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SHRINKING RAIN-DAYS AND THE IMPERATIVES FOR CLIMATE-SMART AGRICULTURE IN THE SUDANO-SAHELIAN REGION OF NIGERIA

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ABSTRACT

Rainfall distribution has far-reaching consequences on ecosystems and socio-economic activities, of which agriculture is most significant. This paper therefore, examined the inter-annual trends of rain-days in the Sudano-Sahelian region of Nigeria using monthly data of eight synoptic weather stations (Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru, Maiduguri and Yola) for 64 years (1951-2014). The inter-annual trends of rain-days of the synoptic weather stations were investigated using simple linear regression while significance of the trends was analysed using correlation. The change in rain-days between the periods 1951-1982 and 1983-2014 was evaluated using pair-wise t-test. Annual rain-day declined in Sokoto, Gusau, Katsina, Kano, Nguru, Potiskum and Maiduguri at the rates of -0.1692, -0.2114, -0.1275, 0.0839, -0.1748 and -0.2357 respectively while Yola witnessed increase and at the rate of 0.0209. The decrease in rain-days were significant in Sokoto, Nguru and Maiduguri with correlation coefficients of -0.348, -0.342, -0.367 ($P<0.01$) respectively and in Gusau at -0.279 ($P<0.05$). The synoptic weather stations, except Yola, showed recovery tendencies. Change in annual rain-days was significant in Sokoto, Gusau, Katsina, Potiskum, Nguru and Maiduguri with t-statistics of 2.282, 2.638, 2.261, 1.730, 2.793 and 2.536 ($P<0.05$) respectively. The linear glides in rain-days in the region suggest the imperatives for climate-smart agricultural practices such as irrigation, mulching and cultivation of drought-tolerant varieties.

1. INTRODUCTION

The distribution of rainfall dictates the rhythm of diverse socio-economic activities in Nigeria of which agriculture is most paramount. Rainfall is therefore considered as the most decisive weather element in crop production (Ayoade, 2002). It dictates the length of the growing season under rain-fed cropping season which is most prevalent in the across the ecological landscape of Nigeria as in sub-Saharan Africa.

Different systems have been used to explain rainfall pattern over the Nigerian landscape. Among the mechanisms is the Inter Tropical Discontinuity (ITD) which is the moisture discontinuity. Associated with the ITD are two air masses, the tropical maritime airmass which originates from the Atlantic and it is coupled with rain-bearing systems such as the disturbance lines, particularly the easterly waves, squall lines and the two tropospheric jet streams while the tropical continental airmass originates from the Sahara Desert and it is dry and dusty (Olaniran, 2002). The south-north excursion and reversal the ITD influence the pattern of rainfall across Nigeria and by extension West Africa. The whole Nigeria receives rainfall in August when the ITD assumes its northern most position of 20^o north in August while it retreats abruptly to around 5^o in January when the country experiences hamarttan due to prevalence of the tropical continental airmass. Accordingly, other mechanisms which influence rainfall pattern in Nigeria are Sea Surface Temperature Anomaly (SSTA), Tropical Jet Stream, and El nino/Southern Oscillation (ENSO) (Olaniran, 2002).

Declining trends of rainfall have been reported in Nigeria, especially in the Sudano-Sahelian belt (Atedhor, 2014; Odekunle, 2010; Atedhor, 2016) as well as change in rainfall seasonality (Atedhor and Enaruvbe, 2016). Droughts incidences of slight to moderate intensities have also been reported across the Nigeria such as occurred in the Sudano-Sahelian region (Abaje *et al.*, 2013; Atedhor and Odjugo, 2012a; Atedhor, 2014) and during the planting season in the rainforest belt (Atedhor, 2016). No study has been fully devoted to the analysis of rain-days, the parameter which highlights the distribution of rainfall. This is particularly important considering the fact only about 4% of arable land is irrigated in sub-Saharan Africa (ACPC, 2011). Umar (2010) has reported change in the length of the cropping season in Nigeria. These events coupled with increasing evapo-transpiration due to global warming will continue to exacerbate crop-moisture stress owing to the predominance of rain-fed agriculture. Thus, the reducing length of the growing season has elicited adaptation strategies such as cultivation of early maturing crops (Odjugo, 2010). It is however, not clear whether the Sudano-Sahelian region of Nigeria is witnessing declining trend and change in rain-days as rainfall. This paper, therefore, examines inter-annual trend and change in rain-days in Sudano-Sahelian region of Nigeria.

2. METHODOLOGY

The Sudano-Sahelian region of Nigeria lies between the northern boundaries of the Guinea Savannah to the northern fringe of the country (Figure 1). The area experiences annual rainfall which decreases from 800mmin its southern boundary to less than 500mm in the extreme north- east. The region experiences wet season for about four months (June to September). Mean temperature is relatively high in the area, particularly during the onset of the wet season and could be above 30 ^{o}C. The savannah vegetation which is predominant in the region becomes scrubby towards the extreme northeast (Aregheore, 2009). Rustic livestock rearing and cereal farming under rain-fed system are the prevalent livelihoods in the region.

Rain-days data for 8 synoptic weather stations (Sokoto, Gusau, Katsina, Kano, Potiskum, Nguru, Maiduguri and Yola) were selected based on spread and uninterrupted availability of data. The data spanned a period of 64 years (1951-2014). The trend of annual rain-days of the synoptic weather stations was analyzed using simple linear regression. The simple linear regression equation is expressed as:

$$Y = \beta_0 + \beta_1 X + \varepsilon \tag{1}$$

Where β_0 is the Y-intercept, $\beta_1$is the change in the mean value of Y associated with a unit increase in$X$, while Ɛ is an error term that describes the effects on y of all factors other than the value of the independent variable X. The significance of the trends of rain-days were computed using Pearson's product moment correlation coefficients (r) were calculated between the rain-days (y) and years (χ) using the following formula:

$$r_s = \frac{\frac{\sum xy}{N} - \bar{x}\,\bar{y}}{\sigma x \; \sigma y} \tag{2}$$

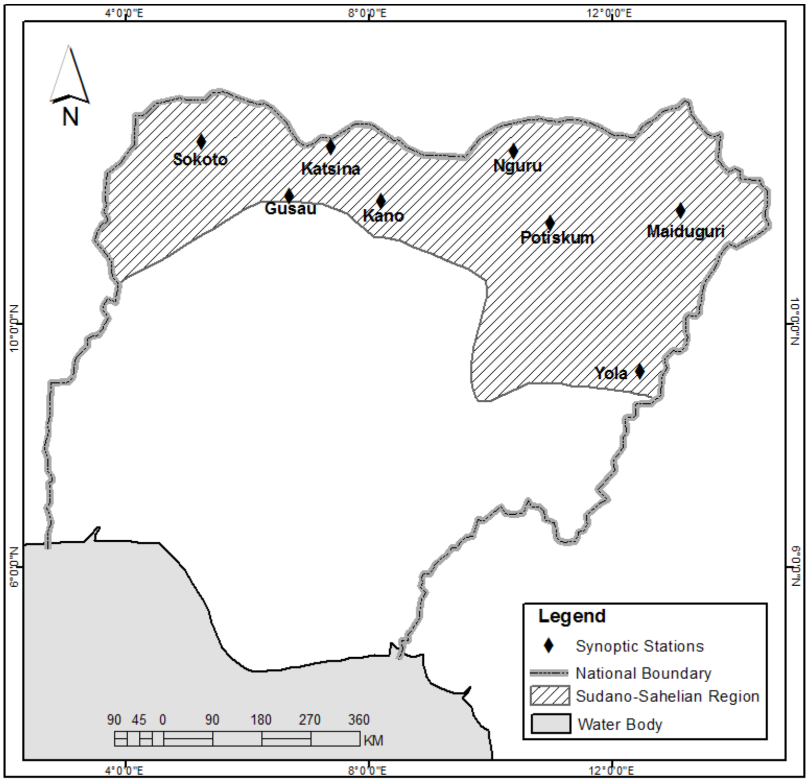

Figure 1: Sudano-Sahelian region and selected synoptic weather stations

The annual rain-days for each of the synoptic weather stations were partitioned into two time slices (1951-1982 and 1983-2014) and the change in rain-days between the two time-slices were investigated using student's *t* test as follows:

$$t = \frac{\bar{a}-\bar{b}}{\sqrt{\frac{\sigma a^2}{na}+\frac{\sigma b^2}{nb}}} \tag{3}$$

Where *a* represents mean rain-days (1951-1982), *b* mean rain-days (1983-2014), σ standard deviation and *n* number of years. The seasonal distribution of rain-days was investigated by computing the monthly mean rain-days for the 1951-2014 period.

3. RESULTS AND DISCUSSION

The annual trends of rain-days for the synoptic weather stations are presented in Figures 2-9. All the synoptic weather stations witnessed declining trends of annual rain-days with the exception of Yola. Annual rain-days in Sokoto, Gusau and Katsina declined at annual rates of -0.1692, -0.1275 and -0.1275 respectively (Table 1). Similarly, annual rain-days in Kano, Nguru, Potiskum and Maiduguri decreased at the rates of -0.0839, -0.1748, -0.0375 and -0.2357 respectively. Thus, out of the synoptic weather stations that were selected in this study, Maiduguri witnessed the sharpest decline in annual rain-days while Potiskum experienced the slightest decline while Yola experienced a slightly linear upward trend of annual rain-days at the rate of 0.0209. Generally, the savannah belts of Nigeria have been identified as the zone that is most characterized with rainfall variability (Owonubi, 1994; Ayanlade *et al.*, 2010). This is reflected in the inter-annual variation of rain-days in the selected synoptic weather stations. Low annual rain-days may translate into annual low rainfall which coincides with the incidence of El-Nino/Southern Oscillation (ENSO) (Ati *et al.*, 2010; Umar, 2012).

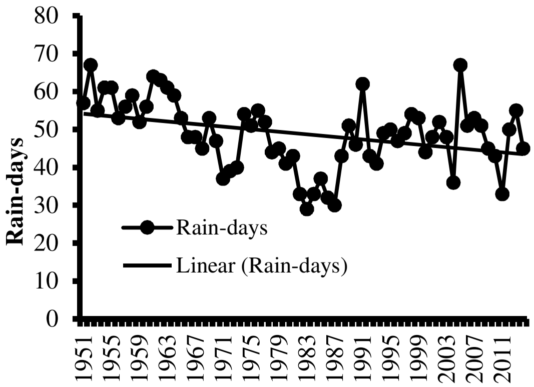

Figure 2: Annual trend of rain-days in Sokoto (1951-2014)

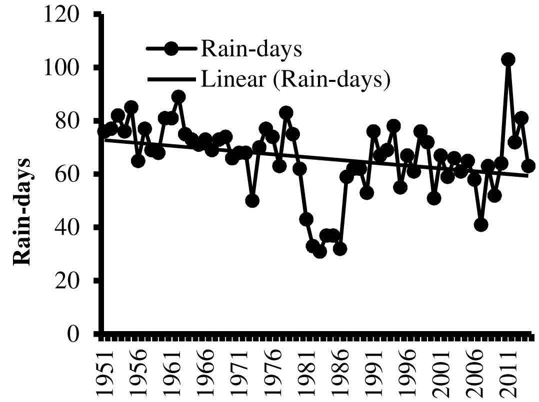

Figure 3: Annual trend of rain-days in Gusau (1951-2014)

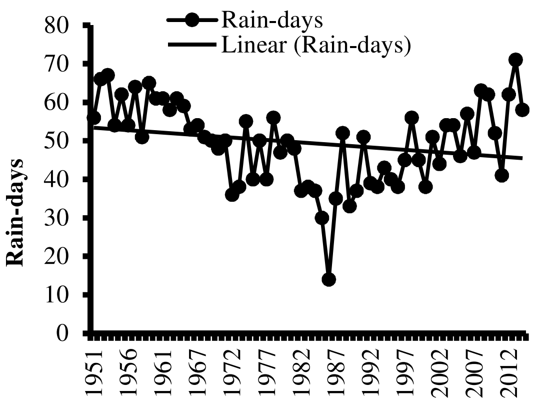

Figure 4: Annual trend of rain-days in Katsina (1951-2014)

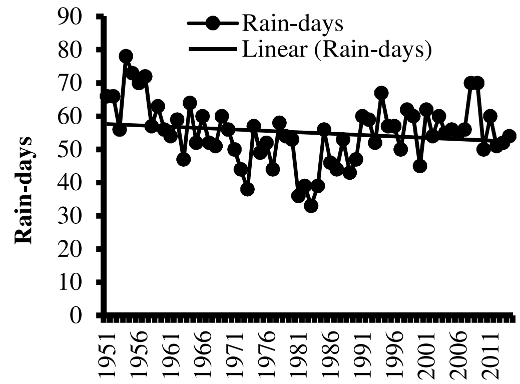

Figure 5: Annual trend of rain-days in Kano (1951-2014)

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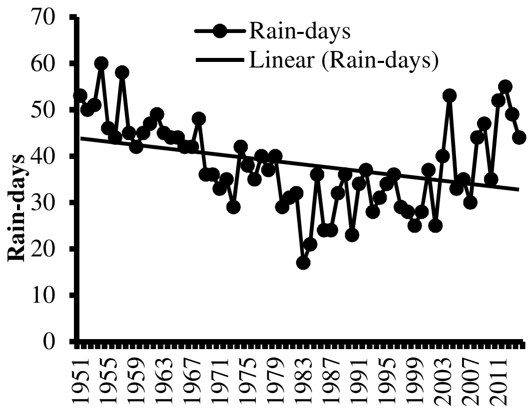

Figure 6: Annual trend of rain-days in Nguru (1951-2014)

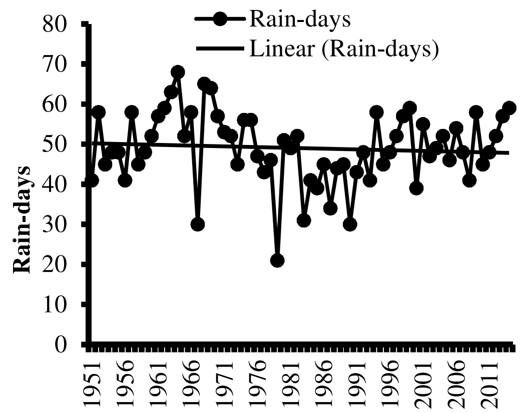

Figure 7: Annual trend of rain-days in Potiskum (1951-2014)

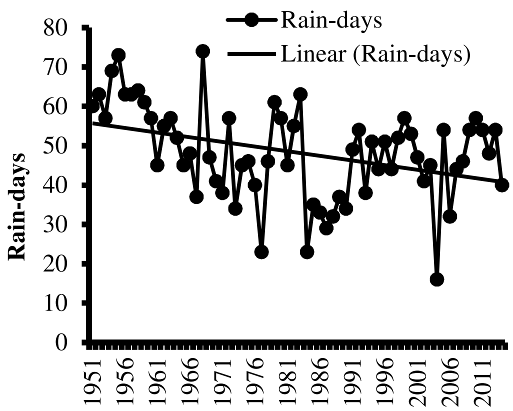

Figure 8: Annual trend of rain-days in Maiduguri (1951-2014)

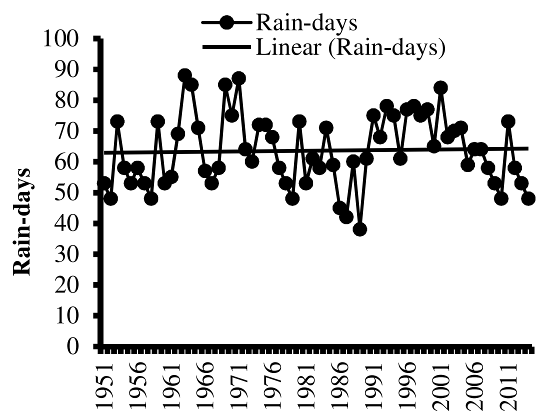

Figure 9: Annual trend of rain-days in Yola (1951-2014)

The monthly distributions of rain-days in the selected synoptic weather stations are presented in Figure 10. In all the stations, rain-days peaked in August with Gusau and Nguru having the highest and lowest rain-days respectively in the month of August. Near zero rain-days were experienced in the all station from the months of November to the month of April with the exception of Yola which witnessed a relatively high rain-day in the month of April. Although the pattern of monthly distribution of rain-days appears to be uniform in the selected synoptic weather stations, the number of rain-days in the stations varied among the stations.

The monthly distribution of rain-days in the selected synoptic weather stations depicts the rhythm of rainfall pattern over the region which portrays the northward excursion and retreat of the ITD in response to the prevalence of the tropical maritime and tropical continental airmasses (Olaniran, 2002). With the exemption of relief modification, the distribution of rainfall is largely a manifestation of the fact that the moisture source for Nigeria is the Atlantic Ocean and the amount of rainfall mainly depends on the penetration inland of the tropical maritime airmass (Ojo *et al*., 2003). The higher rain-days experienced in the month of August in the selected synoptic weather stations highlight the fact that rainfall in the region is of single peak which usually occurs in August (Adebayo, 1999; Aregheore, 2009).

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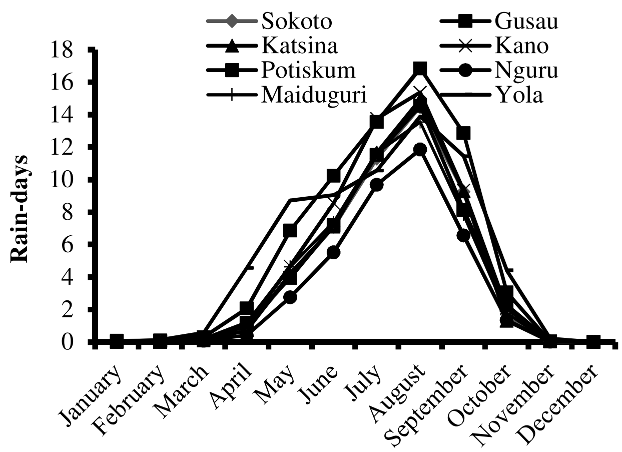

Figure 10: Mean monthly rain-days (1951-2014)

The statistical significance in the trends of rain-days in the selected synoptic weather stations are presented in Table 1. The regression equations and correlation coefficients show that annual rain-day witnessed decline during the period under investigation with the exception of Yola. Thus, rainfall declined at annual rates of -0.1692, -0.2114, -0.1275, -0.0839, -0.1748, -0.0375, -0.2357 in Sokoto, Gusau, Katsina, Kano, Nguru, Potiskum, Maiduguri respectively while it increased at an annual rate of 0.0209. Correlation coefficients for the synoptic weather stations show that among the stations where rain-days witnessed decline, the trends were significant in Sokoto (P<0.01), Gusau (P<0.05), Nguru (P<0.01) and Maiduguri (P<0.01). The positive annual trend of rain-days in Yola was not significant.

Table 1: Regression and correlation coefficient of trends of rain-days

Synoptic Weather Station	Regression Equation	Correlation
Sokoto	y = -0.1692x + 54.281	-0.348**
Gusau	y = -0.2114x + 72.903	-0.279*
Katsina	y = -0.1275x + 53.493	-0.218
Kano	y = -0.0839x + 57.741	-0.170
Nguru	y = -0.1748x + 43.961	-0.342**
Potiskum	y = -0.0375x + 50.251	-0.078
Maiduguri	y = -0.2357x + 55.927	-0.367**
Yola	y = 0.0209x + 62.899	0.033

** Significant at 0.05 (2-tailed); ** Significant at 0.01 (2-tailed)*

The difference in annual rain-days in the selected synoptic weather stations between the 1951-1982 and 1983-2014 normals are presented in Figure 11. All the stations witnessed fewer rain-days during the 1983-2014-time slice. This shrinking of rain-days in decreasing order were Nguru (18.25%), Maiduguri (15.92%), Gusau (13.50%), Katsina (11.94%), Sokoto (10.96), Potiskum (7.25%), Kano (2.85%) and Yola (0.05%). This implies that rainfall witnessed higher frequencies during the 1951-1982 period.

Rainfall amount and distribution are cardinal to crop yield, especially under rain-fed agricultural practice. As earlier noted, studies have reported significant decline in rainfall in synoptic weather stations in the Sudano-Sahelian region of Nigeria (Atedhor, 2014; Odekunle, 2010; Umar, 2010; Umar, 2012). Food security and climate change are closely linked in the agricultural sector and key opportunities exist to transform the sectortowards climate-smart systems that address both (FAO, 2010). It is therefore, likely that the years with poorly distributed rainfall will be associated with crop-moisture stress which could exacerbate food insecurity. FAO (2017) has already reported that Nigeria is food deficit, the most populous country in

Africa. It is therefore, imperative that we rethink our food production strategies by adopting climate-smart agriculture (CSA). CSA practices can sustainably increase food productivity and system resilience while reducing greenhouse gas emissions (FAO, 2010). CSA has the potential to increase productivity and resilience while reducing vulnerability, especially amongst small scale farmers as well as preserve natural resources for posterity.

The negative change in rain-days in most of the synoptic weather stations from the 1951-1982 period to 1983-2014 period, further reinforce the intensification of the anthropogenic factors which mainly constitute the drivers of changing climate. This calls for sustainable use of natural resources. Sustainable agricultural practices exist in the country such as mulching, crop rotation; the cultivation of legumes for soil nitrogen fixation rotational grazing and mixed cropping. Atedhor and Omonigho (2017) have reported significant variation of soil hydrothermal characteristics with tillage systems while the number of leaves and leaf area of green leaf (*Amaranthus cruentus)* were higher in the E–W orientation with bed tillage system having the highest values. Related studies have investigated the effects of tillage and mulch on tomato (Odjugo and Atedhor, 2001), oil palm (Isenmila, 2005), Okro (Atedhor and Odjugo, 2012b) and cucumber (Ibeawuchi *et al.,* 2007). Lamentably, there is also a disconnection between research and farmers in Nigeria. This is largely due to the low ebb of extension services which is supposed to be the vehicle for the transport of research findings to farmers for implementation. One of the implications of this lacuna is that weather and climatic information and measures that can be adopted to ameliorate the suffering of farmers do not get to them. This makes it difficult for farmers, especially small-scale farmers to be weather-ready and climate-smart.

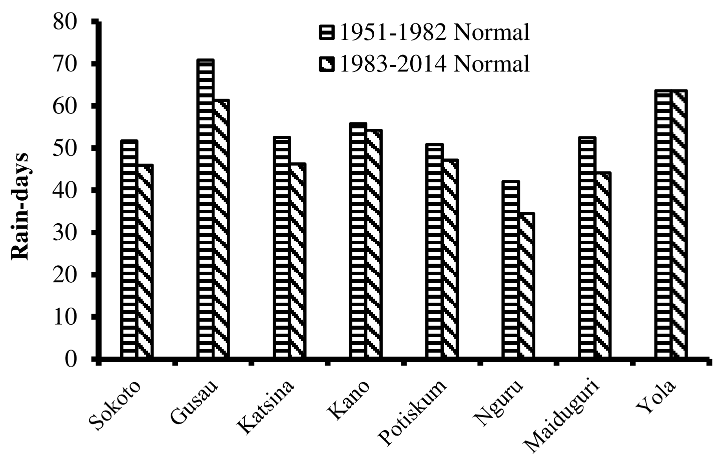

Figure 11: Change in annual rain-days between 1951-1982 and 1983-2014

The significance of the variations of rain-days between the 1951-1982 and 1983-2014 time slices are presented in Table 2. The pair-wise t-test statistics show that rain-days varied significantly in Sokoto (t=2.282, P<0.05), Gusau (t=2.638, P<0.05), Katsina (t=2.261, P<0.05), Nguru (t=2.793, P<0.05) and Maiduguri (t=2.536, P<0.05).

As earlier noted, diverse mechanisms influence rainfall pattern of the Nigerian landscape. Of these mechanisms, biogeophysical feedback mechanisms show that reduction in vegetation cover lead to increase in albedo of the land surface and consequently alter the energy balance of the surface –atmosphere system which eventually induce increased divergence in the lower atmosphere and reduced uplift over higher albedo region and ultimately lead to less rainfall and maintenance of drought condition (Olaniran, 2002). Thus, changes in land cover over the Sudano-Sahelian region of Nigerian due to increasing pressures from urbanization, farming, grazing and felling trees for firewood, inter alia, may have contributed to the significant change in rain-days in most of synoptic weather station between the 1951-1982 and 1983-2014 time slices.

Table 2: T-test of change in rain-days

Pairs	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Sokoto 1 – Sokoto 2	5.68750	14.09973	2.49250	0.60400	10.77100	2.282	31	0.030
Gusau 1 – Gusau 2	9.56250	20.50639	3.62505	2.16916	16.95584	2.638	31	0.013
Katsina 1 – Katsina 2	7.38710	18.18732	3.26654	0.71594	14.05826	2.261	30	0.031
Kano 1 – Kano 2	1.59375	15.41440	2.72491	-3.96374	7.15124	0.585	31	0.563
Potiskum 1 – Potiskum 2	3.68750	12.06017	2.13196	-0.66065	8.03565	1.730	31	0.094
Nguru 1 – Nguru 2	7.68750	15.57176	2.75273	2.07328	13.30172	2.793	31	0.009
Maiduguri 1 – Maiduguri 2	8.34375	18.61080	3.28996	1.63384	15.05366	2.536	31	0.016
Yola 1 – Yola 2	0.03125	13.57057	2.39896	-4.86146	4.92396	0.013	31	0.990

Where 1 and 2 represent 1951-1982 period and 1983-2014 period respectively

4. CONCLUSION

This paper examined the inter-annual trend and change in rain-days in the Sudano-Sahelian region of Nigeria. Annual rain-day experienced declining trend in Sokoto, Gusau, Katsina, Kano, Nguru, Potiskum and Maiduguri while Yola witnessed increasing trend. The decreases in rain-days were statistically significant in Sokoto, Nguru, Maiduguri and Gusau. Change in annual rain-days was significant in Sokoto, Gusau, Katsina, Potiskum, Nguru and Maiduguri between the 1951-1982 and 1983-2014 time frames. The linear glides in rain-days in the region suggest the imperatives for CSA practices such as irrigation, mulching and cultivation of drought-tolerant varieties.

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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