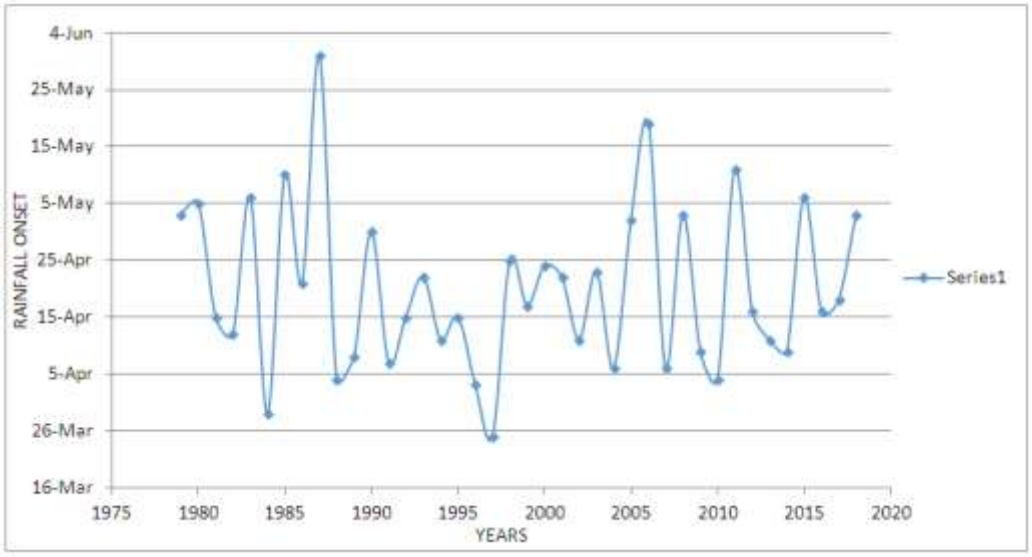

Fig. 3: Trend in Rainfall Onset dates in Jos South LGA (1979-2018)

Rainfall Cessation

Cessation means the termination of effective rainy season. It is not however, the last day rain fell, but when rainfall can no longer be assured. The result in table 1 shows variability in rainfall cessation dates. From table 1, in 2009 there was a late delay in termination of effective rainfall with 67 days (25th October) while early rainfall cessation was noticed in 1983 with 110 days (12th September) as shown in table 1. The mean rainfall cessation date in Jos South Local Government Area over 40 years (1979-2018) is 91 days (1st October) with deviation of 10 days. Rainfall cessation determines the success or failure of crops.

Trend in cessation dates of rainy season during the study period in Jos South Local Government Area is presented in Fig 4. Fig 4 indicates that the cessation date of rains in Jos South Local Government Area is predominant in October. Peaks were noticed in the year 2009 and 2012 while dips were observed in 1983 and 2007. The peaks in 2009 and 2012 maybe as a result of prolong rainfall during the rainy season in that year as shown in Fig 4. The dips in 1983 and 2007 maybe accounted for as a result of short period of rainfall during the rainy season in the same period as seen in Fig 4. From Fig 4 it is evident that rainfall cessation fluctuates from year to year in Jos South Local Government Area. These fluctuations in rainfall cessation may be as a result of climate variations and change in Jos South Local Government Area.

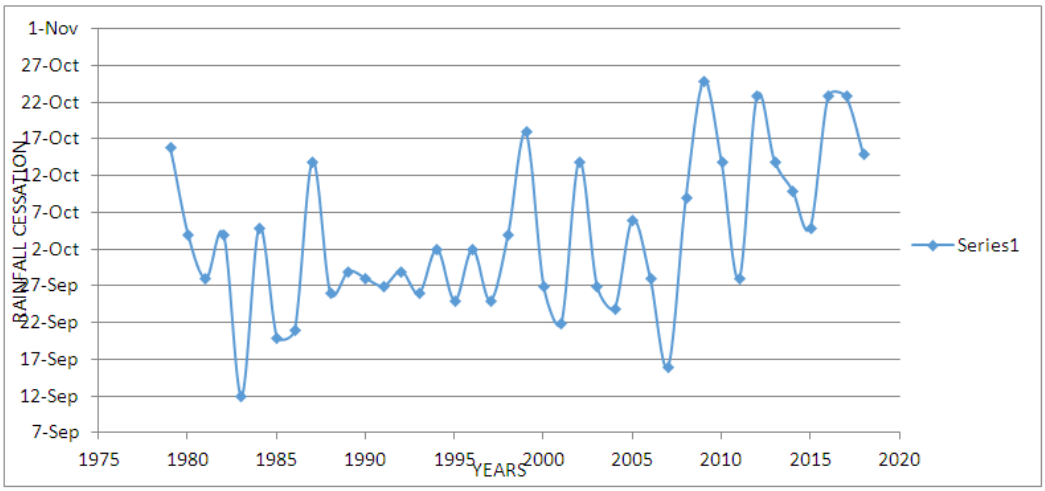

Fig. 4: Trends in Rainfall Cessation dates in Jos South LGA (1979-2018)

Hydrological Growing Season (HGS)

Hydrological Growing Season (HGS) is the period between the onset date of the rains and the end of the rainy season. HGS was derived by counting the number of rain days between the onset-date and the end-date of the rains in a given year for a period of 40 years under study (1979-2018). Findings of HGS result as presented in table 1 shows that average HGS in Jos South Local Government Area is 168 days with deviation of

± 20days. This corroborated the findings of Binbol and Zemba (2007) but against the findings of NIMET (2008) and Sawa et al (2014). The shortest period recorded was 129 days in 1983 while the longest period is 217 in 2002. The pattern of HGS in Jos South Local Government Area is shown in Fig 5. Fig 5 shows the degree of fluctuations experienced in HGS of Jos South Local Government Area. HGS is characterized with marked variability which may be accounted for with changes in onset and cessation which could be as a result of climate variation and change.

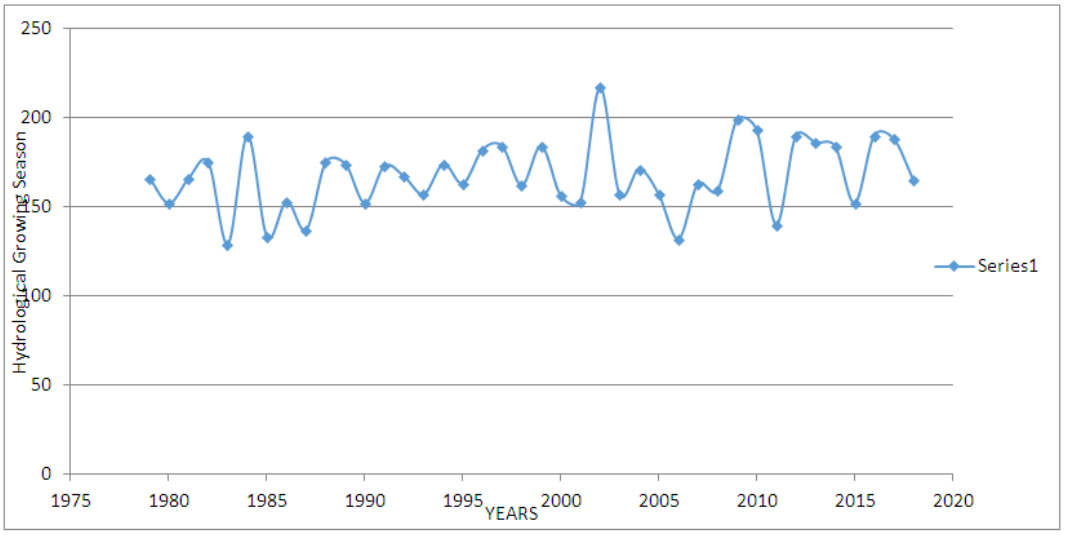

Fig. 5: Trends in HGS in Jos South LGA (1979-2018)

Relationship between HGS and yield of Irish potato in Jos South Local Government Area.

Table 2 shows the annual yield of potato in Jos South for a period of ten (10) years from 2005-2014. The highest yield was recorded in 2013 with amount reaching 101.4 ton/ha and the lowest yield of 15.32 ton/ha was recorded in 2005. The variations in potato yield maybe attributed to other unexplained factors such as soil characteristics, farming methods, planting dates, weeds control, fertilizer application, seed varieties, pest and diseases, harvesting and other rainfall characteristics and climatic factors.

Table 2: Annual Rainfall, HGS and Potato Yield In Jos South LGA(2005-2014)

YEAR	ANNUAL RAINFALL	HGS	POTATO YIELD (ton/hec)
2005	1086.9	157	15.32
2006	1143.3	132	40.4
2007	1187.6	163	22.8
2008	1293.4	159	70.4
2009	1376.3	199	41.1
2010	1342.55	193	30.5
2011	1253.75	140	57.2
2012	1436.1	190	30.7
2013	1580.3	186	101.4
2014	1585.5	184	47.15
Mean	1328.57	170	45.7

Source: Author's Computation (2020)

Table 3: Relationship between HGS and Yields of Irish Potato in Jos South LGA

r	r^2	df	Tcal	Ttab	Remarks
0.05	0.0025	10	0.142	2.228	Significant at 0.10

**. Correlation is significant at the 0.05 level (2-tailed).

From table 3, the calculated t-value gave 0.142 and the critical value is given as 2.306, under 95% confidence levels. Since the calculated t-value is less than the critical value (0.142 < 2.228), this implies that

there is no significant relationship that exist between HGS and yield of potato in Jos South Local Government Area. Similarly, with a correlation coefficient of 0.05, it shows that there is a positive but very weak relationship between HGS and potato yield in the study area. The coefficient of determination (r^2) shows that HGS does not contribute anything to the final yield of potato in Jos South. This can be attributed to the fact that Irish potato is planted in April/May in the study area and harvested in July ending, an average of 92 days.

Analysis of HGS for the period of potato yield record as presented in table 1 shows that all the 10 years chosen have HGS ranging from 132 (2006) to 199 (2009). This is far longer than the period of potato cultivation; therefore HGS plays an insignificant role in the final yield of Irish potato in Jos south Local Government Area.

Relationship Between Annual Rainfall and yield of Irish potato in Jos South Local Government Area.

Annual rainfall data and potato yield from 2005-2014 is presented in table 4. The mean annual rainfall for this period is 1328.57.

Table 4: Relationship between Annual Rainfall and Yields of Irish Potato in Jos South LGA

r	r^2	Df	Tcal	Ttab	Remarks
0.568	0.322624	10	2.371	2.228	Significant at 0.05

**. Correlation is significant at the 0.05 level (2-tailed).

The extent to which the annual rainfall determines the yield of potato in Jos South Local Government Area is shown in Table 4. From table 4, the calculated t-value gave 2.371 and the critical value is given as 2.228, under 95% confidence levels. Since the calculated t-value is greater than the critical value (2.371 > 2.228), this study therefore, ascertain that there is a significant relationship that exist between annual rainfall amount and yield of potato in Jos South Local Government Area, Plateau State. This shows that annual rainfall influences the quality of Irish Potato farming as stated by Niggol and Mendelsohn (2008) that climate can affect the quantity and quality of crops. Thus, the length of rainy season and rainfall spread over a year determines the success or failure of crop.

Furthermore, the r value indicates a strong relationship between annual rainfall and potato yield thereby supporting the t-test at 95% confidence level. This confirms the findings by (Adamgbe and Ujoh, 2013) where they discovered that annual amount had great effect on crop yield in a study conducted in Benue state, Nigeria.

Similarly, the (R-square) value shows that annual rainfall has a strong impact on Irish potato in Jos South Local Government Area of Plateau State. The result gave a correlation coefficient (r) of 0.568. The correlation of determination gave 0.3226. This means that 32% of the variations in the yield of potato per hectare for the past 10 years in Jos South Local Government Area can be explained jointly by the variations in the rainfall characteristics. The remaining 68% of the variations in the yield of potato can be attributed to other unexplained factors such as soil characteristics, farming methods, planting dates, weeds, fertilizer application, seed varieties, pest and diseases, harvesting and other rainfall characteristics/climatic factors not directly considered in this study.

Relationship Between HGS and Annual Rainfall in Jos South LGA

Table 5 shows the correlation coefficient (r) on whether there is a significant relationship between HGS and annual rainfall in Jos South Local Government Area of Plateau State. The calculated correlation (r) value gave 0.417. The calculated correlation value shows a weak positive correlation though the correlation seems weak but significant for crop growth. The tabulated value at 95% confidence level is 2.021 and T calculated is 3.118. The calculated (t) 3.118 was found to be greater than the tabulated value at 95% confidence level thus implying there is a relationship that exists between HGS and annual rainfall in Jos South Local Government Area.

Table 5: Relationship between HGS and Annual Rainfall in Jos South LGA

r	r^2	df	Tcal	Ttab	Remarks
0.417	0.1739	10	0.142	2.228	Significant at 0.05

**. Correlation is significant at the 0.05 level (2-tailed).

More so, the r^2 value (17.4%) as shown in table 5 shows that the impact of annual rainfall on HGS is quite poor. However, it is significant for HGS in Jos South Local Government Area. This impact could be accounted for by climate variations and change in Jos South Local Government Area of Plateau State, Nigeria

IV. Conclusion

The research has established that there is high variability in rainfall characteristics i.e. onset, cessation and hydrological growing season. All statistical analysisof rainfall characteristics revealed a high degree of variability in line with the rainfall pattern. This variability determines the success or failure of crops. The timing

of the rainfall characteristics is very paramount because planting season, types of crops which can be grown is influenced by the seasonal distribution and amount of rainfall. Therefore, this research ascertains that climate change is an existential threat to farmers and humans generally, which requires urgent attention from all stakeholders.

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