

# Monsoonal rainfall characteristics in the context of climate adaptation planning for rain-fed agriculture in the Sudano-Sahelian area of Northwestern Nigeria

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## Research Article

**Keywords:** Adaptation, climate change, rainfall characteristics, Sudano-Sahelian Zone, Northwestern Nigeria

**Posted Date:** June 7th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-206299/v1>

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# Abstract

This study was aimed at assessing monsoonal rainfall real onset dates (RODs), real cessation dates (RCDs) and extent of association between cumulative rainfall (CR) and length of growing season (LGS) in the context of climate adaptation planning for sustainable rain-fed agriculture in the Sudano-Sahelian area of Northwestern Nigeria. Daily rainfall data of four stations purposively selected namely: Gusau, Kano, Katsina and Sokoto for the period 1981–2018 were collected from Nigerian Meteorological Agency. The data were analyzed and the Intra-seasonal Rainfall Monitoring Index (IRMI) was generated. IRMI was used in determining the RODs and RCDs of rainfall and LGS and CR. The Mann–Kendall test was used to detect trends in rainfall characteristics. Findings revealed that RODs, unlike RCDs of rainfall in the study area, show extensive variations from one station to another. There is a very low correlation (0.07 coefficient) between latitudes and early onsets (EOs). There is however a strong positive correlation (0.8 coefficient) between meridians and EOs of rains. Late onsets (LOs) recognize latitudinal differences to the extent that there is strong positive correlation (0.7 coefficient) between lines of parallels and LOs of rains. The three types of onsets interchanged with one another annually without a clear trend in the RODs and RCDs phases. We conclude that non-definite trends in RODs and RCDs pose a strong challenge to long term adaptation planning. The recommendations of the study are geared towards enhancing climate change adaptation in the context of complicated rainfall characteristics of the study area.

## 1.0 Introduction

The monsoonal rainfall season in the Sudano-Sahelian agro-ecological zone of Northwestern Nigeria lasts for only about four to five months in a year. The distribution of rainfall, its commencement and ending in semi-arid and dry sub-humid zones of the study area have been highly variable in both space and time (Umar and Adamu, 2019). Alternating of a moisture-laden wind from Atlantic ocean with a dry wind originating from the Sahara desert derives a cyclic movement of rain-bearing mechanism that ensue high inter annual rainfall variability that frequently culminates into extreme events such as dry spells, droughts and floods (Ati, Strigter & Oladipo, 2002; Umar, 2016; Umar & Adamu, 2019). This has been occurring despite the fact that Northwestern Nigeria has been acknowledged for its high performance in rainfed agricultural productivity of cereals, legumes, vegetables and fruits. Rainfall characteristics such as real onset dates (RODs), real cessation dates (RCDs), length of growing season (LGS), and cumulative rainfall (CR) are critical factors for sustaining crop productivity in rainfed agriculture especially in this drylands region. It is increasingly acknowledged that very early and delayed planting may have damaging effects on the cultivated plants and farmers' financial welfare. Farmers who engaged in early planting may guided by false onset of rainfall and this can lead to the wilting and failure of their crops. False onsets add to the hardship of farmers who have to replant after the destruction of their initial cultivation (Umar & Adamu, 2019). Likewise delayed planting by farmers may induce a reduced the LGS of their cultivated crops that can adversely affect its yields especially the late-maturing varieties.

Researchers (such as: Shevakuma, 1988; Oguntunde, Lischeid, Abiodun & Dietrich, 2014) established a

Loading [MathJax]/jax/output/CommonHTML/jax.js start of rains and the LGS. Thus, earlier onset (EO) most

often leads to longer LGS and late onset (LO) is correlated with shorter LGS. There is an understanding that the LGS is more dependent on rainfall onset than on its cessation (Omotosho, 1992). One of the main determinants of planting suitability for a crop anywhere is its moisture requirement and LGS which is dependent upon RODs and RCDs. Rural households in the dryland of Northwestern Nigeria had been exposed to variety of climate risks such as harvest failure and death of livestock as a result of droughts resulting from extreme rainfall variability (Umar & Adamu, 2019). Thus, determining monsoonal rainfall characteristics is essential in adapting to climate variability and change. The variability and unreliability of LGS in the study area exacerbate great risk to agricultural productivity (Mortimore, 2005; Haruna & Murtala, 2019). It is acknowledged that the extent to which climate variability is managed forms the bedrock for a wise adaptation to climate change and that “adaptation can be motivated by a diverse set of current and future climate hazards, including observed and expected changes in average climate, climate variability, and climate extremes” (Fußsel, 2007, p266).

Water balance models have been extensively built and employed in determining RODs and RCDs by scholars (such as: Walter, 1967; Kowal & Knabe, 1972; Benoit, 1977; Stern, Dennett, & Garbutt, 1981; Faheun, 1983; Nicholls, 1984; Mhita & Nassib, 1987; Sivarkumar, 1988; Nnoli, 1996; Samba 1998; Omotosho, Balogun & Ogunjobi, 2000; Ati, Stigter & Oladipo, 2002; AGRHYMET, 2005). We can deduce from these works that for sure RODs and RCDs differ from place to place and they can be measured using multitude quantitative analytical frameworks ranging from simple to complex mathematical equations. Some of the reasons behind the disparity in these frameworks include that scholars differed in the agroclimatological settings in which their models were developed (predominantly tropical Savannas and forests of Australia, Kenya, Burkina Faso, Southern Nigeria and Northern Nigeria, etc.). Even models that focus on a single setting may yield different results in calculation of RODs and RCDs because scholars differ in the variables they look into while constructing their models. Those variables employed in the models construction include amount of rainfalls (cumulative rainfall) period for distribution of amount of rainfall, local crop water requirement, duration of dry spell, usual time of crop planting and etc.

The model builders tried as much as possible to key into actual or real (actual) onset, avoid false onset and provide a reliable retrospective or proactive prediction of rainfall characteristics, especially the onset which is needed to determine a less risky planting date or planting method, or sowing of less risky types/ varieties of crops in responsive farming (Stewart, 1991). In this regard, using daily rainfall data that has been reduced or summarized into pentads rainfall amounts, Usman & Abdulkadir, (2012) proposed the Intra-seasonal Rainfall Monitoring Index (IRMI) model that determines RODs and RCDs of rainfall. Real or actual onset dates are determined using this index equation's that computes RODs, RCDs and CR commencing from the 1st May. This study adopted the IRMI because apart from being among the latest, when compared with other models, IRMI is very simple to use and has been specifically developed to be applied in the study area and similar agro-ecological zones. Therefore, this study was aimed at assessing monsoonal rainfall real onset, real cessation and extent of association between CR and LGS in the context of climate adaptation planning for sustainable rain-fed agriculture in Sudano-Sahelian area of Northwestern Nigeria. The objectives of the research are to: determine the RODs and RCDs of rainfall in

the study area; to examine spatiotemporal interannual and to establish (if any) nature and extent of trends in and relationships between LGR and CR.

## 2.0 Materials And Methods

### 2.1 Study Area

The study area as can be seen from Fig. 1 is located between latitudes 11° 00' N to 13° 45' N and Longitudes 3° 30' E to 11° 35' E (Umar, Mohammed & Adamu. 2017). The climate of the area is tropical wet and dry type coded  $A_w$  by W. Koppen. The vegetation comprises of tropical grasslands of the Sudan and Sahel Savanna. Agriculture, the predominant economic activity in the study area, is mostly rain fed. Crops produced include millet, sorghum, rice, cowpea, soy beans, wheat, groundnut, maize, cotton, sesame and vegetables (Umar, 2016, Umar & Adamu, 2018). In terms of agricultural land-use, the study area comprises of two wide belts of dominant staple cereals, millet and sorghum grown in varying proportions. There are other common cash crops that further distinguish the local economy namely cowpeas, groundnuts, cotton and sesame.

### 2.2 Procedures for sampling, data collection and analyses

A purposive sampling procedure was adopted in the selection of four synoptic meteorological stations out of the six of them in the Northwestern Nigeria (Fig. 1) namely: Gusau, Kano, Katsina, Sokoto, Yelwa and Zaria. The selection was done while giving consideration to stations with longer consistent and most reliable daily rainfall records.

Daily rainfall data of four stations (Gusau, Kano, Katsina and Sokoto) for the period 1981–2018 were collected from Nigerian Meteorological Agency (NiMet) Head Office, Abuja. The data analyzed and IRMI was generated. This determined RODs, RCDs, LGS and CR of rainfall in the study area. The first step data analysis was compute pentad rainfall summations which formed the units of analysis of the study. This has been done with the aid of rainfall pentad calendar. After this, IRMI was employed to generate an index that determines the real onset date and the real cessation dates on a pentad-by-pentad basis beginning from the 1st May using the Eq. 1:

$$IRMI = \frac{(Cpt)^2}{(hpt \times Nb \times 100)} \text{Eqn. 1}$$

Where  $Cpt$  = Cumulative pentad rainfall since May 1

$hpt$  = The highest pentad total rainfall since May 1

$Nb$  = Number of breaks in rainfall (pentads with less than 5 mm of rainfall) and

100 = a factor

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The 'actual' or 'real' onset of rains is taken as the pentad within which the index is  $\geq 1$  for the first time. The actual or real cessation date is calculated when the cumulative pentad rainfall remain the same for two or more consecutive time.

With regards to detection of trend, a preliminary normality test we conducted on the distribution of RODs and RCDs (Table 1) revealed that these rainfall characteristics in the study area are not normally distributed. Hence employment of non parametric tests such as Mann-Kendall test to detect trend has become necessary. The Mann-Kendall is a nonparametric test for finding trends in time series. This test is widely used because one of the advantages of this test is that it does not require data to conform to any distribution before it can be used. The term trend has been defined to stand for to a change characterized by a smooth, monotonic increase or decrease of average values over the period of record (Donaire, 2000: El-Tantawiy, 2006).

The equations for computation of Mann-Kendall Statistics  $S$ , ( $S$ ) and normalized test statistic  $Z$  are as follows:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n-1} \text{sgn}(x_j - x_k) \text{ Eqn.2}$$

$x_j$  is a time series ranked from  $i = 1, 2, \dots, n-1$  and  $x_j$ , ranked from  $j = i + 1, 2, \dots, n$ .

Where

$$\text{sgn}(x_j - x_k) = \begin{cases} +1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \text{ Eqn. 3}$$

The equation for calculation of the variance of  $S$ .  $\text{VAR}(S)$  is:

$$\text{VAR}(S) = \frac{n(n-1)(2n-5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)}{18} \text{ Eqn. 4}$$

Where  $n$  = number of data points;  $t_i$  = are the ties of the sample time series; and  $m$  = number of tied value (a tied group is a set of sample data having same value)

Equations 2 and 3 were then used to compute the test statistics  $Z$ . The computation for normalized test statistics  $Z$  is given as:

$$Z = \begin{cases} \frac{S - 1}{\sqrt{\text{VAR}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S + 1}{\sqrt{\text{VAR}(S)}} & \text{if } S < 0 \end{cases} \quad \text{Eqn. 5}$$

A positive value of Z indicates an upward trend; a negative value indicates a downward trend, and a zero value indicates no trend. Alternatively, the trend can be determined using computation software applications such as: R-package, SPSS, and PAST3 statistical package.

RODs and RCDs were analysed in PAST3 statistical package where an index was generated through transformation (that is by getting the deviation of all the observations from the RODs and RCDs means). The result was interpreted as follows:

### Index Types of Onset / Cessation

< (less than) 1.99 Early Onset / Cessation

-1.99 to 1.99 Normal Onset/ Cessation

> (greater than) 1.99 Late Onset / Cessation

The rest of the computations and analyses such as normality test, generation of summary statistics/RODs and RCDs anomalies, correlation, fitting to normal of frequency distribution histogram and etc. were done either in MS Excel environment or in the PAST3 statistical package.

## 3.0 Results And Discussions

Result of a preliminary normality test we conducted on the distribution of RODs and RCDs (Table 1) revealed that these rainfall characteristics in the study area are not normally distributed.

Table 1  
Normality test for stations data

Normality Test	Gusau	Kano	Katsina	Sokoto
N	38	38	36	38
Shapiro-Wilk W	0.9478	0.9217	0.9412	0.9857
p(normal)	0.07542	0.01106	0.05554	0.8994
Anderson-Darling A	0.742	1.269	0.6229	0.287
p(normal)	0.04871	0.002302	0.09678	0.6028
p(Monte Carlo)	0.0485	0.0012	0.1013	0.6379

### 3.1 Real Onset Dates (ROD) of rainfall in the study area

The RODs of rainfall in the study area vary from one station to another. There is this variation even between stations on the same latitude and within a station from one time to another. There is very low (0.07) correlation between latitudes and EO hence Early Onsets (EOs) of rainfall are characteristic features of Kano and Katsina stations where their frequencies and percentages of occurrences are both 10 (26.3%) respectively (Table 2). But with regards to longitudinal positions, the two stations are on the more eastward longitudinal positions that is  $7.62^{\circ}$  to  $8.31^{\circ}$  East hence there is strong positive (0.8 coefficient) correlation between meridians and EO of rains in the study area. With regards to late onset (LOs) also this feature recognizes latitudinal differences to the extent that there is strong positive (0.7) correlation between lines of parallels and LO of rains in the study area where Katsina and Sokoto have 29% and 26.3% frequencies of occurrences respectively. This research finding tallies with Amekudzi, et al., (2015) who studied variabilities in rainfall onset, cessation and length of rainy season for the various agro-ecological zones of Ghana and found that onset of rainfall follows latitudinal pattern in Ghana from the forest coastland to savanna hinterlands and that LO is associated feature of the savannah zone.

**Table 2** Frequencies and percentages of occurrences of rainfall onsets

Station	Frequencies and percentages of occurrences of rainfall onsets			Total
	Early onset (EO)	Normal onset (NO)	Late onset (LO)	
Gusau	7 (18.4)	25 (83.3)	6 (15.7)	38 (100)
Kano	10 (26.3)	22 (57.9)	6 (15.7)	38 (100)
Katsina	10 (26.3)	17 (44.7)	11 (29.0)	38 (100)
Sokoto	7 (18.4)	21 (55.3)	10 (26.3)	38 (100)
<b>Total</b>	<b>34 (22.4)</b>	<b>85 (56.0)</b>	<b>33 (21.4)</b>	<b>152 (100)</b>

On average RODs commence earlier (21st May) in Gusau than in other stations of the study area, a difference of 10 days compared to 1st, June the date of the other three stations. This result is in agreement with Odekunle, (2004) who studied rainfall and length of growing season in Nigeria and found rainfall commences in Kano station around early June. Also the higher values of standard deviations and coefficients of variation of all the stations shown in Table 3 when compared with lower values of standard deviations and coefficients of variation for the cessation of rainfall as shown on Table 5 portray that though RODs have higher variability across the stations when compared with RCDs that occur almost the same time across stations in the study area. This result however, contrasts sharply or did not tally with Adejuwon, (2006) and Amekudzi, et al., (2015) who found distinctive dates for rainfall cessations across various agro-climatological zones of Nigeria and Ghana respectively. Another factor that account for the disparity in this study's finding with the two aforementioned results is that the differences in RCD between the Sudan (Latitude 12) and the Sahel (Latitude 13) agro-ecological zones is minimal when compared with differences that exist between say forest and Guinea Savanna or Guinea Savanna and Sudan/Sahel zones.

The distribution of RODs (Table 3) shows that all the stations have near normal distribution which is almost a symmetrical distribution with well-behaved tails. In Sokoto and Katsina both mean and median values in the two stations are nearly 31 and skewness values of -0.057 and 0.154 respectively indicate that RODs occurrences are skewed left and right respectively while Gusau has its both mean and median approaching 29 it has a positive skewness value of 0.26 indicating RODs are skewed right. In the former, it means that the left tail is longer relative to the right tail. Similarly, in the latter it means that the right tail is longer relative to the left tail. Figure 4 has shown that Gusau, Kano and Sokoto are skewed right and as a result they have the least frequencies of occurrences of LOs while Katsina that is skewed left has the highest frequencies of occurrences of LOs of rainfall (table 2). The implication of the foregoing to crop cultivation and adaptation planning is that there is a tendency or propensity of an inclination of cases of LOs and by implication a high probability of occurrence of short LGS, low amount of CR which are more common in the station and other northernmost stations of the study area (Latitude 13° and above) than those on latitude 12°. This result corroborates studies conducted in semi-arid parts of West Africa that indicated a significant positive relationship between the start of rains and the LGS and that EOs most often leads to longer rainy season (Sivakumar, 1988; Ati, Strigter & Oladipo, 2002; Amekudzi et al. 2015).

Farmers in these locations overcome the aforementioned challenge of short LGS through determining the pattern of rainy season to be experienced and what crop to plant based on changes in weather elements such as temperature and direction of winds as well as behavioural changes of some animal and birds and phenological changes in plant species (Umar, 2016). There is the need to blend this traditional weather forecast with modern scientific one plus strengthening of other coping and adaptation strategies like off-farm livelihood diversification such as ownership of small ruminants (Umar & Adamu, 2018), enhancing of small and medium scale irrigation schemes and micro-finance to smallholder farmers (Umar & Adamu, 2019). This is as a result of non definite trends in the RODs phase.

Table 3  
Summary statistics for RODs of the stations

Station	Gusau	Kano	Katsina	Sokoto
Latitude	12.16N	12.00N	13.00N	13.06N
Longitude	6.67E	8.31E	7.62E	5.12E
Elevation (m)	468	488	513	309
Range	25/34	25/39	25/37	25/38
Mean	28.8	30.26	31.03	30.82
Stand. Dev.	2.188	3.03	3.56	3.107
Median	29	30	31	31
Skewness	0.26	0.87	-0.091	0.154
Kurtosis	0.084	0.97	-0.78	-0.07
Coeff. of Var.	7.58	10.0	11.47	9.98

The obtained values of skewness show that only RODs of Katsina are near normally distributed (-0.091). Two stations (Gusau and Sokoto) have one very low positive and another negative kurtosis and the other two stations (Kano and Katsina) have one low positive and one negative kurtosis respectively. This implies a tendency towards having light tails, or lack of outliers (see Fig. 4A-D). This is an indication of low occurrences of extreme events as per very early rainfall onset that could generate confusion to farmers regarding the safe period to plant or very late onset that could drastically affects LGS. However, in terms of variability, the RODs in Katsina are the most variable with 11.47 coefficient of variability and standard deviation of 3.56 while the RODs in Gusau are the least variable with 7.58 coefficient of variability and range of 25 to 34 (Table 3). High variability in the RODs of stations has deleterious implications on crops (maize, rice, sorghum, millet, groundnut and cow peas) yields the least sensitive has been rice because it enjoyed some irrigation supplementation in Kano and other areas of the study area (Adejuwon, 2006). It has been noted that in the study area, the crops whose yields are most sensitive to rainfall variability (essentially it deficiencies) in the months of June, September or both that is onset and cessation periods are cowpeas, maize and millet (Adejuwon, 2006).

### 3.2 Real Cessation Dates (RCDs) of rainfall in the study area

The RCDs of rainfall in the study area contrasted sharply when compared with the RODs. Unlike in the RODs where there is high variability due to occurrences of significant disparity from one station to another (with normal RODs ranging from 83.3% in Gusau, 57.9% in Kano, 55.7% in Sokoto and 44.7% in Katsina) there is however low variation between stations with regards to the cessation of rainfall in the study area due to absence of significant disparity (with normal RCDs ranging from 79.0% in Katsina, 76.3% in Kano, 60.5% in Sokoto and 57.6% in Gusau). There is low (0.3 Spearman's Rank r) correlation between latitudes and EC of rain. EC of rain is to some extent characteristic features of Gusau and Sokoto

stations where their frequencies and percentages of occurrences are 10 (26.3%) and 9 (23.7) respectively despite that the two stations are on different latitudes (12° N and 13° n see Table 3). Katsina and Kano stations that happened to be more eastward longitudes 7.62° to 8.31° East of Greenwich have predominantly NC with frequencies of occurrences of 79.0% and 76.3% respectively (Table 4).

**Table 4** Frequencies and percentages of occurrences of rainfall cessations

Station	Frequency and percentage of occurrences of cessations			Total
	Early cessation (EC)	Normal cessation (NC)	Late cessation (LC)	
Gusau	10 (26.3)	20 (52.6)	8 (21.1)	38 (100)
Kano	6 (15.8)	29 (76.3)	3 (7.9)	38 (100)
Katsina	6 (15.8)	30 (79.0)	2 (5.2)	38 (100)
Sokoto	9 (23.7)	23 (60.5)	6 (15.8)	38 (100)
<b>Total</b>	<b>31 (20.4)</b>	<b>102 (67.1)</b>	<b>19 (12.5)</b>	<b>152 (100)</b>

On average RCDs of rains are experienced earlier (30st September) in Katsina, Sokoto and Kano before Gusau stations of the study area with a difference of 10 days compared to Gusau where RCDs fall by 10th, October on average. This result is in agreement with Odekunle (2004) who studied rainfall and length of growing season in Nigeria and found rainfall retreats in Kano station around early second dekad of September. The lower values of standard deviations and coefficients of variation of all the stations shown in Table 5 when compared with higher values of standard deviations and coefficients of variation for the onset of rainfall as shown on Table 3 portray that RCDs occur almost the same time across stations in the study area. As stated earlier, this result did not tally with Adejuwon, (2006) and Amekudzi, et al., (2015) who found distinctive dates for rainfall cessations across various agro-climatological zones of Nigeria and Ghana respectively.

Table 5  
Summary statistics for Cessation dates of the stations

Station	Gusau	Kano	Katsina	Sokoto
Latitude	12.16N	12.00N	13.00N	13.06N
Longitude	6.67E	8.31E	7.62E	5.12E
Elevation (m)	468	488	513	309
Range	48/61	50/57	50/57	51/59
Mean	56	54.29	54.13	54.37
Stand. Dev.	2.48	1.72	1.68	2.16
Median	56	54	54	54
Skewness	- 0.57	-0.41	-0.29	0.34
Kurtosis	1.88	-0.732	-0.38	- 0.53
Coeff. of Var.	4.43	3.173	3.102	3.97

The obtained values of skewness show that no any station has RCDs that are near normally distributed. Only Gusau station has low positive kurtosis and the other three stations have low negative kurtosis. These show tendencies towards having light tails, or lack of outliers with regards to the all stations except Gusau. This has been confirmed by the station's highest occurrence of ECs (26.3%). This trend has serious implications on the sustainability and yields of late maturing crops such as sorghum, cowpea and soybeans. The RCDs are less variable than the RODs that is why there are low values of standard deviations and consequently also low values of coefficient of variability in the RCDs (Table 5) than in the RODs (Table 3). The RCDs in Gusau are the most variable with 4.43 coefficient of variability and range of 48 to 61. This has sharply contrasted with the station's RODs least value of 7.58 coefficient of variability (Table 3).

### 3.3 Spatiotemporal interannual variability of rainfall characteristics

Since the normality test in Table 1 informed us that our data essentially RODs and RCDs are not normally distributed, consequently, in the process of detection of trend in the values of RODs, RCDs we have to use Mann-Kendall test because of its distribution non-bias. Result in Table 6 shows that, at a 95% confidence level, there is no statistically significant trend in both RODs and RCDs. But considering that there have been variations in those dates and in some stations (all the stations in the cades of RODs and Gusau in the case of RCDs) these variations have been significant, our study answered two questions one of them whether EOs of rainfall leads to longer LGS and invariably LOs shorter LGS and secondly to what extent LGS is dependent on rainfall CR in the study area?

Table 6 Mann-Kendall test of trend detection for RODs and RCDs

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	Gusau	Kano	Katsina	Sokoto
<b>RODS</b>				
S :	-80	-48	-94	74
Z :	1.01	0.60516	1.1798	0.92442
p (no trend):	0.31249	0.54508	0.23809	0.35527
<i>There is no statistically significant trend</i>				
<b>RCDS</b>				
S :	121	102	69	81
Z :	1.5301	1.292	0.87115	1.0173
p (no trend):	0.126	0.19637	0.38367	0.30902
<i>There is no statistically significant trend</i>				

Exploring the variability the foregoing results and discussions show that both RODs and RCDs exhibited varying extent of disparity in their characteristics anomalies. Both Table 6 and Fig. 3 show that among the stations only Sokoto (Fig. 3 Sb) experienced as insignificant increase (positive trend) in RODs which is not statistically significant at 95% confidence level. All the other stations experienced insignificant decrease in RODs. This is indications that although commencement dates of rainfall fluctuated or were unstable from year to year; there was not a significant persistent increase or decrease in the RODs. In Katsina station LOs of rainfall were common around 1983 to 1987 and 1993 to 1995. But from 2002 to 2011 there were more of EOs of rainfall in the station.

In Gusau station LOs of rainfall were common around 1986 to 1989 and 1997 to 1999. But from 2008 to 2018 there were more of EOs of rainfall and NOs of rainfall in the station. In Sokoto and Kano there is inter-annual variation in the occurrences of RODs; various types of onsets from EOs to NOs and LOs interchanged with one another from year to year without any explicit trend (Fig. 3 Sa, Ka). This result corresponds or tallies with Chamberlin and Diop (2003) who studied the rainy season characteristics in Senegal and found that time-series does not show definite trends during the onset and cessation phases.

All the stations experienced insignificant increase in the RCDs or LCs of rainfall as shown by Fig. 4. This is an indication that from 1981 to 2018 there has been a minimal increase in the retreat dates of rainfall in the study area. In the northernmost stations (Katsina and Sokoto) and one of the southernmost stations, Kano, LCs of rainfall took place recently (from around 2006 to 2016). ECs of rainfall are among the characteristic features of rainfall that pose adverse implications on crop cultivation and their adaptation to climate change. Earlier we stated that there is low (0.3 Spearman's Rank r) correlation between latitudes and ECs of rains. But Gusau and Sokoto stations where their frequencies and percentages of occurrences are 10 (26.3%) and 9 (23.7) respectively exhibited ECs characteristic features. Most of the ECs of rainfall occurred around 1980s in Gusau, Sokoto and to a lesser extent in the other stations. This finding corroborates Amekudzi, et al., (2015) who reported that early cessations are indicated around 1972–1988 for the savannah zone of Ghana.

### 3.4 Trends in and relationships between LGS and CR

Figure 5 (A- D) shows that interactions of RODs with RCDs have effects on LGS and CR as the fluctuations in the figure portray. Mann-Kendall test of trend conducted on the stations revealed that there

is a significant increasing trend in CR across all the stations with the exception of Gusau. Conversely, there is no significant trend with regards to LGS in all the stations with the exception of Gusau. It is only in Gusau that there is an increasing trend in the LGS. That is why the correlation between CR and LGS in all the stations is either very low or low correlation (see Table 6).

This result has tallied with Chamberlin and Diop (2003) that a late onset is not necessarily associated with a low seasonal rainfall amount. The implication of this lack of definite trends during both phases of onset and cessation is that long-term adaptation planning will be difficult and rigorous exercise.

**Table 6 Mann-Kendall test of trend detection for CR, LGS and their correlation**

	Gusau	Kano	Katsina	Sokoto
<b>CR</b>				
S :	100	237	159	217
Z :	1.2447	2.967	1.9864	2.7155
p (no trend):	0.21324	0.0030075	0.046993	0.006617
Type and extent of trend	NST	SIT	SIT	SIT
<b>LGS</b>				
S :	190	49	130	14
Z :	2.3823	0.60422	1.6257	0.16397
p (no trend):	0.017204	0.5457	0.10402	0.86976
Type and extent of trend	SIT	NST	NST	NST
<b>Correlation CR and LGS</b>				
	0.145	- 0.018	0.33	-0.01
	VLC	VLC	LC	VLC

NST represents *No significant trend* SIT represents *significant increasing trend*

VLC represents *Very low correlation* LC represents *Low Correlation*

## 4.0 Conclusion And Recommendations

Findings of the study revealed that RODs unlike RCDs of rainfall in the study area so much vary from one station to another. There is this variation even between stations on the same latitude. There is very low (0.07) correlation coefficient between latitudes and EO. Early Onsets (EOs) of rainfall are characteristic features of Kano and Katsina stations where their frequencies and percentages of occurrences are both 26.3% respectively. There is however, a strong positive (0.8 coefficient) correlation between meridians and EO of rains. LOs recognize latitudinal differences to the extent that there is strong positive (0.7 coefficient) correlation between lines of parallels and LO of rains. All the three types of onsets EOs, NOs and LOs interchanged with one another from year to year without any explicit trend with non-definite trends in the RODs as well as RCDs phases. There is a significant increasing trend in CR across all the stations with the exception of Gusau and conversely, there is no significant trend with regards to LGS in all the stations with the exception of Gusau. It is only in Gusau that there is an increasing trend in the

LGS. That is why the correlation between CR and LGS in all the stations is either very low or low correlation.

We conclude that non-definite trends in RODs and RCDs pose strong challenge to long term adaptation planning. In view of the complicating rainfall characteristics of the study area our study recommend as follows:

- a) There is the need to blend the traditional weather forecast system in the study area with modern scientific one plus strengthening of other coping and adaptation strategies like off-farm livelihood diversification such as ownership of small ruminants in order to reduce climate risks;
- b) We also recommend enhancing of small and medium scale irrigation schemes and micro-finance to smallholder farmers in the study area and
- c) Finally this research suggest the need for a further study that will explore the occurrences of extreme events in respect of rainfall of the study area specifically within inter-seasonal time-scale (dekads, pentads and daily) occurrences and their implication to rainfed agriculture.

## Declarations

### ACKNOWLEDGMENTS

The principal researcher and co-authors are grateful to the Nigerian Tertiary Education Trust Fund for sponsoring this study under the Institutional Based Research initiative.

### Declarations

Not applicable.

### Conflicts of interest/Competing interests

I declare there is no conflicts of interest/competing interest

## References

1. Adejuwon J (2006) *Food Security, Climate Variability and Climate Change in Sub Saharan West Africa* A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AF 23 accessed online at <https://www.8230>
2. AGRHYMET (2005) Drought monitoring and early warning in the Sahel: The AGRHYMET experience. A Paper Presented at the World Conference on Disaster Reduction. Kobe, Japan, 18–22 Jan. (accessed January 1, 2012)
3. Amekudzi LK, Yamba IE, Preko K, Asare EO, Aryee J, Baidu M, Codjoe SNA (2015) Variabilities in Rainfall Onset, Onset and Length of Rainy Season for the Various Agro-Ecological Zones of

- Ghana *Climate* 2015, 3, 416–434; doi:10.3390/cli3020416
4. Ati OF, Stigter CJ, Oladipo EO (2002) A comparison of methods to determine the onset of the growing season in northern Nigeria *Int J Climatol*, 22, 731–742, doi:10.1002/joc.712
  5. Benoit P (1977) The start of the growing season in northern Nigeria. *Agric Meteor* 18:91–99. doi:10.1016/0002-1571(77)90042-5
  6. Camberlin P, Diop M (2003) Application of daily rainfall principal component analysis to the assessment of the rainy season characteristics in Senegal *Climate Research* 23: 159–169, 2003
  7. Donaire J(2000). New definitions of climate and climatic change, *Bull. Soc. Geog: Egypt*, Tome LXXIII, 73, Cairo, Egypt
  8. Fasheun A (1983) Modelling of daily rainfall sequence for farm operations planning in Ibadan. *Nigerian Meteorological Journal* 1:102–109
  9. Fußsel HM (2007) Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustain Sci* 2:265–275. DOI 10.1007/s11625-007-0032-y
  10. Lebel T, Ali A (2009) Recent trends in the Central and Western Sahel rainfall regime (1990–2007). *J Hydrol* 375:52–64
  11. Haruna S, Murtala MR (2019) Assessing the length of growing season in the Sudan Savanna Ecological Zone of Nigeria as a challenge to food security for sustainable development *Agro-Science*, 18 (3), 5–10. DOI: <https://dx.doi.org/10.4314/as.v18i3.2>
  12. Kowal JM, Knabe DT (1972) *An Agroclimatological Atlas of the Northern States of Nigeria with Explanatory Notes* Ahmadu Bello University Press, 111 pp
  13. Mhita MS, Nassib IR (1987) The onset and end of rains in Tanzania. In: *Proceedings of the First Technical Conference on Meteorological Research in Eastern and Southern Africa* Kenya Meteorology Department, Nairobi, p 33–37
  14. Mortimore M (2005) Dryland Development: Success Stories from West Africa. *Environment: Science Policy for Sustainable Development* 47:1,8–21. DOI:10.3200/ENVT.47.1.8-21
  15. Nicholls N (1984) A system for predicting the onset of the north Australian wet-season. *Int J Climatol* 4:425–435
  16. Nnoli NO (1996) Mean onset and cessation dates of rainy season in Nigeria. In: *Proceedings of the 11th Nigerian Meteorological society conference on climate change and its impact on Agriculture*, Ibadan, Nigeria, 24–25 October 1996. IFTA
  17. Odekunle TO (2004) Rainfall and the length of the growing season in Nigeria *International Journal of Climatology* 24: 467–479 (2004). DOI: 10.1002/joc.1012
  18. Odekunle TO, Balogun EE, Ogunkoya OO (2005) On the prediction of rainfall onset and retreat dates in Nigeria. *Theor Appl Climatol* 81:101–112. doi:10.1007/s00704-004-0108-x
  19. Oguntunde PG, Lischeid G, Abiodun BJ, Dietrich O (2014) Analysis of spatial and temporal patterns in onset, cessation and length of growing season in Nigeria *Journal of Agricultural and Forest Meteorology* 194:15 77–87 August 2014

20. Omotosho JB (1992) Long-range prediction of the onset and end of the rainy season in the West African Sahel. *Int J Climatol* 12:369–382
21. Omotosho JB, Balogun AA, Ogunjobi K (2000) Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. *Int J Climatol* 20(20000630)20:865–880. doi:10.1002/1097-0088 8,865 :AID-JOC505.3.0.CO;2-R
22. Samba A (1998) Les logiciels DHC de Diagnostic Hydrique des Cultures. Pr evision des rendements du mil en zones soudano-sah eliennes de l’Afrique. de l’Ouest *S cheresse* 9:281–288
23. Sivakumar MVK (1988) Predicting rainy season potential from the onset of rains in southern Sahelian and Sudanian climatic zones of West Africa. *Agric For Meteor* 42:295–305
24. Stern RD, Dennett MD, Garbutt DJ (1981) The start of the rains in West Africa. *J Climatol*. 1981;1:59–68
25. Stewart JI (1991) Principles and performance of response farming. In: Muchow W, Bellamy RC ZA (eds) *Climatic Risk in Crop Production. Models and Management for the Semi-Arid Tropics and Sub-Tropics*. Wallingford, Ford International
26. Umar A (2016) *Vulnerability and Adapting to Drought by Smallholder Farmers in Drylands of North-Western Nigeria* PhD Thesis submitted to the Department of geography, Bayero University Kano, Nigeria which can be accessed online @
27. Umar A, Mohammed S, Adamu IA (2017) Smallholder Farmers’ Drought Contextual Vulnerability Assessment in the Drylands of Northwestern Nigeria. *International Journal of Scientific Engineering Research* 8(1):1486–1491 January-2017
28. Umar A, Adamu IA (2018) Comparative Analysis of Contribution of Assets Ownership and Livelihood Diversification in Adaptation to Drought of Selected Farming Communities in Northwestern Nigeria. *Saudi Journal of Humanities Social Sciences* 3:1A: 29–34. DOI:10.21276/sjhss.2018.3.1.5 (Jan, 2018)
29. Umar A, Adamu IA (2019) Occurrences of Droughts in the Semi-Arid and Sub-Humid Areas of Northwestern Nigeria and Their Implications for Rural Livelihoods in the *Book of Proceedings of the 8th International Conference on Water Resources and Arid Environments (ICWRAE 8)* 22–24 January 2019, Riyadh, Saudi Arabia pp 01–11
30. Usman MT, Abdulkadir A (2012) On determining the ‘Real’ onset date of seasonal rains in the semi-arid and sub-humid areas of West Africa *Nat. Hazard*, DOI: 10.1007/s11069-012-0514-9
31. Walter MW (1967) Length of the rainy season in Nigeria. *Nigerian Geographical Journal* 10:123–128

## Figures

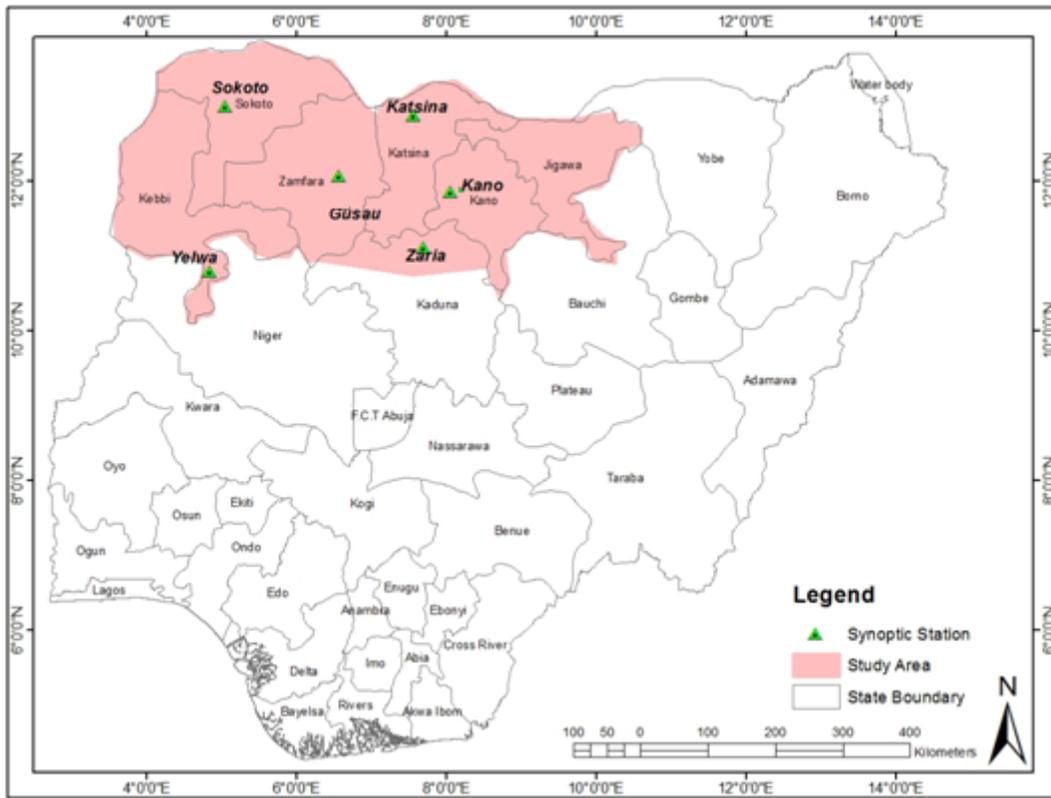
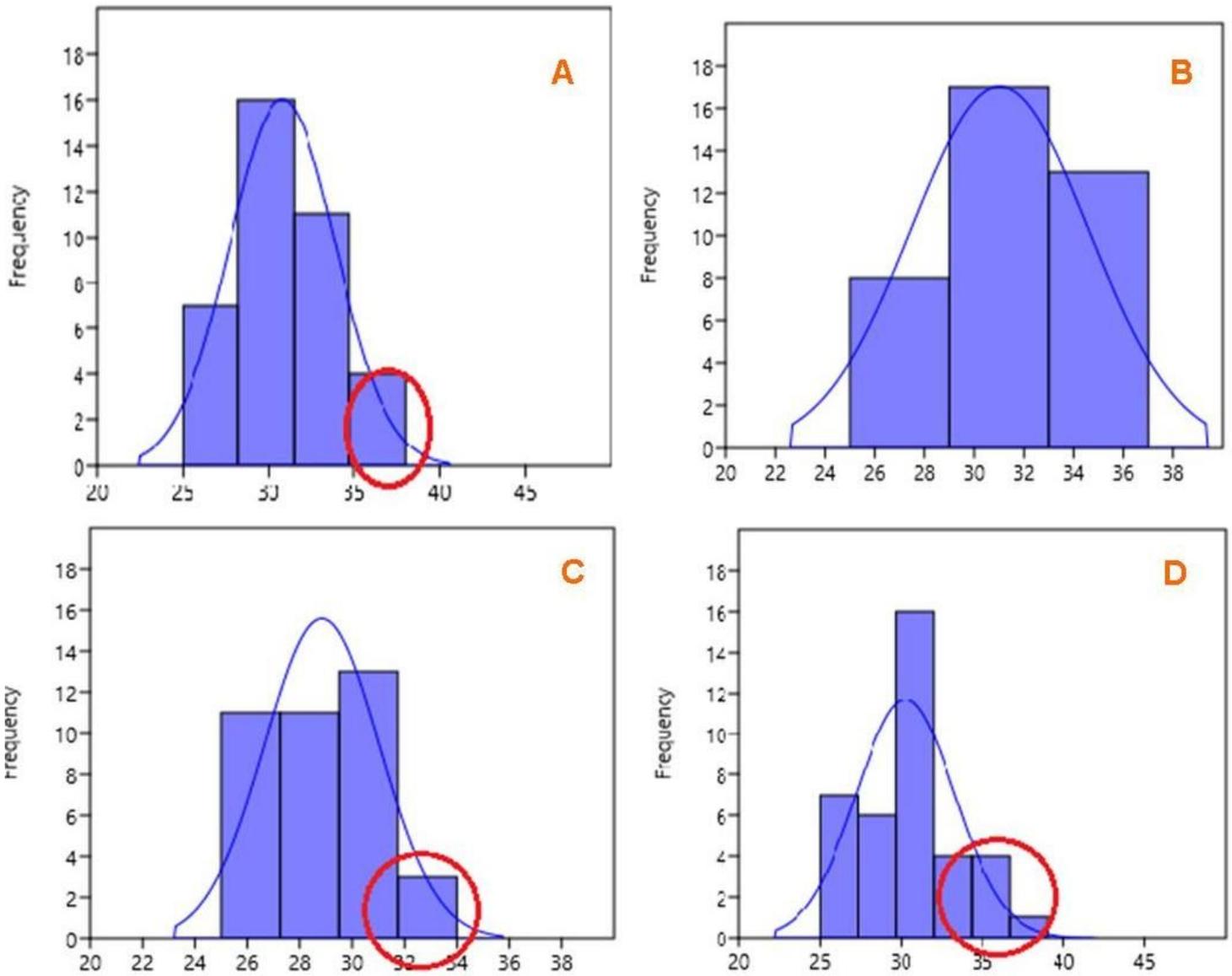


Figure 1

Map of Study Area



**Figure 2**

Distributions of RODs in (A [Sokoto]; B [Katsina]; C [Gusau] and D [Kano]) Source: Author's analysis 2020

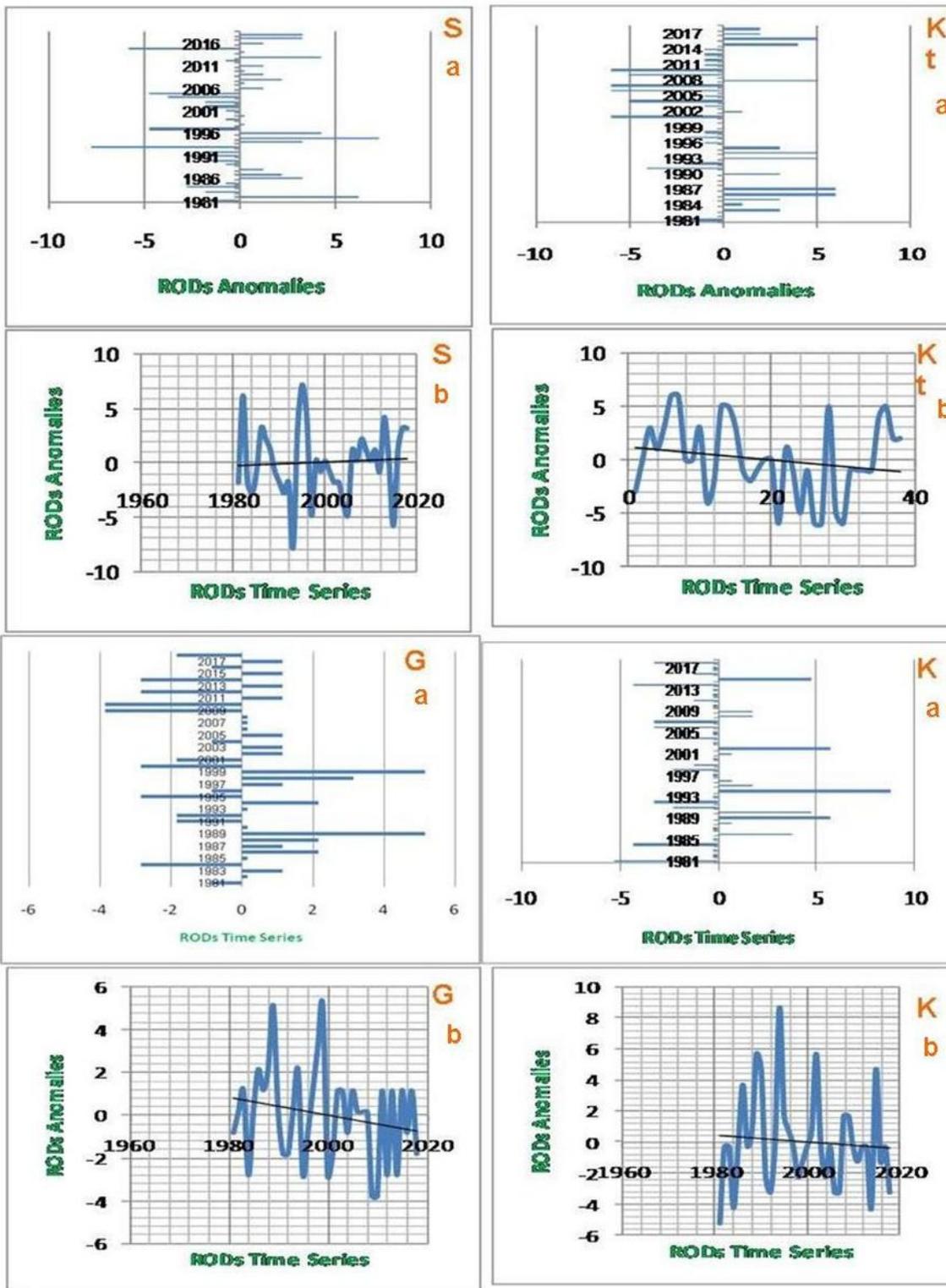


Figure 3

RODs Anomalies

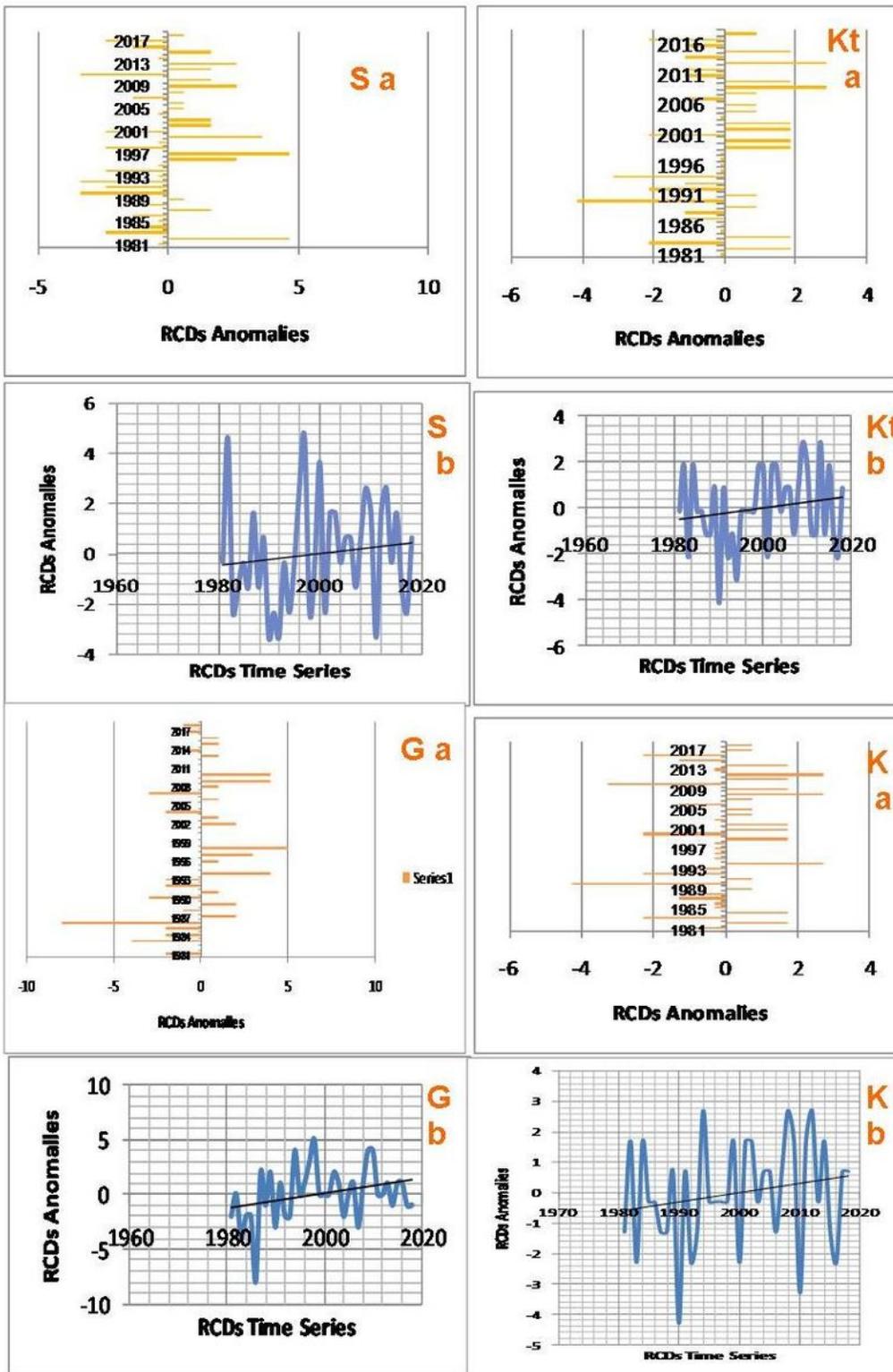


Figure 4

RCDs Anomalies

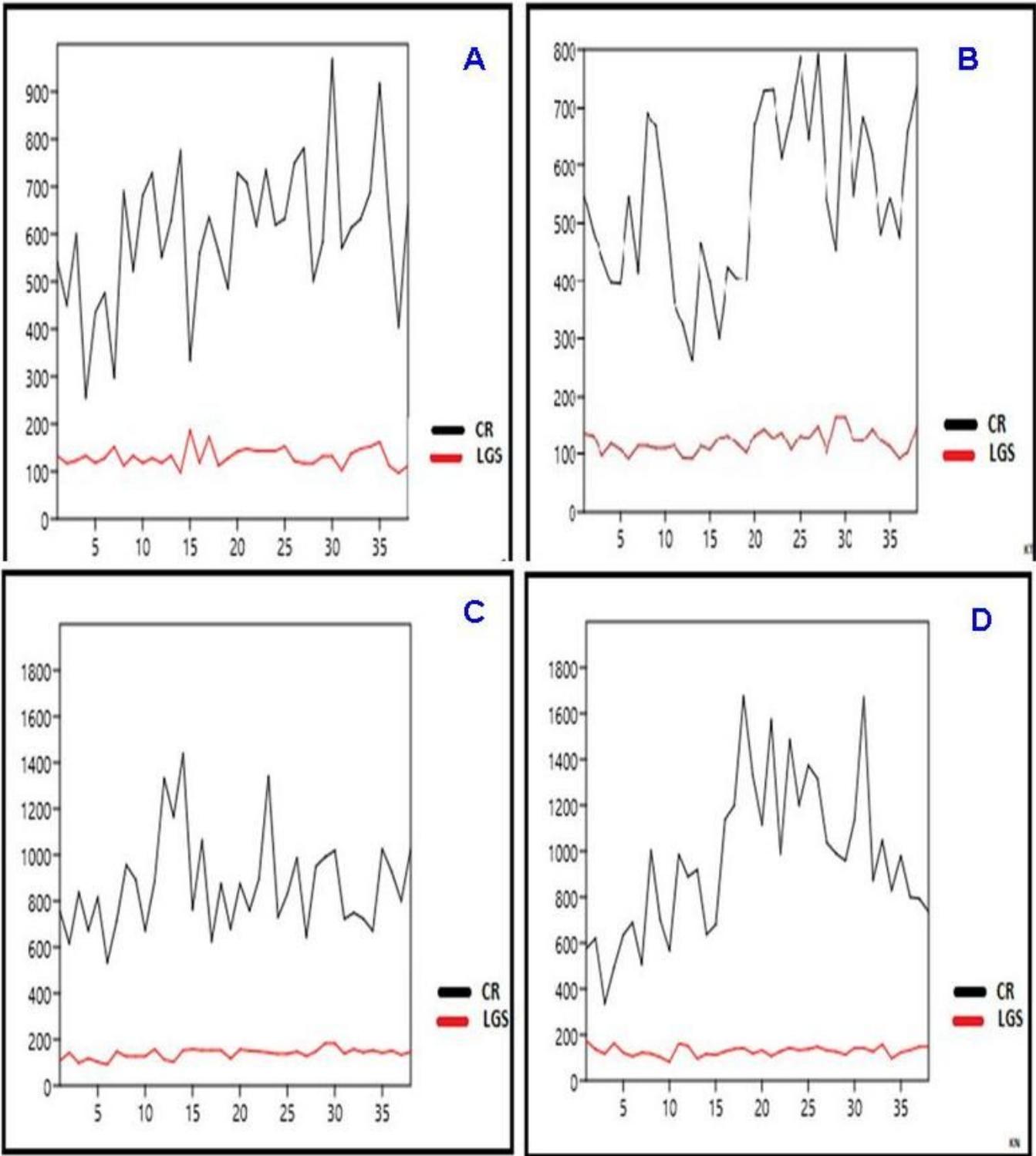


Figure 5

Relationship between CM & LGS A (Sokoto); B (Katsina); C (Gusau) and D (Kano)

## Supplementary Files

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- [Gusaudailymn.xlsx](#)
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- [Sokotodailymn.xlsx](#)