Growing Season Rainfall Trends and Drought Intensities in the Sudano-Sahelian Region of Nigeria

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Abstract

The paper examined rainfall trends and drought intensities during the growing season (June-September) in the Sudano-Sahelian region of Nigeria using rainfall data for Sokoto, Katsina, Kano, Potiskum, Nguru, Maiduguri (1951-2010) and Gusau (1953-2010). Linear trend lines and second order polynomial were used to examine the trends of rainfall at the synoptic weather stations. The growing season drought intensities were computed as percentage deviation from the mean rainfall. The results reveal downward trends of growing season rainfall in all the synoptic weather stations investigated in the study with the exception of Kano which showed positive. The drought intensities were mainly slight, moderate and severe and largely depict spatial and temporal variations. In view of the pivotal role of the Sudano-Sahelian region as the main source of the nation's cereal and animal protein, it is recommended that the establishment of irrigation projects should be intensified and agricultural activities in the region should be aligned with prevailing climatic trends in order to realize the country's quest for food security.

Key Words: Rainfall, trends, drought intensities, Sudano-Sahelian

Introduction

The onset and cessation of rainfall dictate the length of the growing season and amount determine the type of crops that are cultivated in different eco-climatic zones of Nigeria. Despite the pivotal role of rainfall to agriculture, studies have revealed declining rainfall trends coupled with increasing temperature trends especially in the savanna belts (Adebayo, 1999; Olaniran, 2002; Odjugo, 2010a; Umar, 2012a; Atedhor and Odjugo, 2012).

According to Farmer and Wigley cited in Illiya and Sakwah (2006), drought is an uninterrupted period (year, rainy season, month or less) of dry weather when rainfall is significantly lower than the average. Drought has also been defined as a climatic anomaly calculated by the deviation of actual rainfall from the amount necessary for normal operation of an established economy of an area (Oladipo, 1991). The reliance of agriculture on rainfall in Nigeria makes it highly susceptible to drought. The availability and distribution of crop-moisture during the growing season is significant to the healthy growth and yield of crops. Therefore, it is the distribution of rainfall during the growing season that is critical to the growth and yield of crops and not unevenly distributed rainfall. However, despite the relevance of the distribution of rainfall during the growing season, previous studies tend to draw inference on agriculture based on rainfall trends and drought intensities on annual bases (Ayoade, 1988; Ati et al., 2010; Umar, 2012b; Atedhor and Odjugo, 2012) while the monthly and the growing season drought indices have received less attention thus making the scheduling of agricultural activities especially planting and irrigation difficult.

It has been asserted that climate change will intensify the occurrence of extreme weather events (IPCC, 2001; O'Hare, 2002; Odjugo and Ikhuoria, 2003). The Sudano-Sahelian region is most

characterized by erratic rainfall in Nigeria. The region also falls within the areas projected to experience intense drought incidence due to climate change (IPCC, 2001).

Agriculture remains the main source of livelihood in the Sudano-Sahelian region of Nigeria. The region is important to the entire country as the key source of cereals and animal protein. Despite the agricultural significance of the Sudano-Sahelian region as a fulcrum to Nigeria's quest for food security, it essentially dependent on rainfall, farm practices remain subsistence and not aligned to changing climatic trends. This paper therefore examines rainfall trends during the growing season and drought intensities on during the growing season in the Sudano-Sahelian region of Nigeria.

The Study Area

The Sudano-Sahelian region of Nigeria (Figure 1) extends from the northern limits of the country to the northern boundary of the Northern Guinea Savanna. It traverses Sokoto, Zamfara, Kano, Katsina, Jigawa, Yobe and Borno States.

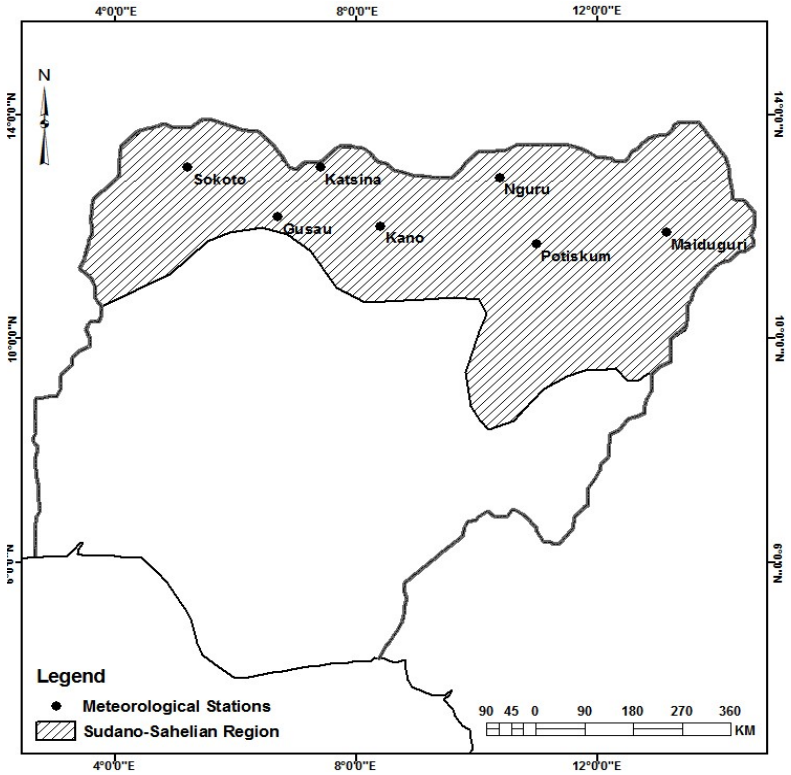

Figure 1: The Sudano-Sahelian Region of Nigeria and the Meteorological Stations for the Study

The Sudano-Sahelian region of Nigeria is dominated by the Sokoto Plains to the north-western areas and the Chad Plains to the north-eastern parts. The Sokoto Plains are flat rolling plains on sedimentary rocks with isolated low, flat-topped hills while the Chad Plains in the north-east are more extensive with Basement Complex and mostly made up of recent deposits of sands and clay and a general elevation of less than 500 m (Ologe, 2002). According to Ologe, the Chad Plain slopes gently towards Lake Chad and much of the area are covered by ancient sand dunes formed at a time when the climate was drier than it is in present day. The Sudano-Sahelian

region of Nigeria is drained by many rivers which suffer seasonal alterations in their volume and flow. Notable among these rivers are River Sokoto which extends from Sokoto State to Niger State in the northwestern part of Nigeria and Rivers Hadejia, Jam'aare, and Komadugu-Gana which drain into Lake Chad in the northeastern parts of the country.

The weather pattern, especially rainfall, in the Sudano-Sahelian region of Nigeria is determined by the movement of the Inter-Tropical Discontinuity (ITD). Associated with the ITD are two air masses, one over the Sahara (Tropical Continental Air Mass, cT) and the other over the Atlantic Ocean (Tropical Maritime Air Mass, mT). The Semi-arid belt of Nigeria exhibits a definite wet season and a marked dry season. It is in this area that rainfall is very variable and unpredictable. Both the onset and cessation of the rains are very irregular in the area and the lengths of the cropping seasons considerably and adversely affected (Ojo, 1991). Rainfall in the semi-arid belt of Nigeria varies from 500mm in the northern extreme to 800 mm in its boundary with the Northern Guinea Savanna (Oduyemi and Ogunkoya, 2006). The growing season lasts from June-September (Odekunle, 2004). Rainfall in the Semi-arid belt of Nigeria is with a single peak. Mean air temperature varies from 29^{o} to 30^{o}C in the Sudano-Sahelian region of Nigeria. Vegetation in the Sudano-Sahelian region of Nigeria varies from short grasses and small, often thorny trees with small leaves in the extreme north particularly in the limited area west of Lake Chad to sparsely-wooded area around its boundary with the Guinea Savanna.

The rapid increase in the demand for raw materials both locally and abroad and the increasing demand for food by rising population coupled with crop failure due to droughts, have encouraged the development of river basin projects (Oguntoyinbo, 1978). Notable among the irrigation projects are Sokoto Rima Project, Gongola River Project, Hadejia Project and Lake Chad Basin Project. Most of these irrigation projects are located in river valleys which contain broad alluvial flat land which are subject to seasonal flooding. The flood plains or *fadamas* are, therefore, cultivated intensively by local farmers who rely on natural irrigation flood waters at the beginning and end of the rainy season (Oguntoyinbo, 1978; Goes, 2001). According to Oguntoyinbo, crop failures are associated with this farming practice due to the occurrence of flash floods which drown or sweep crops away. The wetlands are also important for fishing, groundwater recharge, dry-season grazing and are ecologically rich (Goes, 2001).

Materials and Methods

Monthly rainfall data covering the growing season (June-September) for Sokoto, Kano, Katsina, Potiskum, Nguru, Maiduguri from 1951-2010 and Gusau from 1953-2010 were collected from the archives of the Nigerian Meteorological Agency, Lagos. Linear trend lines and second order polynomial were used to examine the trends of the rainfall during the growing season for each synoptic weather station. The drought intensities during the growing season for each of the selected synoptic weather stations were computed as percentage deviation from the mean growing season (June-September) and classified according to Ayoade (1988 and 2008) as follow:

Drought type	Percent deviation from the mean
Slight drought	11-25
Moderate drought	26-45
Severe drought	46-60
Disastrous drought	more than 60

Results and Discussion

Rainfall Trends at Sokoto

Figure 2 reveals the rainfall trends in Sokoto during the growing season (June-September). The During the growing season, the 1952-1964 period was relatively wetter while relatively low rainfall characterized the periods 1965-1975 and 1979-1987 with the period 1988-2010 revealing recovering trend from dryness although intermixed with some years of below average rainfall. This sign of recovery from dryness to wetness is confirmed by the second order polynomial trend line which clearly depict unfolding of a wet episode in Sokoto. While the highest rainfall during the growing season (1951-2010) occurred in 1965 (938.8 mm), the lowest rainfall was recorded in 1987 (299.2 mm). It is remarkable to note the unprecedented rainfall (894.7 mm) in 2010 during the growing season during 1966-2010. Overall, the linear trend line reveals that Sokoto witnessed a downward rainfall trend during the 1951-2010 periods.

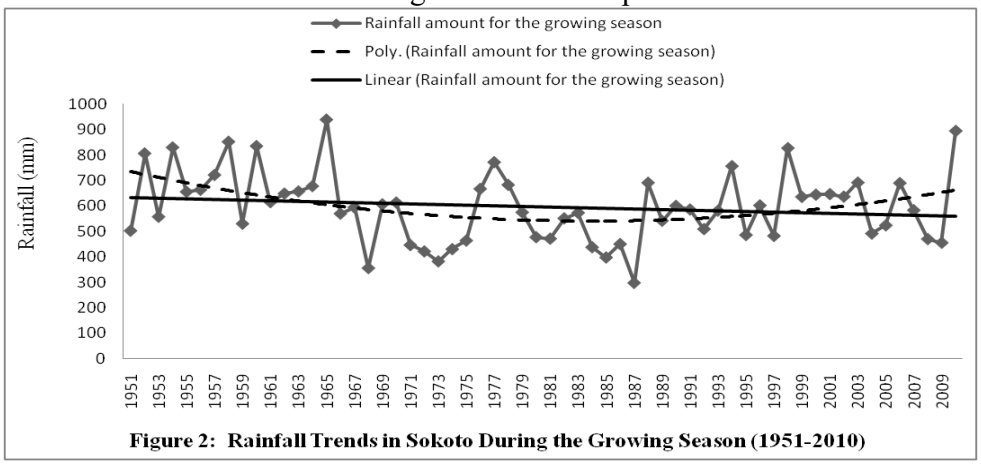

Figure 2: Rainfall Trends in Sokoto During the Growing Season (1951-2010)

Rainfall Trends at Gusau

Like Sokoto, the linear rainfall trend during the growing season in Gusau (1953-2010) reveals a downward trend. However, unlike Sokoto, rainfall during the growing season in Gusau reveals near consistent downward trends from 1954-1991 (Figure 3). Apart from the 1992-1994 period, rainfall amount during the growing season did not reveal clear partitions of wet and dry periods. During the period under consideration, the highest rainfall during the growing season was recorded in 1994 (1301.4 mm) while the lowest was recorded in 1972 (495.7 mm). The second order polynomial indicates recovery from the downward rainfall trend in Gusau.

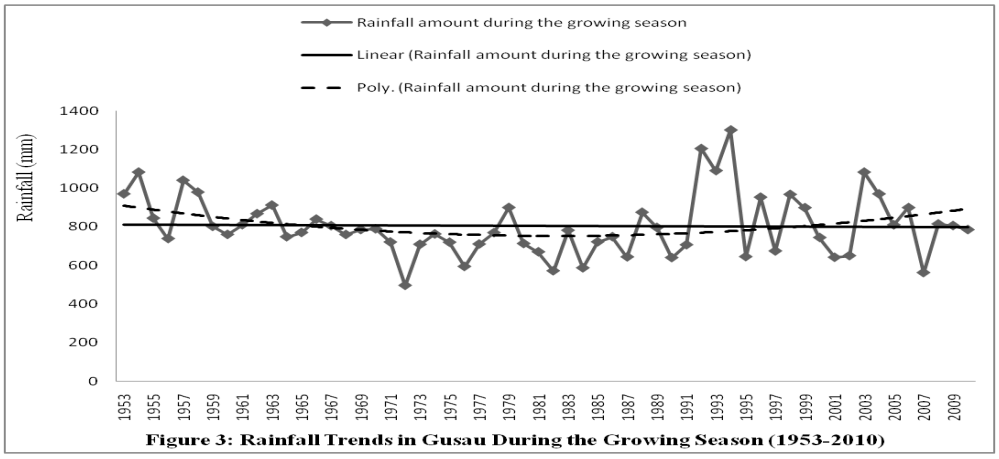

Figure 3: Rainfall Trends in Gusau During the Growing Season (1953-2010)

Rainfall Trends at Katsina

The rainfall trend in Katsina during the growing season (1951-2010) is somewhat similar to that of Sokoto although the the linear trend line reveals a sharper decreasing trend in the former (Figure 4). The declining rainfall trend nothwithstanding, the second order polynomial reveals recovery from dryness to wetness in Katsina. The periods 1954-1965 and 2000-2006 were relatively wetter while the periods 1966-1978 and 1981-1999 were marked with relatively low rainfall. Overall, the highest rainfall during the growing season (1951-2010) was recorded in 1964 (912.8 mm) while driest was witnessed in 1966 (217.2 mm).

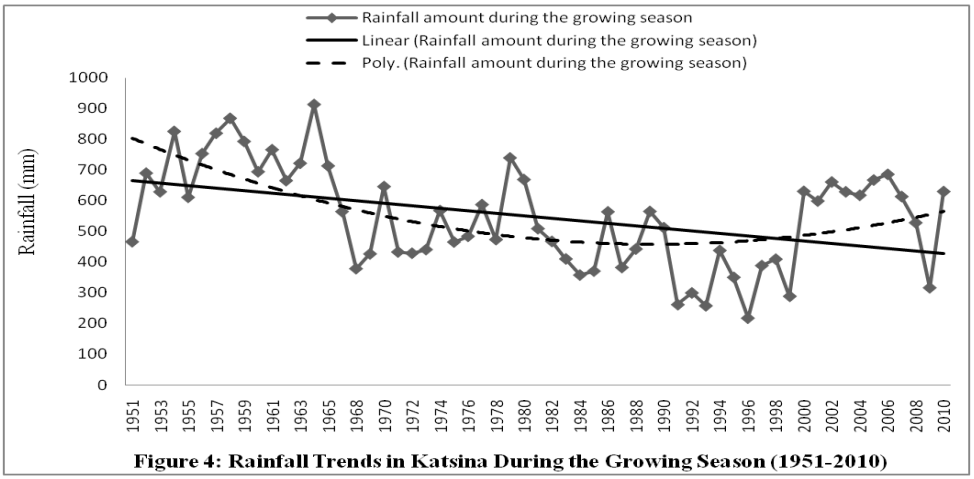

Figure 4: Rainfall Trends in Katsina During the Growing Season (1951-2010)

Rainfall Trends at Kano

Unlike Sokoto, Gusau and Katsina, the linear rainfall trend during the growing season in Kano reveals upward movement during the 1951-2010 period (Figure 5). However, Katsina witnessed slight rainfall decline from 1970 to mid 1980s following by recovering trend. This recovery trend is supported by the second order polynomial trend line which reveals upward movement. Thus, although rainfall decreased from 1761.9mm in 1998 to 1159.3mm in 2006, the period 1998-2006 appeared to be relatively wetter during the period under consideration (1951-2010). The highest rainfall was recorded in 1998 (1761.9 mm) while the lowest was witnessed in 1987 (354.9 mm).

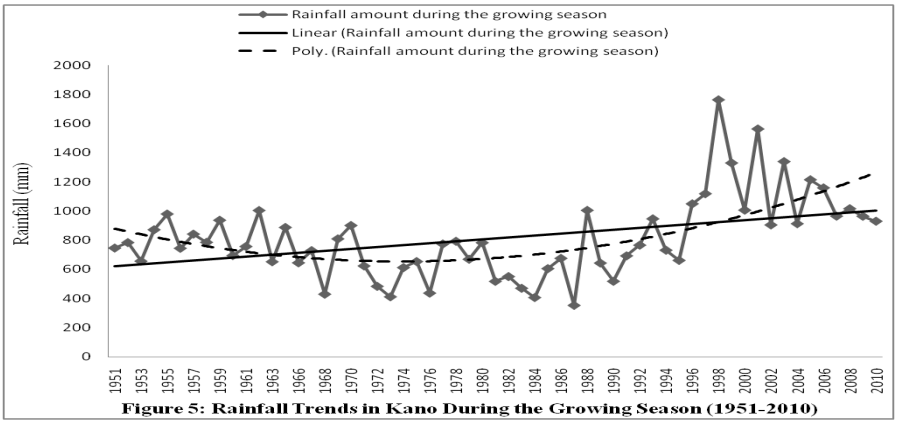

Figure 5: Rainfall Trends in Kano During the Growing Season (1951-2010)

Rainfall Trends at Potiskum

The linear trend line indicates that rainfall in Potiskum during the growing season witnessed a downward trend during the 1951-2010 periods. However, the second order polynomial trend line indicates slight upward movement which suggests unfolding of a wet episode. Figure 6 reveals that the 1954-1968 period was wetter while the 1969-1989 period was characterized by low rainfall during the growing season. Overall, the highest rainfall during the growing season was recorded in 1990 (1393.5mm) while the lowest was recorded in 1984 (235.9 mm).

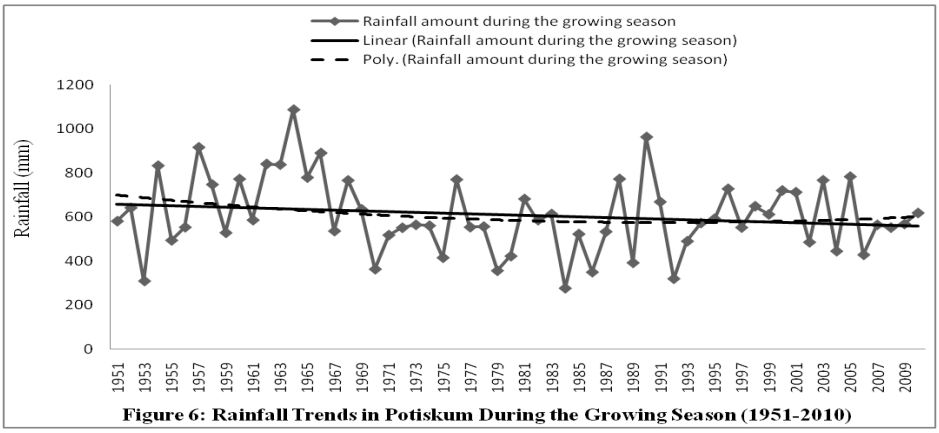

Figure 6: Rainfall Trends in Potiskum During the Growing Season (1951-2010)

Rainfall Trends at Nguru

The linear trend line indicates that in Nguru, rainfall for the growing season during the 1951-2010 period witnessed downward trend (Figure 7). The 1951-1965 period was characterized by relatively wet episode while the period 1980-1993 is marked by relative dryness with the period 1994-2010 staggering between wet and dry. However, the second order polynomial trend line suggests recovery from the downward rainfall trend. Overall, the highest rainfall was recorded in 1990 (1393.5 mm) while the lowest rainfall was recorded in 1984 (235.9 mm).

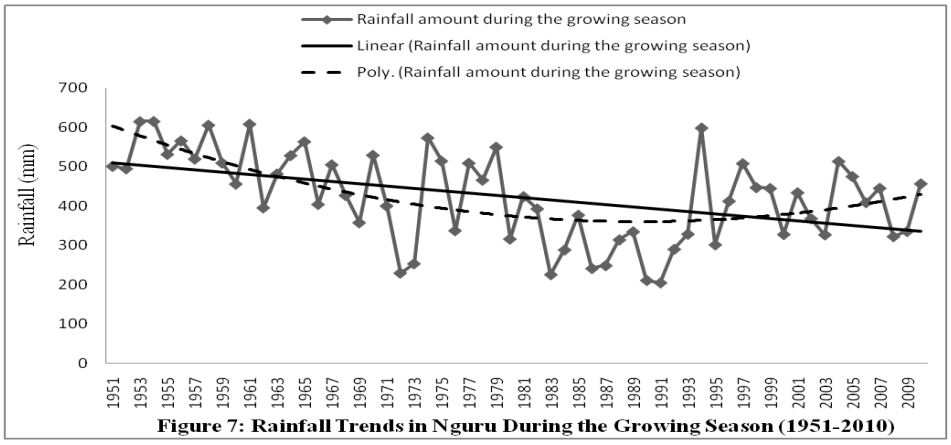

Figure 7: Rainfall Trends in Nguru During the Growing Season (1951-2010)

Rainfall Trends at Maiduguri

The linear trend line reveals that rainfall during the growing season in Maiduguri witnessed a downward trend during the 1951-2010 period (Figure 8). With an initial downward trend of rainfall, the second order polynomial trend line reveals recovery. Rainfall for the growing season shows marked deviations low amount during 1964, 1971-73, 1981-85, 1990-91 and 1993-94. The period 1995-2010 however show a recovery trend.

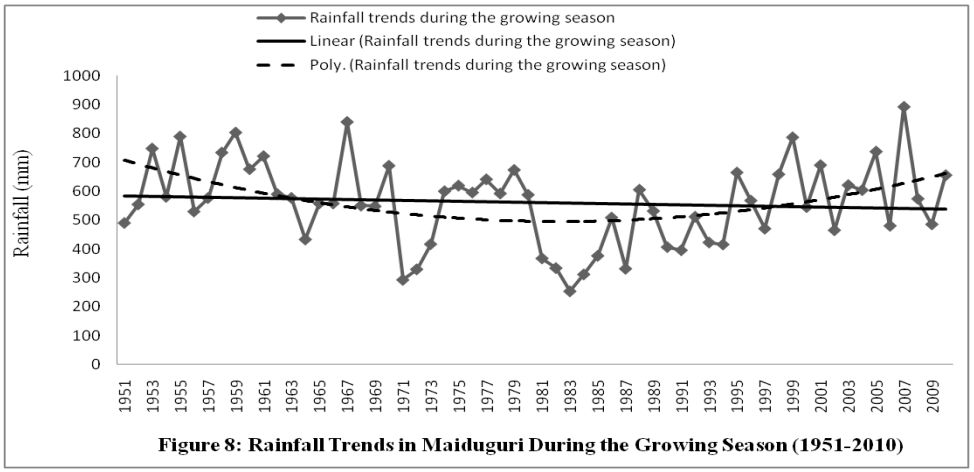

Figure 8: Rainfall Trends in Maiduguri During the Growing Season (1951-2010)

Drought Intensities at the Sudano-Sahelian Region of Nigeria

Table 1 reveals the intensities of drought during the growing season in the Sudano-Sahelian belt of Nigeria during the period under consideration. The highest incidences of slight drought occurred in Sokoto, Kano and Nguru while the lowest were witnessed in Maiduguri. Moderate droughts were most prevalent in Maiduguri but least experienced in Gusau. While there was no incidence of severe drought in Gusau, it was most prevalent in Katsina and Nguru but least experienced Sokoto. The only incidence of disastrous drought during the 1951-2010 period was witnessed in Katsina. The intensities of drought during the growing season shows spatial and temporal variations in the Sudano-Sahelian belt of Nigeria, with the exception of few cases such Katsina and Nguru which witnessed severe droughts during 1990 and 1991. This underscores the role of local factors in the incidence and intensity of drought.

Table 1: Growing Season (June-September) Drought Intensities in the Sudano-Sahelian Region of Nigeria

Year	Drought Intensity Index (Sokoto)	Classification (Sokoto)	Drought Intensity Index (Gusau)	Classification (Gusau)	Drought Intensity Index (Katsina)	Classification (Katsina)	Drought Intensity Index (Kano)	Classification (Kano)	Drought Intensity Index (Potiskum)	Classification (Potiskum)	Drought Intensity Index (Nguru)	Classification (Nguru)	Drought Intensity Index (Maiduguri)	Classification (Maiduguri)
1951	-	-	ND	ND	-	-		-	-	-	-	-	12.4	
1952	-	-	ND	ND	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	17	Slight	49.7	Severe	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	19.6	Slight	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1959	11.1	Slight	-	-	-	-	-	-	14	Slight	-	-	-	-
1960	-	-	-	-	-	-	12.3	Slight	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	17.5	Slight	-	-	-	-	-	-
1964	-	-	-	-	-	-	-	-	-	-	-	-	22.5	Slight
1965	-	-	-	-	-	-	18.4	Slight	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	31	Moderate	44.8	Moderate	12.7	Slight	-	-	-	-
1968	40.1	Moderate	-	-	22.2	Slight	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	15.5	Slight	-	-
1970	-	-	-	-	21.2	Slight	21.1	Slight	21.2	Slight	-	-	-	-
1971	25.1	Moderate	-	-	21.9	Slight	38.2	Moderate	15.7	Slight	-	-	47.5	Severe
1972	29.2	Moderate	38.4	Moderate	19.7	Slight	47	Severe	-	-	45.9	Severe	41	Moderate
1973	35.7	Moderate	11.8	Slight	-	-	22.4	Slight	-	-	40.3	Moderate	25.6	Moderate
1974	27.7	Moderate	-	-	15.2	Slight	17.3	Slight	-	-	-	-	-	-
1975	22.1	Slight	-	-	11	Slight	44	Moderate	32.5	Moderate	-	-	-	-
1976	-	-	26.2	Moderate	-	-	-	-	-	-	20.3	Slight	-	-
1977	-	-	11.7	Slight	13.7	Slight	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	15.4	Slight	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	42.1	Moderate	-	-	-	-
1980	19.9	Slight	11.3	Slight	-	-	34	Moderate	31.3	Moderate	25.4	Moderate	-	-
1981	20.8	Slight	16.7	Slight	14.9	Slight	30	Moderate	-	-	-	-	34.2	Moderate
1982	-	-	29	Moderate	25.2	Moderate	39.8	Moderate	-	-	-	-	40.2	Moderate
1983	-	-	-	-	34.8	Moderate	47.7	Severe	-	-	46.9	Severe	54.5	Severe
1984	26.5	Moderate	27.1	Moderate	32.5	Moderate	23.2	Slight	55.1	Severe	31.9	Slight	44.1	Moderate
1985	33.2	Moderate	-	-	-	-	14.6	Slight	14.9	Slight	11	Slight	32.6	Moderate
1986	24.4	Slight	-	-	30.3	Moderate	54.3	Severe	43.2	Moderate	43.1	Moderate	-	-
1987	49.9	Severe	20	Slight	19.3	Slight	-	-	13.2	Slight	41.4	Moderate	40.6	Moderate
1988	-	-	-	-	-	-	18.6	Slight	-	-	25.9	Slight	-	-
1989	-	-	-	-	-	-	34	Moderate	36.3	Moderate	21	Slight	-	-
1990	-	-	20.4	Slight	52.4	Severe	12.6	Slight	-	-	50.3	Severe	27.3	Moderate
1991	-	-	12.1	Slight	45.4	Severe	-	-	-	-	51.8	Severe	29.2	Moderate
1992	14.5	Slight	-	-	53	Severe	-	-	48.1	Severe	31.5	Moderate	-	-
1993	-	-	-	-	20.2	Slight	-	-	-	-	22.4	Slight	24.4	Slight
1994	-	-	-	-	36.2	Moderate	16.3	Slight	-	-			25.6	Moderate
1995	18.4	Slight	19.9	Slight	60.4	Disastrous	-	-	-	-	28.8	Moderate	-	-
1996	-	-	-	-	29.2	Moderate	-	-	-	-	-	-	-	-
1997	19	Slight	16.2	Slight	25.4	Moderate	-	-	-	-	-	-	15.9	Slight
1998	-	-	-	-	47.4	Severe	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	-	-	22.6	Slight	-	-
2001	-	-	20.2	Slight	-	-	-	-	-	-	-	-	-	-
2002	-	-	19.1	Slight	-	-	-	-	21	Slight	13.1	Slight	16.8	Slight
2003	-	-	-	-	-	-	-	-	-	-	22.8	Slight	-	-
2004	17.5	Slight	-	-	-	-	-	-	27.6	Moderate	-	-	-	-
2005	12.1	Slight	-	-	-	-	-	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	30.3	Moderate	-	-	14.1	Slight
2007	-	-	30.1	Moderate	-	-	-	-	-	-	-	-	-	-
2008	21.1	Slight	-	-	42.4	Moderate	-	-	-	-	23.9	Slight	-	-
2009	23.5	Slight	-	-	-	-	-	-	-	-	20.8	Slight	13.2	Slight
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-

ND = No data

Discussion

The rainfall amount during the growing season (June-September) in the Sudano-Sahelian region of Nigeria exhibits negative trends during the 1951-2010 periods with exception of Kano. The downward trends of annual rainfall revealed in the synoptic weather stations investigated in this study particularly since the 1960s corroborate earlier studies (Boko *et al*., 2007; Odjugo, 2010a and 2010b; Odekunle, 2010; Umar, 2012a). The downward trends of rainfall during the growing season have contributed to the seasonal and long-term fluctuations of the volume of water in rivers and the recession of Lake Chad. The scramble for the fertile and pastures-rich floodplains for *fadama* farming and livestock grazing with accessible water have therefore induced conflicts in the region (Fasona and Omojola, 2005) which have led to loss of lives and properties as well as displacement of people.

The study reveals that droughts of varying magnitudes occurred across the Sudano-Sahelian region of Nigeria between the 1951-2010 period. The occurrence of droughts of various intensities in the study area therefore agrees with previous studies (Ayoade, 1988; Olaniran, 2002; Gworgwor, 2006; Ati et al, 2010; Atedhor and Odjugo, 2012; Umar, 2012b). Drought has therefore, been reported as one of the major drawbacks of crop production in the semi-arid belt of Nigeria (Ati *et al.*, 2010). Furthermore, the dry spells which account for the high frequency of disastrous droughts in the month of June which coincides with the onset of the growing season could delay the commencement of planting due moisture inadequacy especially with the prevalence of rainfed agriculture and poorly developed irrigation schemes in the region. The shrinking growing season and below average rainfall account for the shift in crop production from late to early maturing crops in the sahelian region (Odjugo, 2010b).

It is therefore imperative that resources should be galvanized to harness the irrigation potentials of the region for enhanced and sustainable agricultural productivity. Apart from the agricultural impacts of the decreasing rainfall trends as well as the frequent incidence of droughts in the Sudano-Sahelian region of Nigeria, the region has also been under the threat of desertification (Odjugo and Ikhuoria, 2003; Henah, 2012). Some of the consequences of desertification as revealed by previous studies are loss of arable land, outmigration farmer to more favourable environments (Evans and Mohieldeen, 2003), increasing conflicts (Fasona *et al*, 2005) and increasing incidence of migratory pests attacks (Omiunu, 1985; Ishaya and Abaje, 2008).

Conclusion and Recommendations

This paper examined rainfall trends and drought intensities during the growing season in the Sudano-Sahelian region of Nigeria. The results reveal negative trends of monthly and growing season rainfall in all the synoptic weather stations investigated in the study with the exception of Kano which showed positive trend. The drought incidences were predominantly of slight and moderate intensities. The drought intensities largely reveal spatial and temporal variations which underscore the role of local factors in the occurrence and intensities of droughts. In view of the pivotal role of the Sudano-Sahelian region as the main source of the nation's cereal and animal protein, it is recommended that the provision of irrigation should be intensified and agricultural activities in the region should be aligned with prevailing climatic trends in order to realize the country's quest for food security.

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