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Analysis of Rainfall Trend and Its Relationship with Sorghum Yield in Sudan Savanna Region of Nigeria

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ABSTRACT: *This study analyzed rainfall trend and its relationship with sorghum yield in Sudan Savanna region of Nigeria by examining the trends of rainfall, crop yield and relate annual rainfall trend with length of the growing season. Rainfall data for 62 years (1956-2018) were obtained and subjected to statistical analysis. Pearson's correlation was employed to test the relationship between rainfall and sorghum yield in the study area. The result shows increase in annual rainfall in Bauchi, Gusau, Kano, and Yola polygons while there was a decrease in annual rainfall in Katsina, Potiskum and Sokoto polygons. In terms of trend, there was a relatively earlier rainfall onset dates in all the Thiessen polygons with exception of Bauchi and Yola area where rainfall onset date changes insignificantly toward early pattern. There was also a decline in rainfall cessation in Bauchi, Gusau, Kano, Katsina and Sokoto Thiessen polygons within the study period. The Pearson's correlation indicates a significant relationship between annual rainfall and sorghum yield in the study area with an average P-value of 0.71 which indicates a strong and positive relationship. The study therefore recommends sensitization of sorghum farmers on the relationship between sorghum and rainfall and the need to adopt variety of sorghum that can endure drought as a way of reducing the possible crop loss due to rainfall variability since rainfall show high variability.*

Key words: Sudan savanna, rainfall, trend, sorghum, yield

INTRODUCTION

Rainfall is one of the most important natural factors that determines the agricultural production especially in the northern part of Nigeria (Odjugo, 2012). The variability of rainfall and the pattern of extreme high or low precipitation are very important for agriculture as well as the economy of the country. It is well established by Oladipo (2008) that rainfall is changing on both the global and the regional scales due to global warming. As the move to encourage agriculture to ensure food security continues to gain ground and acceptability, information on rainfall pattern and trend is inevitable for the design of water supply, irrigation schemes and the evaluation of alternative cropping and of soil water management plans (Ouedraogo, Some & Dembele, 2006).

Majority of the population in the Sudan Savannah region of Nigeria live on marginal lands in rural areas practicing rain-fed agriculture. Any negative change in rainfall amount threatens agricultural production on these marginal lands, exacerbating poverty and undermining economic development. The impact of rainfall variability in both economic and mortality terms is generally larger for relatively simple and predominantly agricultural economies. The poor crop yields or total crop failure due to drought results in mass poverty and starvation as agriculture is the mainstay of Nigeria's rural economy (Nwafor, 2007). The poor households that are affected by drought and desertification do not have adequate resources to deal with food shortages leading to food insecurity and hunger that affects millions of people (Adefolalu, 2007).

Agriculture is one of the main economic activities in Nigeria (which account for around 40 percent of the country's GDP and employs about 60 percent of the active labour force), thus rainfall anomaly would lead to a catastrophe with unprecedented repercussions (Ariyo, 2002). The most severe consequence of rainfall variability is drought which culminates to famine. This problem of rainfall variability in Sudano-agro-ecological zone has attracted many research interests to investigate either the level of change in climate or its concormitant effects on agriculture and other sources of livelihood especially in northern Nigeria. Sorghum is one of the major staple crops grown in the study area, and is sensitive to rainfall excess or deficit (Ati et al, 2002; Sawa, 2010). A study of this nature needs continuous and serious attention due to the importance of crop production in this area, the proportion of the population that engage in farming and the climate change reality on agriculture (Oladipo, 2008). This study therefore, sought to examine the relationship between rainfall and the yield of sorghum in the study area. Objectives for the study are to; analyze annual rainfall trend, rainfall onset, cessation and length of the growing season and their relationship with Sorghum Yield.

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THE STUDY AREA

The Sudan Savannah region is located in northern Nigeria, approximately between Latitudes 10°N to14°N and Longitudes 4°E to 15°E (see Figure 1). The Sudan Savannah accounts for more than 25% (230,942 km^2) of the entire land area of Nigeria (FGN, 2000). The climate of this ecological region is the tropical wet and dry type, classified by Koppen as Aw.

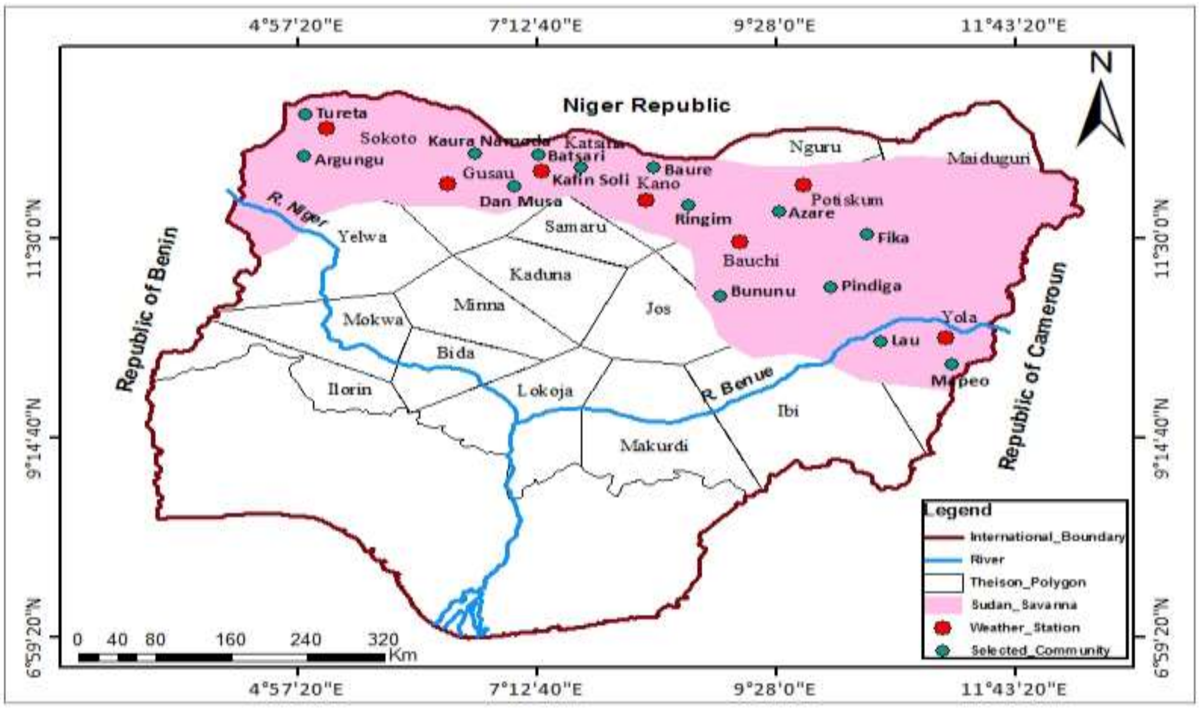

Figure 1: Study Area Map
Source: Adopted and Modified from the Administrative Map of Nigeria (2018)

METHODOLOGY

The average annual rainfall is between 500 mm in the northern part to 1000 mm in the southern part of the ecological zone (Oladipo, 1993). The seasonality of the rainfall is highly influenced by the interaction of two air masses: the relatively warm and moist tropical maritime (mT) air mass, which originates from the Atlantic Ocean; and the relatively cool, dry and stable tropical continental (cT) air mass that originates from the Sahara Desert and is associated with the dry, cool and dusty North-East winds known as the Harmattan (Ayoade, 2004). The boundary or the meeting point of these two influential air masses has been named differently by tropical climatologist: Inter-tropical Front (ITF), Inter-tropical Confluence (ITC), Equatorial Front (ET) and Inter-tropical Discontinuity (ITD) and Intertropical Convergernce Zone (ITCZ) (Ayoade, 2004). The vegetation of this area is that of Sudan savannah as the name implies, with short grasses and shrubs dominating. The seasonal character of rainfall in this area has influenced the vegetation which turns evergreen during the wet season and pale brown in the dry season respectively. This vegetation belt is found in the north-west stretching from the Sokoto plains in the west, through the northern sections of the central highland (Oguntoyinbo, 1983)

Rainfall data and geographical location of the meteorological stations were acquired from the archive of the Nigerian Meteorological Agency (NIMET), Oshodi-Lagos. Information on the Thiessen polygons of meteorological stations in the study area was obtained from Agro-climatological Atlas of the northern States of Nigeria by Kowal and Knabe (1972). The selected Meteorological stations are presented in Table 1.

Table 1: Selected Meteorological Stations in the Sudan Savannah and their Locations

Station	Station WOM Index No.	Latitude	Longitude	Altitude
Bauchi	650550	10°17’N	09°49’E	609.7m
Gusau	650150	12°10’N	06°42’E	468.00m
Kano	650460	12°03’N	08°32’E	475.80m
Katsina	650460	13°01’N	07°41’E	516.63m
Potiskum	650730	11°43’N	11°07’E	487.68m
Sokoto	650100	12°55’N	05°12’E	309.00m
Yola	651670	09°14’N	12°28’E	214.00m

Source, NIMET, 2007

To compute the Total Annual Rainfall (TAR) for each station, rainfall amount received from January to December of each station were sum up for every year. Rainfall onset date was calculated using the formula below:

$$\text{Rainfall onset} = \text{No of days in the month} \times \frac{51 - \text{Accumulated rainfall of the previous months}}{\text{Total rainfall for the month}}$$

The computation of the cessation date is done in the same way as the onset except that the computation is done backward from December following Walter’s (1967) method, it is:

$$= \frac{51\text{- rainfall total of the previous month}}{\text{Total rainfall of the first month with greater that 51mm.}}$$

The length of the Growing Season (LGS) is the difference between the cessation date of rains and the onset date. The LGS can be computed or obtained by subtracting the onset date from the cessation date (Adefolalu, 1986). The Julian calendar dates were used to determine the onset and cessation.

Trend charts were employed to examine the annual rainfall trend, rainfall onset and cessation trend and the trend of Length of the Growing Season (LGS). Sorghum yield of the study area were sourced from states agriculture and rural development authority, agricultural development projects and national bureau of statistics. The sorghum yield was subjected to simple Correlation using the statistical package for social science (SPSS) at 0.05 significance level to ascertain its relationship with TAR, onset and cessation dates and LGS.

RESULTS AND DISCUSSIONS

Rainfall Trend in the Sudan Savanna Region of Nigeria

The rainfall trends from 1956-2018 computed for the selected Meteorological stations in the Sudan savanna region of Nigeria are presented in Figure 2. The trends revealed a general decreasing pattern of rainfall from 1956-1974 in Bauchi, Gusau, Katsina, Potiskum, and Sokoto polygons. Kano and Yola polygons exhibited an irregular pattern characterized by fluctuations within this same period. From the trends, it is observed that Bauchi, Gusau, Kano, Katsina, Potiskum, Sokoto and Yola areas experienced the least TAR in 1972, 1988, 1974, 1998, 1994, 1984 and 1970 respectively. Within these periods, there was no location that experienced a TAR that exceeded 400mm. This result is in agreement with Ogungberon and Morakinyo (2014) which reported low rainfall amount in the Sudan savanna ecological zone during these years. The result disagrees with the findings of Ikpe (2021) which reported an increasing TAR in Sokoto State between 1970 – 2018.

As indicated in Figure 2 There was an increase in rainfall in Bauchi, Gusau, Kano, Katsina and Sokoto from 1975-1980. These same areas experienced a general decline in rainfall from 1981-1986. However, the Bauchi station has not experienced an annual rainfall that dropped below 800 mm from 1976 -2015. The wettest years at Gusau were 1983, 2004 and 2010. These are years that the TAR was 1000 mm and above. Similarly, 1963, 1981, 2000, 2006 were the wettest years at Kano. These were years that rainfall was 1000 mm and above. The wettest years at Katsina area were 1967 and 1981, when TAR was 1000 mm. The wettest years in Potiskum area were 1962, 1964 1990 and 2014; with annual rainfall reaching 1000 mm or more. Sokoto area is the driest area in the ecological zone. The station has only one year with annual rainfall that exceeded 900 mm.

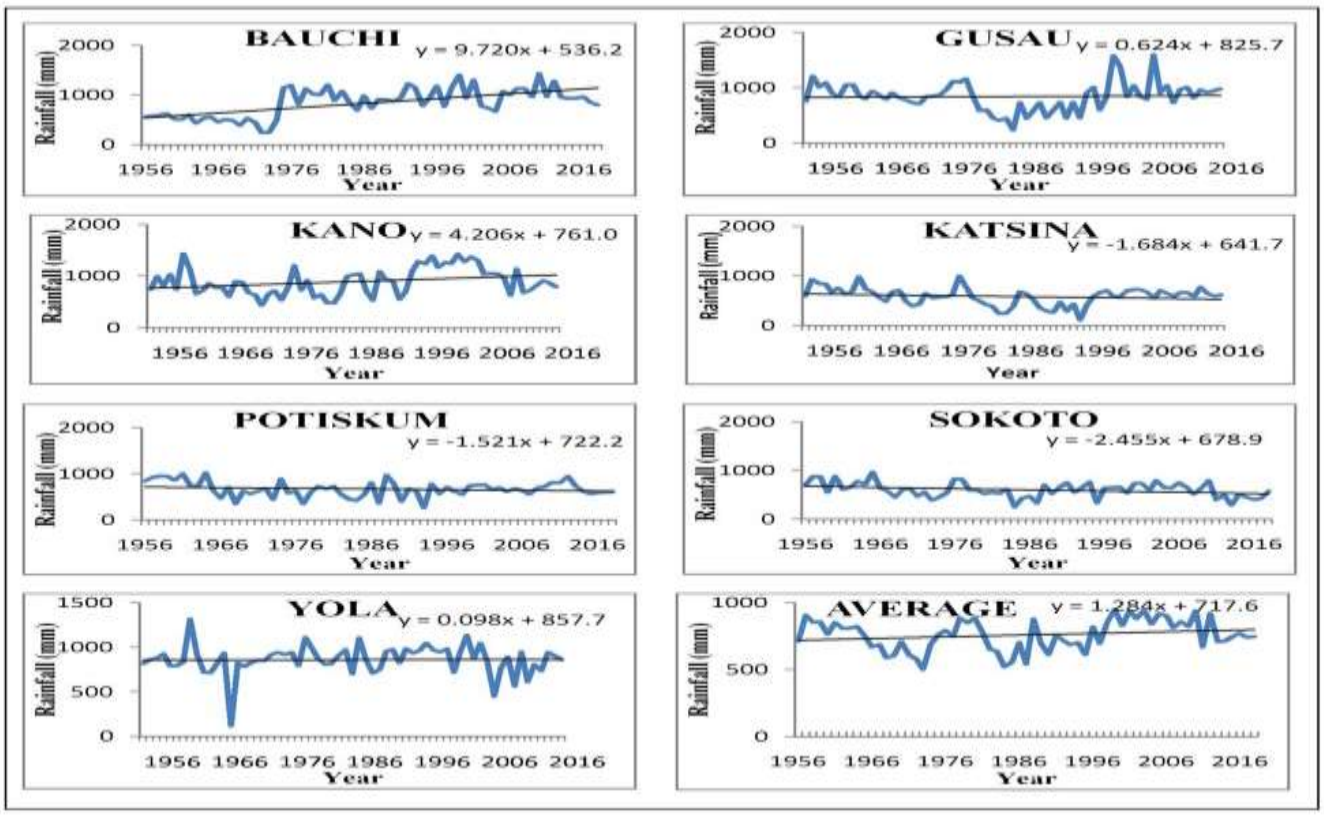

Figure 2: Rainfall Trends in Sudan Savanna Region of Nigeria

This result confirmed the study of Umar (2012) on climate change evidence from meteorological parameters; which suggested a high degree of rainfall dynamism in Northern Nigeria.

It should be noted however that 1970s and 1990s were periods of the great Sudano-Sahelian droughts as documented in the literature (Winstanley, 1973; Apeldoorn, 1981; Nicholson, 1993). The observed variability in rainfall in this area could be associated with the anomalies in South-North movement of the inter-tropical discontinuity (ITD) and associated surface conditions (Olaniran, 1991).

The lines of best-fit in Figure 2 indicate an increase in annual rainfall in Bauchi, Gusau, Kano, and Yola polygons from 1956-2018. Similarly, the result revealed a decreasing annual rainfall in

Katsina, Potiskum and Sokoto polygons from 1956 - 2018. This result shows that despite the similarity in the ecological location of these polygons, the rainfall trend varies from one location to the other. It is also observed that the Sudan Savanna is getting wetter than what was attainable in the past. This result contradicts the ascertion of Adefolalu (1986) which shows that the Savanna region is getting drier. Similarly, Odjugo (2012), Efe (2012) and Umar (2012) in separate studies recorded rainfall decline in most stations in the Sudan Savanna. The result is in agreement with the ascertions of Omotosho (2007), Sawa (2010) and Ogunbero and Morakinyo (2014) which observed an increase in rainfall in most parts of the savanna.

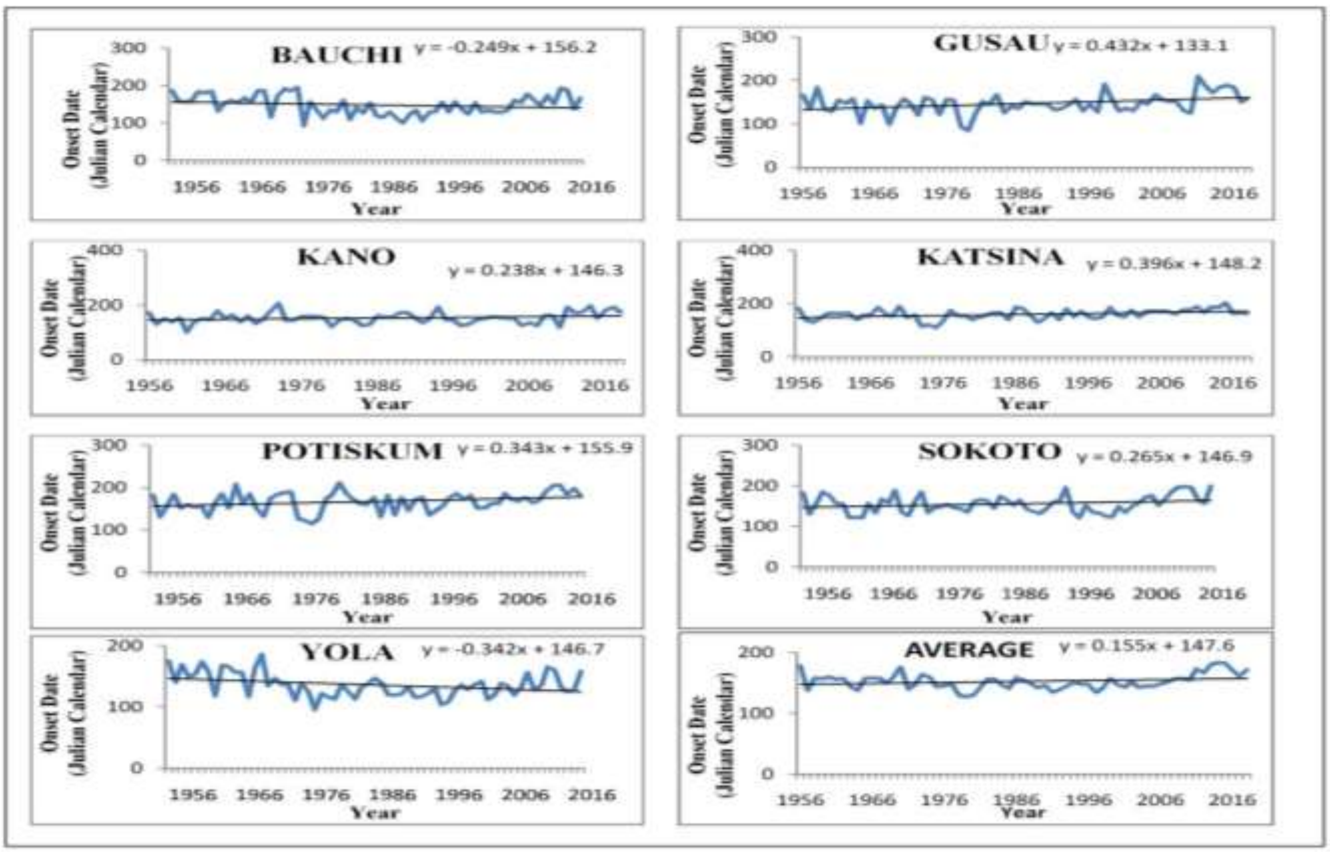

Figure 3: Rainfall Onset trend in Sudan Savanna Region of Nigeria

Figure 3 presents rainfall onset trend in the Sudan savanna region of Nigeria. From the result, it is observed that there is a relative decline in rainfall onset dates in all the polygons with exception of Bauchi and Yola area where rainfall onset date changes insignificantly toward early pattern. However, the trend in Bauchi area exhibits a delay in rainfall onset between 1966 to 1974 and 2006 to 2016. However, earlier rainfall onset in Bauchi area was experienced between 1976 and year 2000. Within these periods rainfall onset was experienced as early as between 9th April and 28 may (100 and 150 day of the Julian calendar).

The rainfall onset dates average in Gusau is 25th of May (146 day of the Julian calendar). However, a later onset dates were experienced between 1996 and 2016, when rainfall onsets were delay up to between 28th June and 18th July. Earlier rainfall onset was experienced between 1978 and 1980 when the onset date of between 5th and 11th April (96 and 102 days of the Julian calendar) was recorded in Gusau area. The results in Kano polygon revealed an average rainfall onset date of 1st June, which is equivalent to 153 days of the Julian calendar. A delay in rainfall onset was recorded in Kano the years: 1968, 1989 and between 1997 and 2018. Within these periods, rainfall onset delayed as late as July 18th (200 day of the Julian calendar). The years: 1957, 1959, 1961, 1970, 1980 and 1985 saw earlier rainfall onset in Kano area. Within these periods rainfall onset of between 11th April and 28th May (102 and 149 days of the Julian calendar) was recorded in this area.

Katsina area has an average rainfall onset date of 9th June which is equivalent to 161 day of Julian calendar. This area experienced relatively later rainfall onset between the years 1986 and 2018 when rainfall onset dates of between 5th and 22nd July (187 and 204 days of the Julian calendar) were recorded. Earlier onset dates of between 11th April and 30th May (102 and 151 days of the Julian calendar) were recorded in the years: 1961, 1974 - 1975, 1980-85 and 1998 - 2010. The average onset date in Potiskum Polygon between the years1956-2018 was 15th June which is equivalent to 167 days of the Julian calendar. This area experienced a delayed rainfall onset in the years; 1956, 1971, 1975, 1997 and 2009-2018. During these periods, there was delay in onset date as late as between 18th June and 24th July. Relatively early rainfall onset was recorded in: 1965, 1975 - 1986 and 1990. These years saw a relatively early rainfall onset of 24th April -13th may (115-135 days of the Julian calendar).

The rainfall onset in Sokoto polygon from the year 1956 to 2018 was averagely around 16th July which is equivalent to 167th day of the Julian calendar. There was delay in rainfall onset in the years: 1956, 1960, 1971, 1975, 1987, 1997 and 2000-2018. During these period rainfall onsets delayed as late as 23rd June and 13th August (150 and 226 days of the Julian calendar). However, a relatively early rainfall onset was experienced in this area in the years: 1965, 1975-1981 and 1990. During these years rainfall onset of between 1st and 28th May (122 and 149 day of the Julian calendar) was recorded in this area. Yola polygon has mean rainfall onset date 136 day of the Julian calendar which is equivalent to 15th May. In other words, this area has relatively earlier rainfall onset compared with other polygons, though late rainfall onset was recorded in the years: 1956 and 1970 when onset dates of 25th June and 4th July (175 and 186 days of the Julian calendar) were recorded respectively. The result confirmed the findings of Saleh (2014) and Emeghara (2015) whom in their separate studies on the relationship between rainfall variability on Millet and Sorghum yield in Sudan savanna ecological zone and effect of precipitation effectiveness indices on the yield of some selected cereal crops in Sokoto. Both studies recorded a delayed rainfall onset trend. The average onset date as indicated in Figure 3 showed delaying trend of rainfall onset in the study area. However, the average trend does not depict the reality of most polygons. Though the outcome shows gradual delaying trend of rainfall onset the ecological zone which translates into either delay in planting of crops or crop loss due to insufficient soil moisture in most of the polygons.

Figure 4 presents rainfall cessation trend in the Sudan Savanna region of Nigeria. As presented in Figure 4, there was a general decline in rainfall cessation in Bauchi, Gusau, Kano, Katsina and Sokoto polygons within the study period. Potiskum and Yola areas had a relative delayed rainfall cessation date. The ecological zone has an average cessation date of 24th September, which is equivalent to 268th day of the Julian calendar. The average cessation date in Bauchi polygon was 15th September which is equivalent to 259th day of the Julian calendar. Early rainfall cessation date was recorded in the year 1996; this was a period when rainfall cessation was experienced on the 21st June. The year1990 recorded latest rainfall cessation in Bauchi area; during this period a cessation date of 23rd October was recorded.

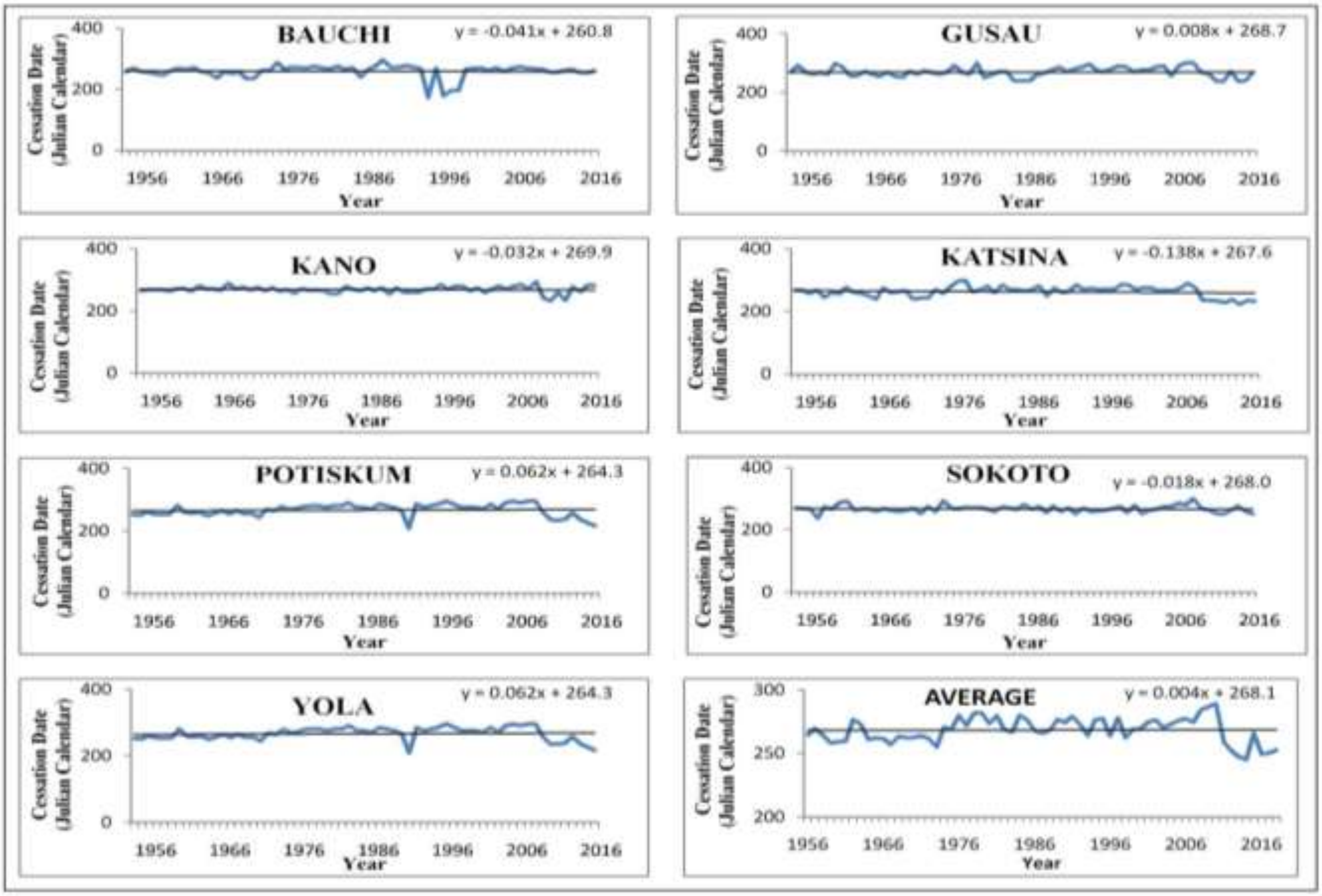

Figure 4: Rainfall Cessation Trend in Sudan Savanna Region of Nigeria

As presented in Figure 4, Gusau polygon has an average rainfall cessation date of 25th September, which is equivalent to 269th day of the Julian calendar. However, a later rainfall cessation date of 26th October (300 day of the Julian calendar) was recorded in the years: 1981, 2008 and 2011; while the years: 2014 and 2016 recorded early rainfall cessation (19th August). The mean rainfall cessation date in Kano area within the study period was 21st September (265 day of the Julian calendar). However, Kano polygon recorded a relatively later rainfall cessation in the years 1997, 2008 and 2010. Within these years, cessation dates of 11th -25th October (285-295 days of Julian calendar) were recorded. The area saw a relatively earlier rainfall cessation 19th-22nd August (232-235 day of Julian calendar) in the years: 2012 and 2014.

Katsina polygon has an average rainfall cessation date of 25th September, which is equivalent to 265 days of the Julian calendar. The area recorded a relatively later rainfall cessation of 25th October in 1979; and a relatively earlier rainfall cessation of 10th -25th August (232-238 days of the Julian calendar) the years: 2011-2018. Potiskum area has an average rainfall cessation date of 22nd September (266 day of Julian calendar) within the study period. However, a relatively later rainfall cessation was recorded between 2006-2010. Within these years a cessation date of 17th - 22nd October (290-295 days of the Julian calendar) was recorded.

The rainfall cessation date in Sokoto area within the study period was 23rd September, which is equivalent to 267 days of the Julian calendar. However, a relatively later rainfall cessation of 19th -26th October was recorded in this area in the years, 1976 and 2010. Earlier rainfall cessation of 8th -9th September was recorded in the years, 2013 and 2018. The result in Yola Polygon was relatively different from other polygons; the average rainfall cessation date in this area during the study period was 9th October which is equal to 283 days of the Julian calendar. In other words, Yola experiences a relatively later rainfall cessation compared to other areas in Sudan Savanna region of Nigeria. A relatively later rainfall cessation of after 26th October (300 day of the Julian calendar) was recorded in the years: 1976, 1978-1979, 1985, 1988, 1990-1992, 1994-1995, 1997 and 2009. However, a relatively earlier cessation of 12th September (255 day of Julian calendar) was recorded in the years: 1961 and 2017-2018. This implies that different area polygons in Sudan Savanna region have different rainfall cessation dates; which call for different agricultural planning regarding to farm preparation, planting and harvesting of the products. The average rainfall cessation in the study area indicates a relative increasing trend in the ecological zone. It is therefore important to educate farmers about the difference, as ignorance could lead to wrong planning that may culminate into crop failure due to early or late rainfall cessation.

Figure 5 presents trends in LGS in the study area. The result indicates a decreasing trend in LGS in Gusau, Kano, Katsina, Potiskum and Sokoto polygons within the study period. Bauchi and Yola Polygon have relatively increased trend in LGS. Bauchi area had a mean LGS of 111 days within the study period. The area recorded a shortest LGS of 39 days in 1999 and a longest LGS of 197 days in 1976. An average LGS in Gusau within the study period was 122 days; and the shortest LGS of 53 days was recorded in 2014, while the longest growing season of 198 days was recorded in 1978. The average for the ecological zone shows a general decrease in length of the growing season. This implies that the wetter Savanna is not as a result of the length of the growing season, but due to the increase in rainfall amount received within a shorter growing season.

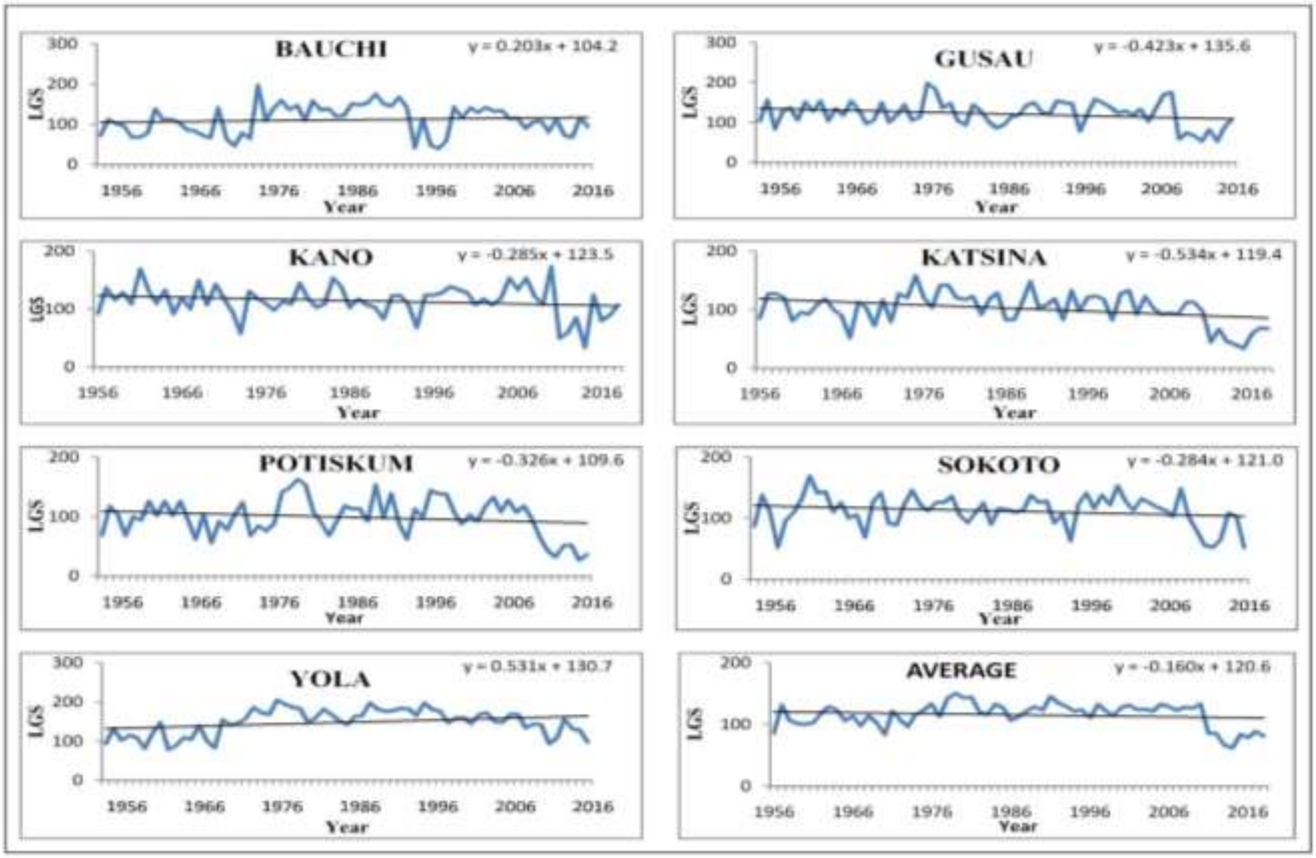

Figure 5: LGS Trend in Sudan Savanna Region of Nigeria

Kano polygon recorded a mean LGS of 114 days with the study period. However, the shortest LGS was recorded in the year 2014 when the growing season lasted for only 34 days; the year 2010 recorded 174 days of the growing season which seems to be the longest from 1956-2018 in the polygon. Katsina station recorded a mean LGS of 102 day and a shortest growing season of 34 days in the year 2014; the longest growing season was experienced in the year 1975 when the growing season lasted for 159 days.

The average length of growing season in Potiskum from 1956-2018 was 99 days and the shortest growing season was experienced in 2017 when the season lasted for only 27 days. The 1981 had the longest growing season in Potiskum area; this was the year the growing season lasted for 163 days. The average LGS in Sokoto station within the study period was 112 days. The shortest growing season in Sokoto was recorded in the year 1959; this was when the season lasted for only 52 days. The year 1963 experienced the longest growing season in Sokoto area; during this year the growing season lasted for169 days. Yola area has an average LGS of 148 days, the shortest growing season in Yola was recorded in 1964, this was when the season lasted for 78 days; while the longest growing season in Yola was 1978 this was the year the season lasted for 205 days.

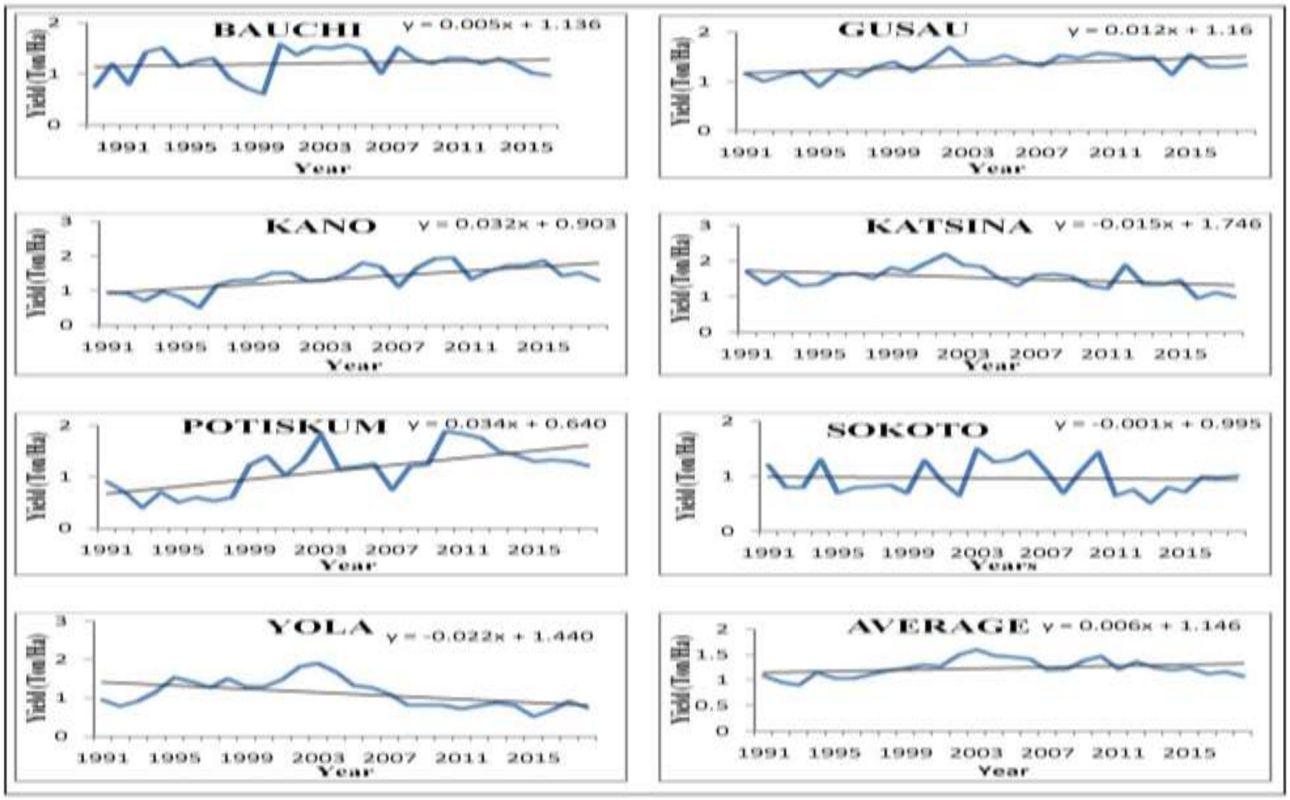

Figure 6: Sorghum Yield Trend in the Sudan Savanna Region of Nigeria

The sorghum yield trend in the Sudan savanna region of Nigeria is shown in Figure 6. From figure 6 it was observed that the trend in sorghum yield in the Sudan region of Nigeria is not stable, but characterized by variability. The line of best-fit revealed a general increasing trend in Bauchi, Gusau, Kano and Potiskum areas and a decreasing trend in Katsina and Sokoto Polygons. The result revealed that Bauchi experienced an increase in sorghum yield in 1990-1993, 1996-1998 and 2002 - 2006; whereas 1994 - 1995, 1999 - 2001 and 2007 - 2015 were years of low sorghum yield in this area. The average sorghum yield in the study area indicates an increase. This result agrees with the findings of Emeghara (2015) which revealed an increase in Maize, Rice and Sorghum yield in Sokoto. The years of increased crop yield are related to years of relatively more rainfall in the study area. This implies that rainfall is one of the major factors of sorghum production in this area.

The result of Gusau is not far from that of Bauchi polygon; the years 1991-2000 and 2014-2015 saw increase in sorghum yield whereby years 2002-2008 and 2015 were years of increase in sorghum yield in Gusau area. In Kano polygon, the result revealed that there was increase in sorghum yield in the years 1996-2003 and 2014; the years 1991-1995, 2004-2012 and 2015 witness a decrease in sorghum yield in this area. Katsina area has relatively general increase in sorghum yield. However, the area experienced a slight decrease in sorghum yield during the years 1997-1998 and 2012. There was a general increase in sorghum yield in Potiskum polygon with relative decrease in the years 1991-1993, 2007 and 2015.

The result at Sokoto presents a cyclical trend with increased sorghum yield in the years 1995, 2000, 2002-2006 but the years 1992, 1994-1999, 2007 and 2011-2015 experienced decrease sorghum yields. Yola polygon experienced a general decreased in sorghum yield with slight increase in the years 1995-2003. Rainfall may not be the only determinant of sorghum yield; however, the sorghum yield trends show a slight resemblance with the rainfall trend in these areas.

Table 2 Correlation Test Results between Rainfall and Sorghum Yield in the Selected Thiessen **Polygon in Sudan Savanna Region of Nigeria**

Theison Polygon	DF	Sig. Level	Critical-r	Observed-r			
				Total AR	Onset	Cessation	LGS
Bauchi	26	0.05	0.396	0.319	0.081	0.784*	0.230
Gusau	26	0.05	0.396	0.768*	0.279	0.470*	0.401*
Kano	26	0.05	0.396	0.666*	0.385	0.509*	0.416*
Katsina	26	0.05	0.396	0.741*	0.421*	0.260	0.398*
Potiskum	26	0.05	0.396	0.600*	0.355	0.398*	0.560*
Sokoto	26	0.05	0.396	0.409*	0.601*	0.208	0.319
Yola	26	0.05	0.396	0.397*	0.24	0.184	0.010
Average	**26**	**0.05**	**0.396**	**0.711***	**0.19**	**0.177**	**0.099**

***. Correlation is significant at the 0.05 level**

The relationship between rainfall trend and sorghum yield is presented in Table 2. As indicated in Table 1 there is a significant relationship between sorghum yield and TAR in all the polygons except Bauchi, there is also an insignificant relationship between rainfall onset and sorghum yield in Bauchi, Gusau and Postikum areas; while Kano, Katsina, Sokoto and Yola seem to have significant relationship between Sorghum yield and rainfall onset. There is a significant relationship between rainfall cessation date and sorghum yield in Bauchi, Gusau and Kano, while the relationship between rainfall cessation date and sorghum yield in Katsina, Sokoto and Yola areas are statistically in significant. There exists a significant relationship between length of the growing season and sorghum yield in Gusau, Kano, Katsina and Potiskum areas; while an insignificant relationship is between sorghum yield and length of the growing season is revealed in Bauchi, Sokoto and Yola Polygons. The correlation between averages indicates a strong relationship between Annual rainfall and sorghum yield and insignificant relationship between sorghum yield and rainfall onset, cessation and length of the growing season. This is an indication that rainfall has a significant effect on sorghum yield and is one of the major determining factors of sorghum production in the ecological zone. In other words, increase in rainfall may lead to increase in sorghum yield and decreased in rainfall may also lead to decrease in sorghum yield.

This result confirmed the result of Abdulhamed et al. (2011) which show a significant relationship between rainfall and sorghum yield in Wailo. Similarly, the result also confirmed the ascertion of Sultan *et al.*, (2005) that rainfall has significant influence on agricultural productivity in West Africa. The result is in disagreement with Emeghrah's (2015) results which revealed a significant relationship between TAR and crop yield but insignificant relationship between crop yield and other precipitation parameters in the study area; this may be due to the nature of data collected.

CONCLUSION

From the results of this study, it can be concluded that there was an increase in annual rainfall in Bauchi, Gusau, Kano, and Yola polygons from 1956-2018; Katsina, Potiskum and Sokoto experienced a decrease. Also, there was a relative decline in rainfall onset dates in all the polygons with exception of Bauchi and Yola area where rainfall onset date changes insignificantly toward early pattern. There was a general decline in rainfall cessation in Bauchi, Gusau, Kano, Katsina and Sokoto polygons within the study period. Potiskum and Yola areas had a relative delayed rainfall cessation date. There was a decreasing trend in LGS in Gusau, Kano, Katsina, Potiskum and Sokoto polygons within the study period. Bauchi and Yola Polygon have relatively increasing trend in LGS. There is a significant relationship between sorghum yield and TAR, rainfall cessation date and LGS in all polygons selected from the ecological zone. Similarly, the result revealed a significant relationship between crop yield and rainfall onset date in all the polygons except Katsina. The study therefore recommends sensitization of sorghum farmers on the relationship between sorghum and rainfall and the need to adopt variety of sorghum that can endure drought as a way of reducing the possible crop loss due to rainfall variability since rainfall show high variability.

RECOMMENDATION

Based on the findings of the study, the following recommendations are made:

Qualitative climatic data should be made available and accessible to sectors that are sensitive to climate such as agriculture and water resources; efforts should be made to provide early warning weather information to farmers; policies should be formulated to ensure unlimited access to seed varieties and credit facilities by farmers. More so, soil moisture conservation, use of high yielding cultivars and fertilizer management will play a major role in improving the productivity of Sorghum in the study area. In addition, land use must continue to be monitored to determine their effects on changes in rainfall amounts and distribution. Establishment of agro-climatological research institutes in the study area for academic research and development planning purposes.

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