Research Article

Rainfall Variability and Drought during the Sowing Season and Mid-Season of Rice in the Sudano-Sahelian Region of Nigeria

Godwin O. Atedhor

Department of Geography and Regional Planning, University of Benin, Benin City, Nigeria

godwin.atedhor@uniben.edu, +2348136446117

Abstract

This paper examines rainfall variability and change as well as drought intensities in the Sudano-Sahelian region of Nigeria with a focus on the sowing season (June - July) and mid-season (August - October) of the farming calendar of rice. Monthly rainfall and rain-days data for Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru, Maiduguri and Yola for 65 years (1951-2015) were sourced from the archives of the Nigerian Meteorological Agency. Rainfall decreased in Katsina and Nguru at annual rates of 0.69mm and 1.12mm respectively while it increased in Sokoto, Gusau, Kano, Potiskum, Maiduguri and Yola at annual rates of 0.39mm, 0.34mm, 03.77mm, 0.18mm and 0.37mm respectively during the sowing season. Rainfall decreased at annual rates of 1.38mm, 1.96mm, 0.57mm, 0.84mm, 0.71mm and 1.54mm in Sokoto, Katsina, Potiskum, Nguru, Maiduguri and Yola respectively while it increased at 2.31mm and 3.70mm in Gusau and Kano respectively. Rainfall changed significantly in Nguru during the sowing season and Sokoto Katsina, Kano, and Yola during the mid-season. Rain-days declined annually at the rate of 0.062, 0.049, 0.058, 0.042, 0.001, 0.083 and 0.070 in Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru and Maiduguri respectively while it increased in Yola at 0.038 during the sowing season. It decreased at annual rates of 0.119, 0.120, 0.079, 0.052, 0.016, 0.006 and 0.316 in Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru and Maiduguri respectively while it increased in Yola at 0.001 during the mid-season. Rain-days changed significantly in Potiskum, Nguru and Maiduguri during the sowing season while it changed significantly in Sokoto, Gusau,, Potiskum and Maiduguri during the mid-season. Generally, droughts were more of slight and moderate intensities with Sokoto having the highest percentages of severe and disastrous categories. Timely weather forecasts and irrigation practice in relation with the different phases during rice farming calendar as well as cultivation of improved varieties are recommended.

Keywords: Drought, Mid-season, Rainfall, Rice, Sowing season, Sudano-Sahelian region, Nigeria

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Abstrait

Cet article examine la variabilité et le changement des précipitations ainsi que l'intensité de la sécheresse dans la région soudano-sahélienne du Nigéria, en mettant l'accent sur la saison des semailles (juin - juillet) et la mi-saison (août - octobre) du calendrier agricole du riz. Les données mensuelles sur les précipitations et les jours de pluie pour Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru, Maiduguri et Yola pour 65 ans (1951-2015) proviennent des archives de l'Agence de météorologie du Nigéria. Les précipitations ont diminué à Katsina et à Nguru à des taux annuels respectifs de 0,69 mm et 1,12 mm, alors qu'elles ont augmenté à Sokoto, à Gusau, à Kano, à Potiskum, à Maiduguri et à Yola à des taux annuels de 0,39 mm, 0,34 mm, de 03,77 mm, de 0,18 mm et de 0,37 mm pendant la saison des semailles. Les précipitations ont diminué aux taux annuels de 1,38 mm, 1,96 mm, 0,57 mm, 0,84 mm, 0,71 mm et 1,54 mm à Sokoto, Katsina, Potiskum, Nguru, Maiduguri et Yola, respectivement, alors qu'elles ont augmenté à 2,31 mm et 3,70 mm à Gusau et Kano, respectivement. . Les précipitations ont beaucoup changé à Nguru pendant la saison des semailles et à Sokoto Katsina, Kano et Yola pendant la mi-saison. Les jours de pluie ont diminué annuellement au taux de 0,062, 0,049, 0,058, 0,042, 0,001, 0,083 et 0,070 à Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru et Maiduguri, alors qu'ils augmentaient à Yola à 0,038 pendant la saison des semailles. Il a diminué aux taux annuels de 0,119, 0,120, 0,079, 0,052, 0,016, 0,006 et 0,316 à Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru et Maiduguri, alors qu'il a augmenté à Yola à 0,001 pendant la mi-saison. Les jours de pluie ont beaucoup changé à Potiskum, Nguru et Maiduguri pendant la saison des semailles, tandis qu'ils ont beaucoup changé à Sokoto, Gusau, Potiskum et Maiduguri à la mi-saison. En règle générale, les sécheresses étaient plutôt d'intensité légère et d'intensité modérée, Sokoto présentant les pourcentages les plus élevés de catégories de catastrophes graves et désastreuses. Des prévisions météorologiques opportunes et des pratiques d'irrigation en relation avec les différentes phases du calendrier de la riziculture, ainsi que la culture de variétés améliorées sont recommandées.

Mots-clés: Sécheresse, Moyenne saison, Précipitations, Riz, Saison de semis, Région soudano-sahélienne, Nigéria

1. Introduction

Crop yields must increase significantly in the approaching decades to match tempo with worldwide food demand as a result of population and income expansion (Zhao & Fitzgerald, 2013; van Ittersum *et al*., 2013; van Wart *et al*., 2013; Ajala & Gana, 2015; Islam *et al*., 2016) amid the challenges of climate change which will militate against food production (Abeysingha *et al*., 2016; Ekpa *et al*., 2018). Climatic variability is among the most important parameters determining annual variations in crop yields (Kang *et al*., 2009; Craufurd and Wheeler, 2009; Nyang'au *et al*., 2014; Ray *et al*., 2015). Therefore, dipping threats to food security due to climate change is among the key challenges of the 21st century (Campbell *et al*., 2016).

Changes in temperature and precipitation owing to global climate change possibly will have severe impacts on hydrologic processes, water resources availability, irrigation water demand, and thus upset agricultural production and output (Abeysingha *et al*., 2016). Radical alteration in rainfall distribution and increase in temperatures will lead to adverse growing environment into the cropping schedules thus changing the growing seasons and consequently decrease output (Nwalieji & Uzuegbunam, 2012).

Although drought is a recurrent global phenomenon (Masih *et al*., 2014; Mera, 2018), Africa has been identified as one of the areas that have witnessed significant increase in drought occurrence, interval, and severity; making it one of hot spots of the natural hazard (Spinoni *et al*, 2014). Although drought incidence is rampant in the horn of Africa (Mera, 2018), it is also prevalent in other parts of Africa such as the Sahel. Studies have shown that drought is a regular occurrence in the northern parts of Nigeria, especially in the 1970s and 1980s (Street-Perrott *et al*., 2000; Adeniyi and Uzoma, 2016). Drought has been identified as a recurrent phenomenon in the Sudano-Sahelian region of Nigeria (Atedhor 2014; Adegun, 2015). It impact on every facet of the natural and socio-economic environments (Olagunju, 2015; Eze, 2018). Drought causes extensive crop failure, loss of livestock, water scarcity, food crisis leading to loss of human lives (Abaje *et al*., 2013; Masih *et al*., 2014; Mera, 2018). Alarmingly, it has been stated that grain-related hunger could escalate if grain production does not witness corresponding increase as population growth in an unpredictable environment (Apata, 2011). Decline in water yield has been linked with climatic variability and droughts (Ekpoh and Nsa, 2011; Abaje *et al*., 2013; Han *et al*., 2019). Drought incidences are therefore capable of exacerbating scarcity of water for irrigation in the Sudano-Sahelian region of Nigeria where rainfall is markedly variable.

Until recent years when Nigeria started witnessing increase in rice production (Morem *et al*., 2017), studies have shown that Nigeria is a major rice importer (Ogundele & Okoruwa, 2006; Erenstein *et al*., 2003; Fakoyode *et al*., 2010; Ajijola *et al*, 2012; Onu *et al*., 2015). Rice is rated uppermost in Nigeria based on the worth of import weighed against to other key victuals products (Osawe *et al*., 2017). This therefore calls for evaluation of the factors that influence rice production of which climate is cardinal. Regrettably, previous studies on rice largely centred on adoption of improved varieties (Adenuga *et al*., 2016), processing (Ajala & Gana, 2015), value chain (Chidiebere-Mark, 2017), consumption pattern (Fakoyode *et al*., 2010) and production system and technology (Longtau, 2003; Ogundele & Okoruwa, 2006; Onu *et al*., 2015; Osawe *et al*., 2017; Okeke & Oluka, 2017; Morem *et al*., 2017).

Analysis of environmental change is useful in providing a guide for the formulation of regional and national policies (van Wart *et al*., 2013).

Specifically, analysis of climatic patterns could provide a fulcrum for possible informed agricultural adaptation to climate change. This could facilitate the realisation of sustainable development goals (SDGs), especially as it relates to poverty and hunger reduction and enhanced good health and well-being. The objective of this paper, therefore, is to examine rainfall variability and change as well as drought intensities during the sowing season and mid-season in the Sudano-Sahelian region of Nigeria which is one of the major rice producing areas.

2. Materials and Methods

2.1 Study Area

The Sudano-Sahelian region of Nigeria (Figure 1) lies between latitude 10ÚN and 14ÚN and longitude 4ÚE and 14ÚE (Fabeku & Okogbue, 2014) in the north extreme of the country. The vegetation is savannah although less dense compared to the guinea savannah beyond its southern boundary. Agriculture is the main source of livelihood (Atedhor, 2014). Other livelihoods in the area include fishing, mining, leather works, pottery works, brass and silver works (Kayode & Francis, 2012).

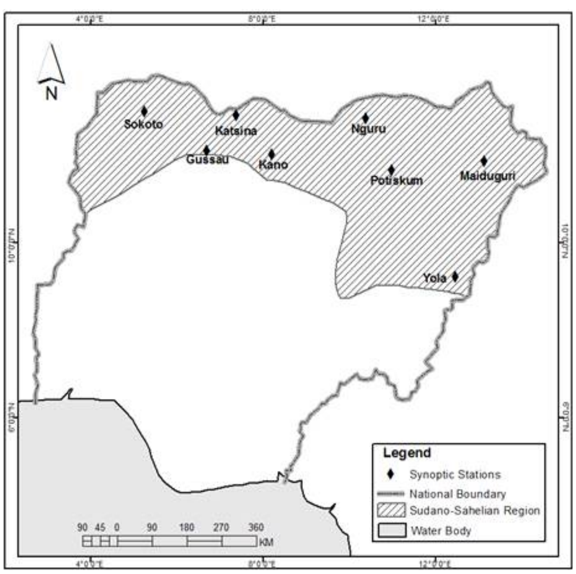

Figure 1: Sudano-Sahelian Region and Selected Synoptic Weather Stations

2.2 Data Source

While solar radiation and temperature are the critical factors in determining crop yield in the temperate region (Espe *et al*., 2016), rainfall determines the length of the growing season in the tropics (Ayoade, 2002; Odekunle, 2004). While rice sowing season and mid-season last from April-May and June-July respectively in the forest belt of Nigeria (Atedhor & Ayeni, 2017), its sowing season and mid-season last from June-July and August-October respectively in northern Nigeria (Shiru *et al*., 2018). Consequently, rainfall and rain-days (1951-2015) covering the sowing season and mid-sowing season were sourced from the archives of the Nigerian Meteorological Agency. Eight (8) synoptic weather stations (Figure 1) were selected for the study based on spatial distribution and availability of long-term rainfall and rain-days data for the specified seasons.

2.3. Data Analysis

The data were partitioned into two time slices (1951-1980 and 1981-2015). The rainfall amount and rain-days for the sowing season and mid-season were computed for the selected synoptic weather stations. Simple linear regression and second order polynomial were used to examine the annual linear and curvilinear trends of the rainfall and rain-days for the two seasons. Pearson Product Moment correlation was used to investigate the significance of the trends of rainfall and rain-days during the 1951-2015 period. The significance of changes in rainfall amount and rain-days between 1951-1980 and 1981-2015 for the two seasons were analysed using student's *t* test. Drought intensities during the two seasons were computed as percentage derivation below the mean and classified as shown in Table 1 according to Ayoade, (2008).

Table 1: Classification of drought severity

Drought type	Percentage derivation from the Mean
Slight drought	11-25
Moderate drought	26-45
Severe drought	46-60
Disastrous drought	more than 60

3 Results

3.1. Rainfall

The annual trends of rainfall are presented in Figures 2a-h while the regression equations and correlation coefficients of their trends are presented in Table 2. Rainfall witnessed increasing and declining trends in Sokoto during the sowing and mid-season respectively during the 1951-2015 period. Polynomial of trends of rainfall in Sokoto depicted a sharper decline during the 1950s-70s and a less sharp recovery tendency during the mid-season while that of the sowing season revealed both gentle initial decline and a later recovery tendency. While rainfall in Sokoto increased at annual rate of 0.39mm, it decreased at the rate of 1.38mm during the sowing and mid-season although the trends were not significant (Table 2).

Gusau recorded upward linear annual rainfall trends during the sowing and mid-seasons at the rates of 0.34mm and 2.32mm respectively. The positive rainfall trends experienced in Gusau was only positive during the mid-season ($P<0.05$). Still on Gusau, the polynomial trend of mid-season rainfall after initial glide from the 1950s to 70s showed a tendency towards recovery from 1980s while the trend during the sowing season revealed an upward tendency but less curvilinear. Katsina experienced negative annual linear trends of rainfall during the sowing season and mid-season at the rates of 0.69mm and 1.96mm respectively with only that of the mid-season being significant ($P<0.05$). Again Katsina, the polynomials of the annual trends of rainfall during the mid-season depicts a steeper declining and recovery gradient unlike that of the sowing season. The linear annual trends of rainfall for Kano were positive during the sowing season and mid-season at the rates of 3.77mm and 3.70mm respectively. The positive linear trends of rainfall in Kano during the two seasons are statistically significant ($P<0.01$) while the polynomials of annual trends of rainfall during the two seasons showed a sharper degree of recovery.

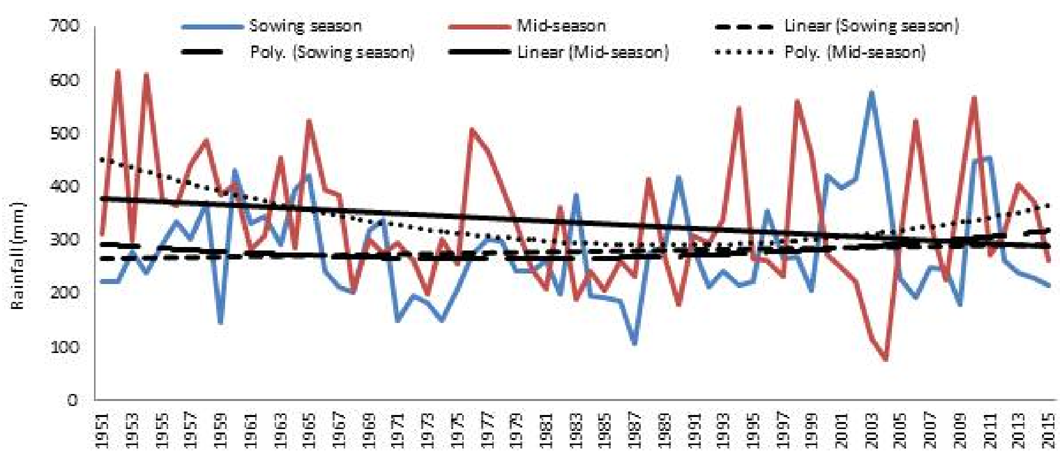

Figure 2a: Annual trends of rainfall during sowing season and mid-season in Sokoto

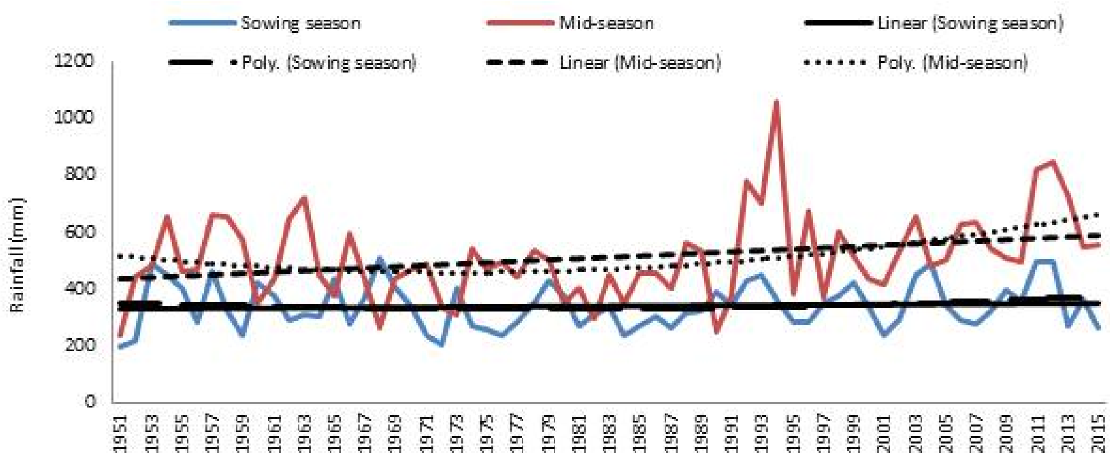

Figure 2b: Annual trends of rainfall during sowing season and mid-season in Gusau

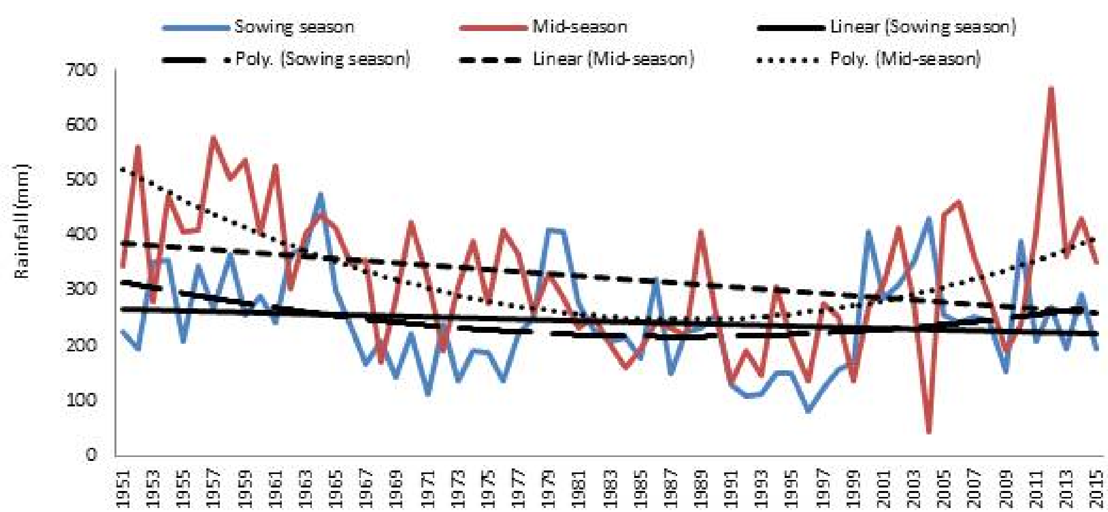

Figure 2c: Annual trends of rainfall during sowing season and mid-season in Katsina

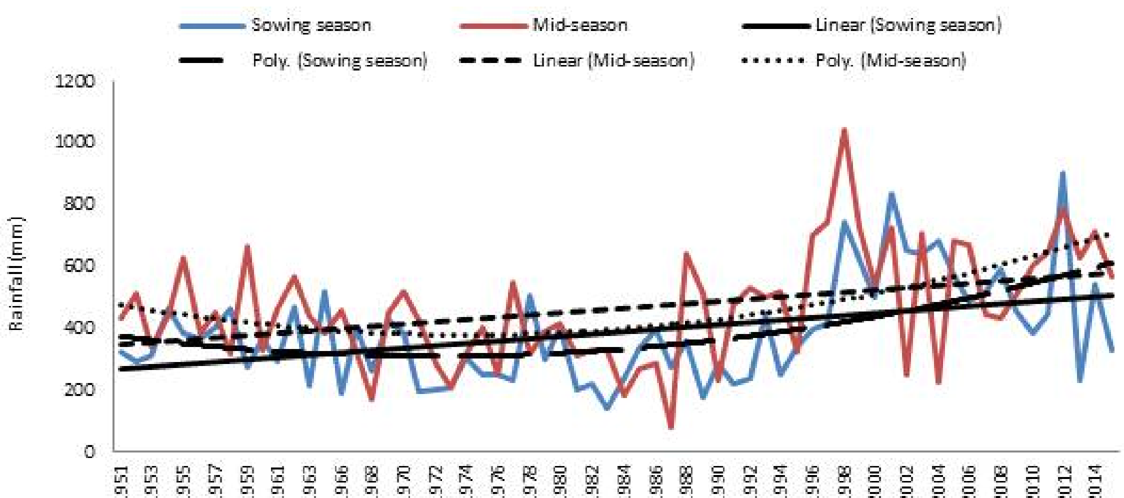

Figure 2d: Annual trends of rainfall during sowing season and mid-season in Kano

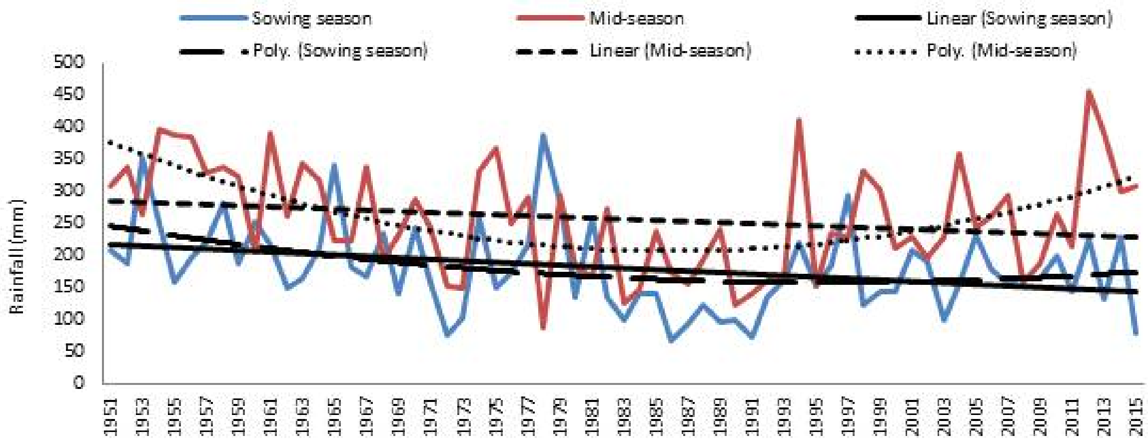

Figure 2e: Annual trends of rainfall during sowing season and mid-season in Nguru

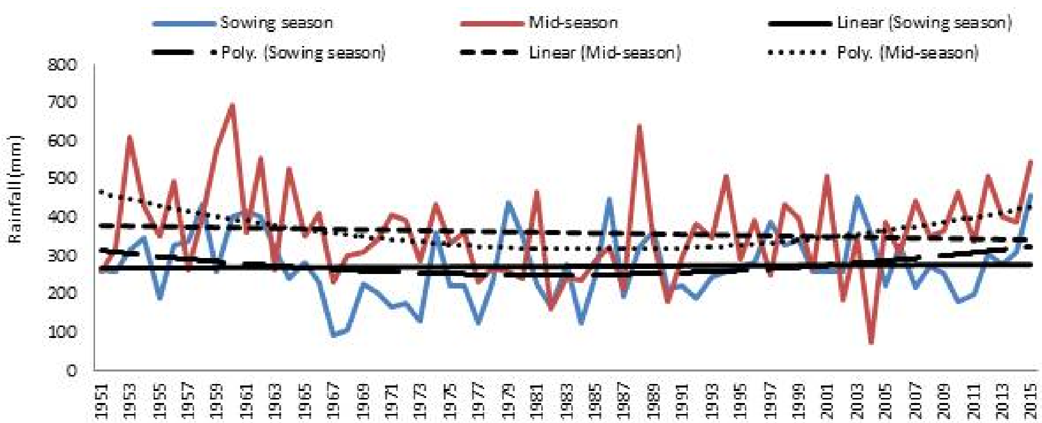

Figure 2f: Annual trends of rainfall during sowing season and mid-season in Potiskum

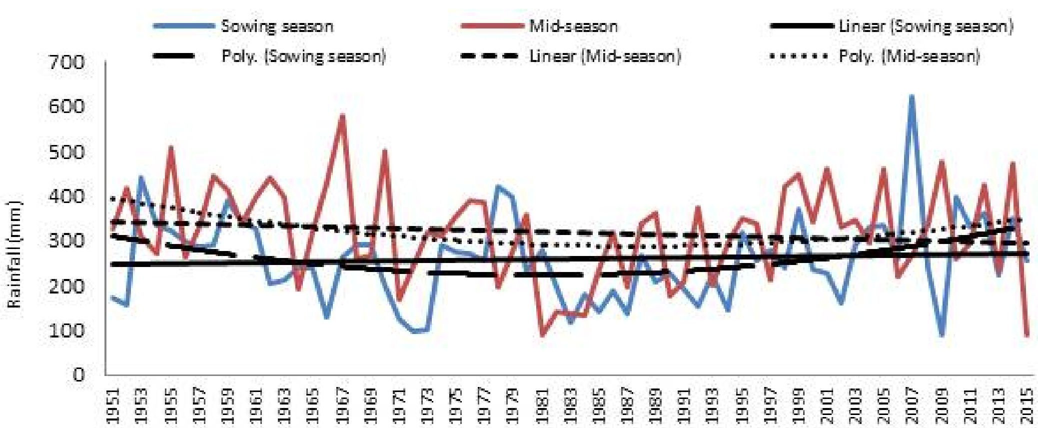

Figure 2g: Annual trends of rainfall during sowing season and mid-season in Maiduguri

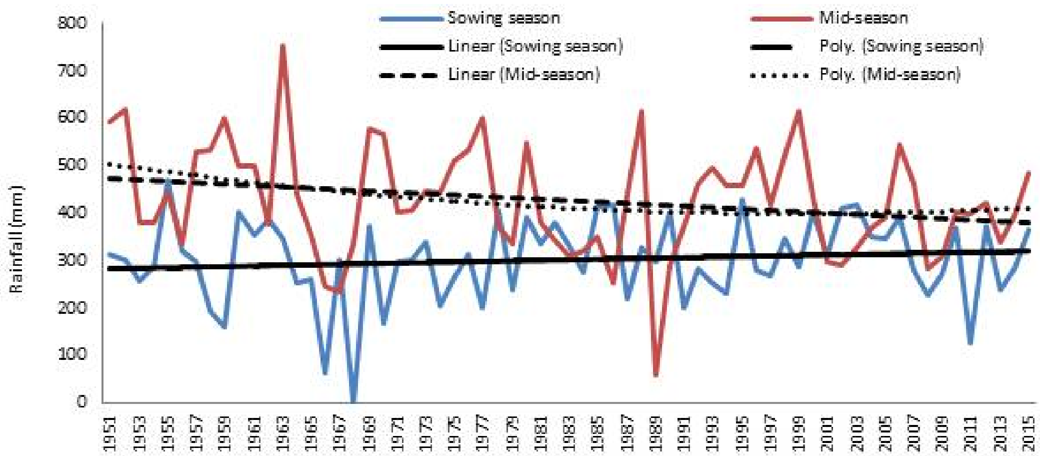

Figure 2h: Annual trends of rainfall during sowing season and mid-season in Yola

Table 2: Annual rates of change and correlation coefficients of rainfall during sowing season and mid-season

Synoptic weather stations		**Annual rate of sowing season rainfall (mm)**		**Annual rate of mid-season rainfall**
(mm)	**Correlation coefficient(sowing season)**			**Correlation coefficient(mid-season)**
Sokoto	0.385	-1.380	0.079	-0.222
Gusau	0.336	2.314	0.079	0.290*
Katsina	-0.693	-1.958	-0.145	-0.302*
Kano	3.772	3.704	0.424**	0.376**
Potiskum	0.178	-0.574	0.038	-0.090
Nguru	-1.118	-0.843	-0.312*	-0.190
Maiduguri	0.368	-0.712	0.073	-0.125
Yola	0.582	-1.446	0.125	-0.232

* *Correlation is significant at 0.05 confidence level*
** *Correlation is significant at 0.01 confidence level*

The t-test statistics of the difference in rainfall for the synoptic weather stations between 1951-1980 and 1981-2015 are presented in Table 3. Kano and Nguru showed significant differences in rainfall amounts during the sowing season between the two periods while Sokoto, Katsina, Nguru and Yola witnessed significant differences in the mid-season rainfall amount between the two periods. Rainfall during the mid-season revealed significant differences in Sokoto, Katsina, Nguru and Yola between the two periods.

Table 3: Significance of the difference in rainfall and rain-days during sowing season and mid-season between 1951-1980 and 1981-2015

Pairs	Paired Differences					*t*	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Sokoto sowing1- Sokoto sowing	-12.29	148.58	27.13	-67.77	43.19	-0.45	29	0.65
Sokoto Mid-season1 - Sokoto Mid-season2	62.09	168.25	30.72	-0.74	124.92	2.02	29	0.05
Gusau sowing1 - Gusau sowing 2	1.68	102.72	18.76	-36.68	40.04	0.09	29	0.93
Gusau Mid-season1 - Gusau Mid-season2	-38.33	181.55	33.15	-106.12	29.46	-1.16	29	0.26
Katsina sowing1 - Katsina sowing2	36.19	144.26	26.34	-17.68	90.06	1.37	29	0.18
Katsina Mid-season1 - Katsina Mid-season2	127.63	149.78	27.35	71.70	183.55	4.67	29	0.00
Kano sowing1 - Kano sowing2	-88.78	235.95	43.81	-178.53	0.97	-2.03	28	0.05
Kano mid-season1 - Kano mid-season2	-72.16	260.55	48.38	-171.27	26.95	-1.49	28	0.15
Nguru sowing1 - Nguru sowing2	55.21	98.17	17.92	18.55	91.87	3.08	29	0.00
Nguru mid-season1 - Nguru mid-season2	61.51	107.12	19.56	21.51	101.51	3.15	29	0.00
Potiskum sowing1 - Potiskum sowing2	-2.78	144.72	26.42	-56.82	51.26	-0.11	29	0.92
Potiskum mid-season1 - Potiskum mid-season2	38.98	185.50	33.87	-30.29	108.25	1.15	29	0.26
Maiduguri sowing 1 - Maiduguri sowing2	19.78	149.91	27.37	-36.20	75.75	0.72	29	0.48
Maiduguri mid-season 1 - Maiduguri mid-season2	53.73	162.18	29.61	-6.82	114.29	1.82	29	0.08
Yola sowing 1 - Yola sowing 2	-42.64	118.50	21.64	-86.89	1.61	-1.97	29	0.06
Yola mid-season1 - Yola mid-season2	69.54	158.94	29.02	10.195	128.89	2.40	29	0.02

Where 1 and 2 represent 1951-1980 and 1981-2015 respectively

3.2 Rain-days

The annual trends of rain-days during the sowing season and mid-season are presented in Figure 3a-h. Sokoto witnessed a decline in the trends of rain-days during the sowing and mid-season at annual rates of 0.06 and 0.12 respectively but the trend was only significant in the mid-season (P< 0.01) while the polynomial of the trends of the sowing season and mid-season rain-days appeared to be similar to those of rainfall. Unlike rainfall, linear annual trends of rain-days for Gusau were positive at the rates of 0.05 and 0.12 respectively but only significant during the mid-season (P<0.05).The polynomial of the trends of rain-days for Gusau during the mid-season showed a sharp decline from the 1950s to 70s while the decline and recovery tendency appeared to be gentle during the sowing season. Annual rain-days in Katsina witnessed declining trends during the sowing and mid-season at the rates of 0.04 and 0.05 respectively with the declining annual trends of rain-days during the two seasons not statistically significant. The polynomial of annual trend of rain-days for Katsina indicated a near equal magnitude of decline and recovery during the mid-season. The same is true of the annual trend of rain-days during the sowing season, although with a lower degree of glide. In Kano, the annual trends of rain-days revealed declines at the rates of 0.04 and 0.05 respectively but the declining trends recorded during the two seasons are not statistically significant. Polynomials of trends of annual rain-days for Kano for the sowing season and mid-season indicated recovery tendencies after initial slides with those of the mid-season appearing to be steeper.

In Nguru, rain-days during the growing season declined only slightly at an annual rate of -0.083with a slight recovery tendency while during the mid-season, it declined insignificantly at an annual rate of -0.086 with a sharp decrease from 1951 to the mid 80s followed by a sharp recovery tendency thereafter. In Potiskum, rain-days decreased linearly during the growing season and mid-season at the rates of -0.001 and -0.016 respectively. The decreasing trends of rain-days were significant during the sowing season (P < 0.01) and mid-season (P < 0.05). The second order polynomials of the trends of rain-days during the two seasons depicted similar linear decreasing trends.

Maiduguri witnessed declining rain-days trends during the sowing season and mid-season at annual rates of -0.070 and -0.134 respectively. The glides in rain-days during the two seasons are significant (P < 0.05). The polynomials of trends of rain-days showed a slight recovery tendency during the sowing season while that of the mid-season depicted a stronger recovery tendency. Yola experienced slight increasing trends in rain-days at annual rates of 0.038 and 0.001 respectively. The polynomial of rain-days in Yola showed a slight initial increase which was followed by a slight decreasing tendency during the sowing season while that of the mid-season depicted a near linear increase.

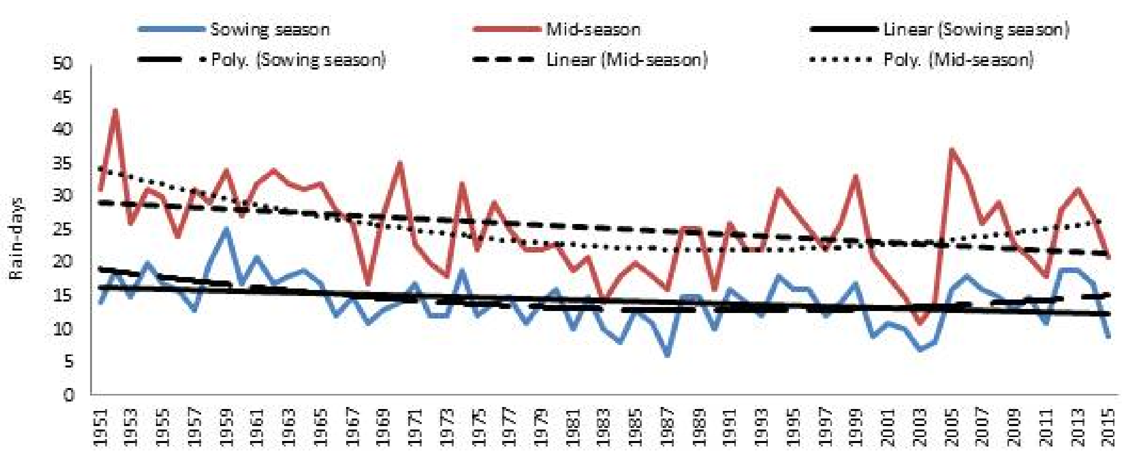

Figure 3a: Annual trends of rain-days during sowing season and mid-season in Sokoto

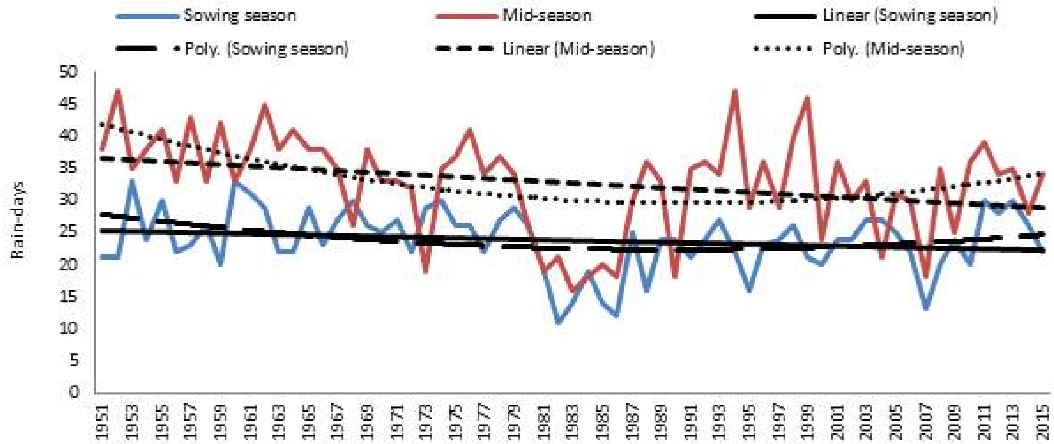

Figure 3b: Annual trends of rain-days during sowing season and mid-season in Gusau

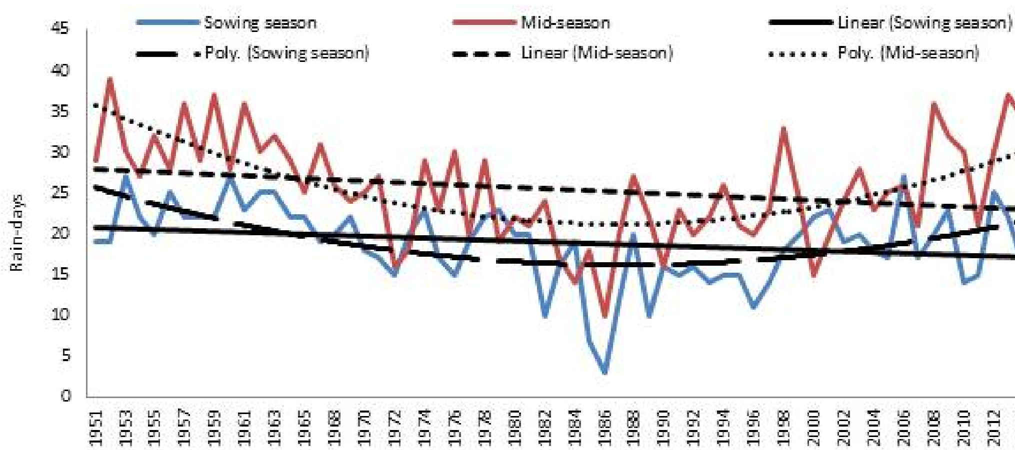

Figure 3c: Annual trends of rain-days during sowing season and mid-season in Katsina

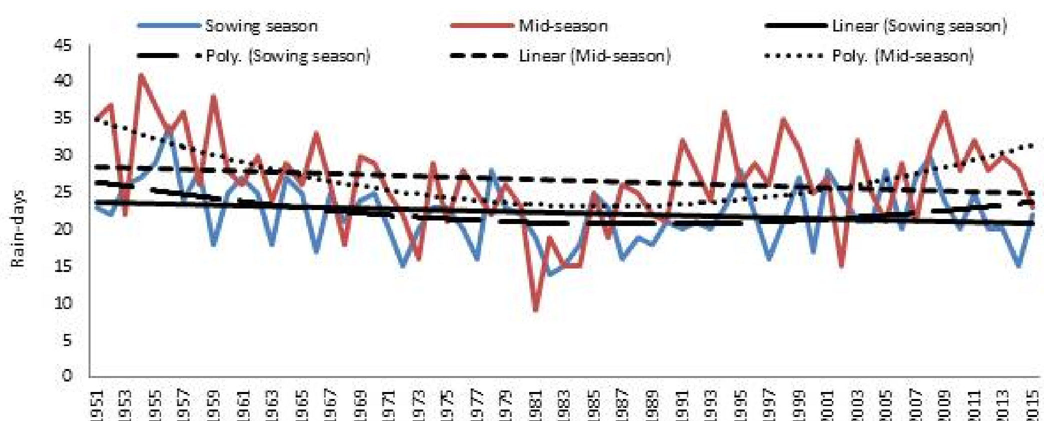

Figure 3d: Annual trends of rain-days during sowing season and mid-season in Kano

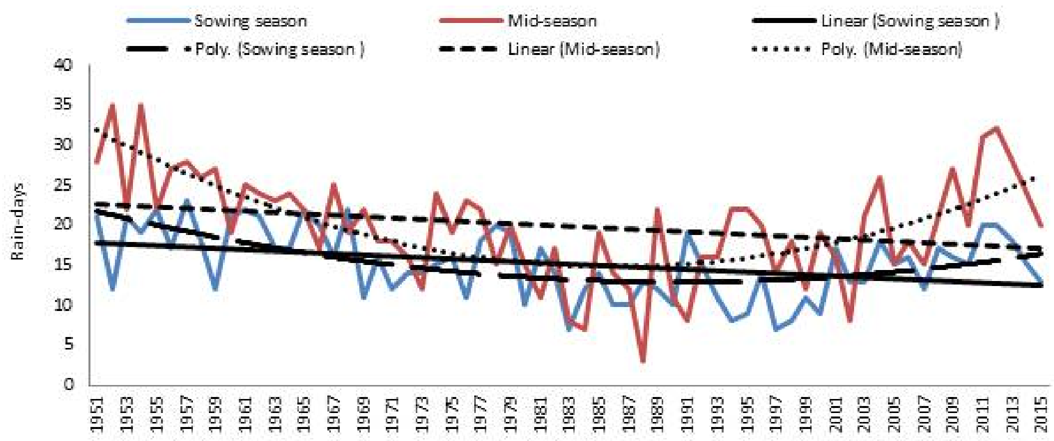

Figure 3e: Annual trends of rain-days during sowing season and mid-season in Nguru

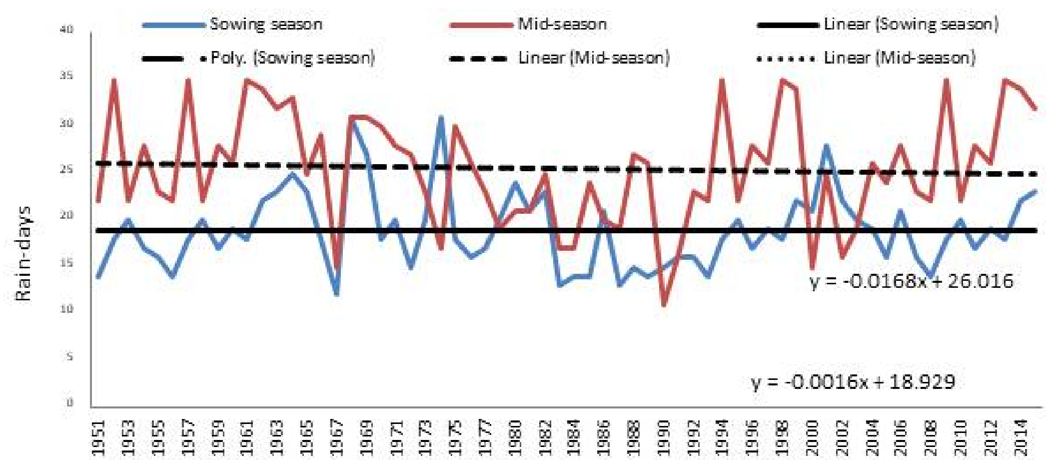

Figure 3f: Annual trends of rain-days during sowing season and mid-season in Potiskum

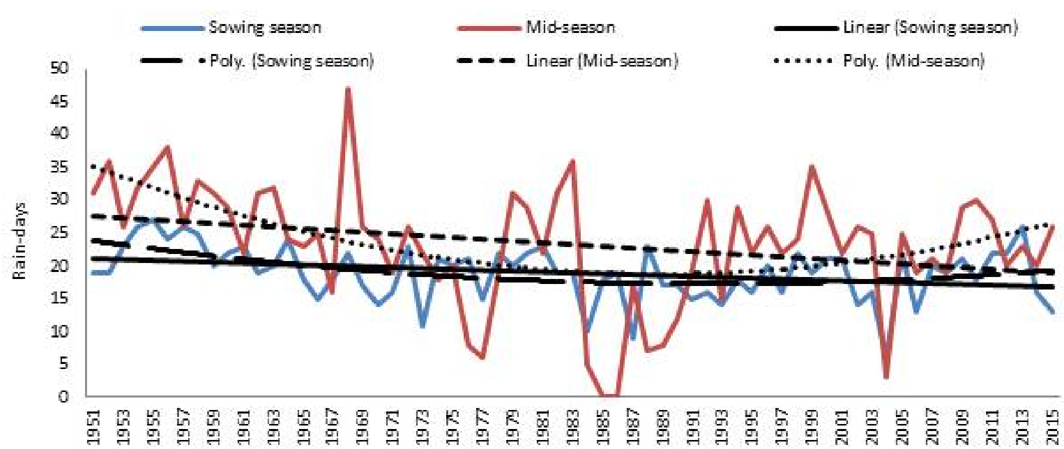

Figure 3g: Annual trends of rain-days during sowing season and mid-season in Maiduguri

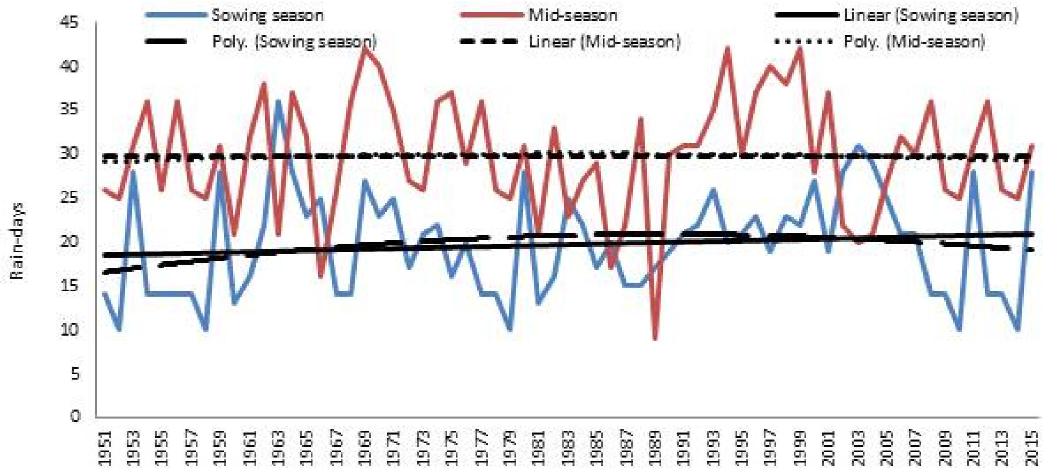

Figure 3h: Annual trends of rain-days during sowing season and mid-season in Yola

Table 4: Annual rates of change and correlation coefficients of rain-days during sowing season and mid-season

Synoptic weather stations	Annual rate of rain-days (sowing season)	Annual rates of change of rain-days (mid-season)	Correlation coefficient (sowing season)	Correlation coefficient (mid-season)
Sokoto	-0.062	-0.119	-0.148	-0.355**
Gusau	-0.049	-0.120	-0.192	-0.296*
Katsina	-0.058	-0.079	-0.228	-0.244
Kano	-0.042	-0.052	-0.188	-0.159
Potiskum	-0.001	-0.016	-0.372**	-0.248*
Nguru	-0.083	-0.086	-0.006	-0.037
Maiduguri	-0.070	-0.134	-0.316*	-0.272*
Yola	0.038	0.001	0.120	0.005

****Significant at 0.05 confidence level***
*****Significant at 0.01 confidence level***

The statistical differences in rain-days in the selected synoptic weather stations during the sowing and mid-season between the 1951-1980 and 1981-2015 periods are presented in Table 5. The difference in rain-days in Sokoto between the two periods was only significant in the mid-season. Gusau, Katsina, Potiskum and Maiduguri witnessed significant differences in rain-days between the two periods in the sowing and mid-season while Kano, Nguru and Yola revealed insignificant differences.

Table 5: Change in rain-days during sowing season and mid-season between 1951-80 and 1981-2014

Pairs	Paired Differences					*t*	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Sokoto sowing season rain-days1 - Sokoto sowing season rain-days2	1.77	6.33	1.16	-0.60	4.13	1.53	29	0.14
Sokoto mid-season rain-fall1 - Sokoto mid-season rain-days2	5.37	8.32	1.52	2.26	8.47	3.532	29	0.00
Gusau sowing season rain-days1 - Gusau sowing season rain-days2	5.10	5.55	1.01	3.03	7.17	5.03	29	0.00
Gusau mid-season rain-days1 - Gusau mid-season rain-days2	6.70	10.52	1.92	2.77	10.63	3.49	29	0.00
Katsina sowing season rain-days1 - Katsina sowing season rain-days2	4.66	6.82	1.27	2.06	7.25	3.68	28	0.00
Katsina mid-season rain-days1 - Katsina mid-season rain-days2	5.34	8.99	1.67	1.92	8.77	3.20	28	0.00
Kano sowing season rain-days1 - Kano sowing season rain-days2	1.77	6.11	1.12	-0.52	4.05	1.58	29	0.12
Kano mid-season rain-days1 - Kano mid-season rain-days2	2.93	10.46	1.91	-0.97	6.84	1.54	29	0.14
Potiskum sowing season rain-days1 - Potiskum sowing season rain-days2	4.57	5.58	1.02	2.48	6.65	4.49	29	0.00
Potiskum mid-season rain-days1 - Potiskum mid-season rain-days2	6.47	9.06	1.65	3.08	9.85	3.91	29	0.00
Nguru sowing season rain-days1 - Nguru sowing season rain-days2	1.53	5.83	1.06	-0.64	3.71	1.44	29	0.16
Nguru mid-season rain-days1 - Nguru mid-season rain-days2	2.30	10.29	1.88	-1.54	6.14	1.22	29	0.23
Maiduguri sowing season rain-days1 - Maiduguri sowing season rain-days2	3.03	6.30	1.15	0.68	5.39	2.64	29	0.01
Maiduguri mid-season rain-days1 - Maiduguri mid-season rain-days2	5.93	14.06	2.57	0.68	11.18	2.31	29	0.03
Yola sowing season rain-days1 - Yola sowing season rain-days2	-1.37	6.96	1.27	-3.96	1.23	-1.08	29	0.29
Yola mid-season rain-days1 - Yola mid-season rain-days2	1.20	9.92	1.81	-2.50	4.90	0.66	29	0.51

Where 1 and 2 represent 1951-1980 and 1981-2015 respectively

3.3 Drought

The percentage distribution of drought intensities is presented in Table 6. Drought of slight intensity occurred mainly in Gusau (69.2%) and less in Sokoto (26%) during the sowing season. During the mid-sowing season, it occurred more in Yola (58.3%) and less in Kano (19%). Drought of moderate intensity occurred most in Kano (43.3%) and least in Sokoto (26%) during the sowing season while it occurred most Potiskum (52%) and least in Sokoto (17.4%) during the mid-season. The highest and lowest percentages of drought of severe intensities occurred in Sokoto (26%) and Gusau (0.0%) respectively during the sowing season while it was witnessed most and least in Katsina (21.4%) and Yola (4.2%) respectively during the mid-season. Similarly, the percentage distribution of drought of disastrous intensity shows that it was witnessed more in Sokoto (15.8%) and least in Gusau and Katsina during the sowing season while it was more experienced in Sokoto (21.7%) and equally less in Gusau and Katsina (0.0%).

Table 6: Percentage distribution of drought intensities

Classification	Sokoto		Gusau		Katsina		Kano		Nguru		Potiskum		Maiduguri		Yola	
	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season	Sowing season	Mid-season
Slight	26	43.5	69.2	48	38.5	39.3	26.7	19.2	44.8	40.7	48	32	30.4	33.3	45	58.3
Moderate	26	17.4	30.8	40	38.5	35.7	43.3	50	27.6	44.4	32	52	34.8	41.6	35	33.3
Severe	26	13.0	0.0	12	15.4	21.4	23.3	19.2	24.1	11.1	12	8	21.7	16.7	10	4.2
Disastrous	15.8	21.7	0.0	0.0	0.0	0.0	3.3	7.7	3.4	3.7	8	12	13.0	8.3	10	4.2

3.4 Discussion

Climatic variability and change and drought are inimical to crop production. Climatic variables are therefore important factors for future sustainability of rice production (Ara *et al*., 2016). The downward trends of rainfall and rain-days coupled with droughts during the sowing season and mid-season of rice farming calendar as observed in this study could pose adverse consequences to rice production in the Sudano-Sahelian region of Nigeria. As Atedhor and Ayeni (2017) argued, while the sowing season coincides with the period of cultivation and germination of rice, sustained rainfall is critical to the normal development and yield of the crop. Unfortunately, irrigation practice is at low ebb in the Sub-Saharan Africa (ACPC, 2011). Until recently small-scale farmers dominated and produced 80-90% of local rice production (SAHEL, 2015). Small-scale farmers are faced with low adaptive capacity to climate change. It is therefore not surprising that Nigeria witnessed diminishing self-sufficiency in rice production from 1961-2015 (Oladimeji, 2017) amid increasing rice importation during 1983-2013 (Ajala & Gana, 2015). The rise in temperature based on climate change scenarios is likely to increase the evapo-transpiration (ET) demand (Abeysingha *et al*., 2016). The impact of elevated temperature on rice output is not merely reflected on yield but as well on grain quality (Zhao & Fitzgerald, 2013).Understanding of rainfall variability and change as well as drought intensity during the different phases of the farming calendar of the crop could provide a fulcrum for informed agricultural adaptation to climate change.

Optimum Agricultural Production (2007) noted that one of the challenges militating against rice production is water shortage as a result of drought. Crop production can increase if irrigated areas are extended or irrigation is strengthened (Kang *et al*., 2009). Rice needs particular conditions with reference to water administration schemes as well as high temperatures necessary to sustain its growth (Guedes *et al*., 2015). Irrigated rice farming schemes lead to higher yields, finest input and elevated proceeds in all agroecological regions of Nigeria in contrast to rain-fed methods (Osawe *et al*., 2017).While pursuing rice irrigation as an adaptation option, it is also important to consider crop selection. As Adenuga *et al. (*2016) note, implementation of improved rice selection has an encouraging impact on the multifaceted poverty standing of the rice cultivating family units.

In spite of numerous policies of the Federal Government of Nigeria, increasing local demand for rice outweighs production (Onyekwena, 2016). Considering the general prevalence of inefficient cropping practices in Nigeria, achieving self-sufficiency in rice production may continue to remain elusive. This could be complicated by the escalating population. Ekpa *et al* (2018), therefore, argues that the present fast population explosion in Sub-Saharan Africa, together with constantly soaring malnutrition magnitudes, demand approaches that traverse the entire food value chain.

5. Conclusion

The paper examined rainfall variability and change as well as drought intensities in the Sudano-Sahelian region of Nigeria with a focus on the sowing season (June - July) and mid-season (August - October) of the farming calendar of rice using monthly rainfall and rain-days data for 8 synoptic weather stations (Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru, Maiduguri and Yola) and rain-days for 65 years (1951-2015). Rainfall decreased annually in Katsina and Nguru while it increased in Sokoto, Gusau, Kano, Potiskum, Maiduguri and Yola during the sowing season. Rainfall decreased in Sokoto, Katsina, Potiskum, Nguru, Maiduguri and Yola while it increased in Gusau and Kano during the mid-season. The annual trends of rainfall during the sowing seasons are significant in Kano and Nguru while it is significant in Gusau, Katsina and Kano during the mid-season. Rainfall changed significantly in Sokoto Katsina, Kano, Nguru, and Yola during the mid-season.

Rain-days declined annually in Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru and Maiduguri while it increased in Yola during the sowing season. It decreased annually in Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru and Maiduguri while it increased in Yola during the mid-season. The annual trend of rain-days was significant in Potiskum and Maiduguri during the sowing season while it was significant in Sokoto, Gusau, Potiskum and Maiduguri during the mid-season. Rain-days changed significantly in Gusau, Katsina, Potiskum and Maiduguri during the sowing season while it changed significantly in Sokoto, Gusau, Katsina, Potiskum and Maiduguri during the mid-seasons. Generally, droughts were more of slight and moderate intensities with Sokoto having the highest percentages of severe and disastrous categories. Timely weather forecasts and irrigation in relation with the different phases during rice farming calendar are recommended.

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Declaration of interests

None

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