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Investigating agricultural calendar in a changing climate of the semi-arid tropics

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ABSTRACT
The farmers' farming activities and seasons are usually guided by agricultural calendar, which is liable to alteration by a change in climate. This study examined the effect of climate change on agricultural calendar in Sokoto-Rima River Basin, semi-arid Nigeria. We found out that climate changed from drought prevalent period (1970s and 1980s) towards wetter years (1990s and 2000s). The rainfall onset, cessation and duration varied from May 1 to June 2, September 3 to October 29, and 131 days to 183 days respectively. Farmers' response confirmed April and May/June as the onset of rain in the 1970s and 2000s respectively, and September as the cessation for the two periods. A shift in rainfall onset from April to May and an unchanged rainfall retreat in four decades (a reduced agricultural calendar by one month) were discovered. A precise agricultural planning will enable farmers to cope with future changes in climate.

Keywords: Climate change; agricultural calendar; human impact; semi-arid tropics.

INTRODUCTION
Climate change is the permanent alteration of weather patterns over a long period usually three decades or more. It is substantially influenced by a number of factors including the amount of solar radiation received by the earth and the various latitudinal zones, the position of continents and oceans in relation to the poles, the height of the continents and the concentration of carbon dioxide and atmospheric aerosol in the air (Goosse *et al*., 2010; Haigh, 2011; Mimura, 2013; Ming *et al*., 2014).

Climatic fluctuation has been linked to human activities such as industrialisation, deforestation, urbanisation and overgrazing (Adejuwon, 2000; IPCC, 2014). Schmid (1998) reported that the current severe drought occurrences are indications that climate has previously changed due to human impacts. The present normal climate was not normal in the longer perspective of the recent centuries. A change in climate was evident in Africa, as the areas north of the Sahara such as the Maghrib-Morocco, Algeria, Tunisia (the ancient Carthage) and south Sahara (including the semi-arid region of Nigeria) were covered with forest during the Holocene, that is, the last 11,500 years and a fertile grassland until the end of the last Ice Age, about 8000 B.C. (Larrasoana *et al.,* 2013; Darfeuil and Bouchez, 2015; Boissoneault, 2017.).

The seasonal components of rainfall including onset, duration, and retreat are important for agriculture and are highly important in the tropical conditions. Rainfall onset signifies there is adequate rainfall for planting and there is an assurance that the

rainfall will be uninterrupted, while retreat of rainfall means the termination of the wet season (Adejuwon, 2008). It is the most infamous seasonal component of rainfall in Nigeria because it is usually prefigured by a sequence of isolated showers of uncertain intensity with superseding dry period of varying duration. A postponement of one or two weeks in rainfall onset could obliterate the expectation of normal crop yield (Eggenberger and Hunde, 2001; Ayodele, 2016; Agidi *et al.*, 2018). Rainfall onset is more variable than the cessation (Camberlin *et al.*, 2009) and is often inconsistent in its continuity at the beginning of the wet season.

The problem of climate change is a threat to the sustainable growth of socio-economic and agricultural activities. In spite of this, literatures on the impact of climate change on the productivity of agricultural dates are still very scanty in Africa (Sivakumar's, 1992; Anuforom, 2009; Van de Giesen *et al.*, 2010). However, there is no documented study on the effect of a changing climate on agricultural calendar in the study area (hence this study).

MATERIAL AND METHODS

The Study Area

Sokoto Rima River Basin lies between latitude 10.8^{o}N and 13.58^{o}N and longitude 3.30^{o}E and 7.13^{o}E (Figure 1a). It is bounded in the north by Niger Republic, south by Niger and Kaduna States and southeast, west by Benin Republic and east by Katsina State.

The basin exhibits a tropical wet and dry climate. The wet season is between May/June to September while the dry season make-up the remaining part of the year (Adejuwon, 2015). The two air masses - the tropical maritime (mT) air mass and tropical continental (cT) air mass which prevails over the basin in the wet and dry season respectively influence the climate. Rain falls when an area is overlain by mT air mass while dryness prevails when an area is overlain by cT. Annual rainfall amount varied from 1013 mm in the south to 650 mm in the north while the mean annual temperature is 34.5^{o}C. The rainfall is single maxima in character and decreases in both duration and amount from the south northward. Humidity reaches an average of 80% in the wet season and 30% in the dry season (Emielu, 2000). The dry and dust-laden northeast trade wind called 'Harmattan' accompanied by very low temperatures and thick fog blows from the Sahara Desert under cloudless but dusty conditions in November to February (Adejuwon, 2016).

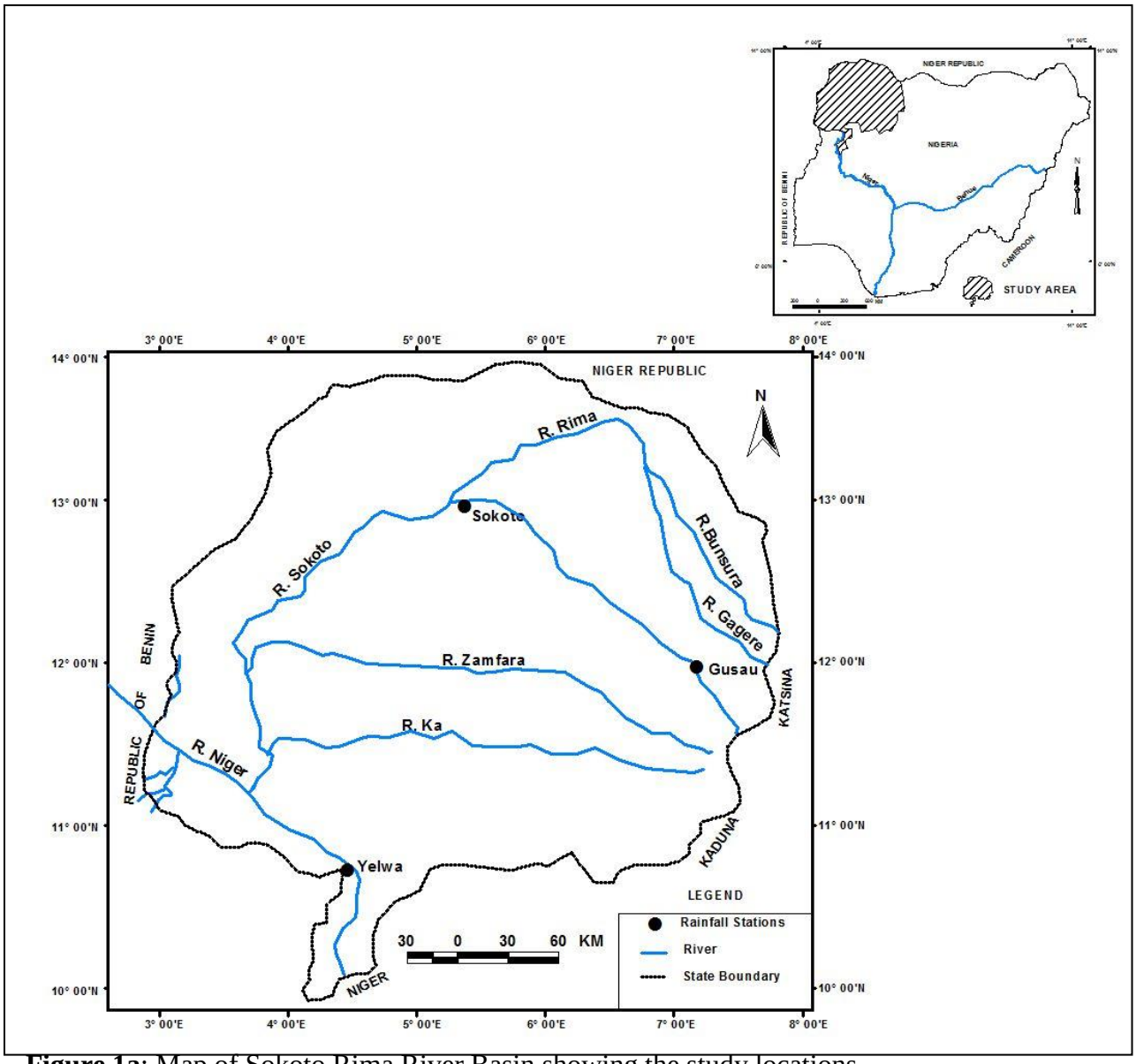


Figure 1a: Map of Sokoto Rima River Basin showing the study locations.

Data Collection, Sampling and Analysis

The data on the pattern of climate variability were collected from farmers with structured questionnaires. A total number of four hundred and fifty copies of questionnaire were administered to farmers in fifteen agricultural settlements in fifteen Local Governments (Table 1). Cluster sampling technique was used for the study. The study area was delineated into three zones. Five agricultural settlements were systematically selected from 5 local governments in each zone shown in Figure 1b below. The farmers interviewed were 40 years and above and have been farming for at least 30 years.

Table 1: Location of primary data collection in Sokoto-Rima River Basin

S/N	State	Local Government	Community
1	Sokoto	Wamakko	Gumbi
		Bodinga	Mil Goma
		Kware	Durbawa
		Dange Shuni	Dange
		Rabah	Maikujera
2	Kebbi	Kalgo	Kalgo
		Birni-Kebbi	Gulumbe
		Aliero	Dakala
		Jega	Basaura
		Argungu	Alwasa
3	Zamfara	Talata Mafara	Tunfafiya
		Gusau	Madidi
		Maradun	Dosara
		Bungudu	Tazame
		Tsafe	Tsafe

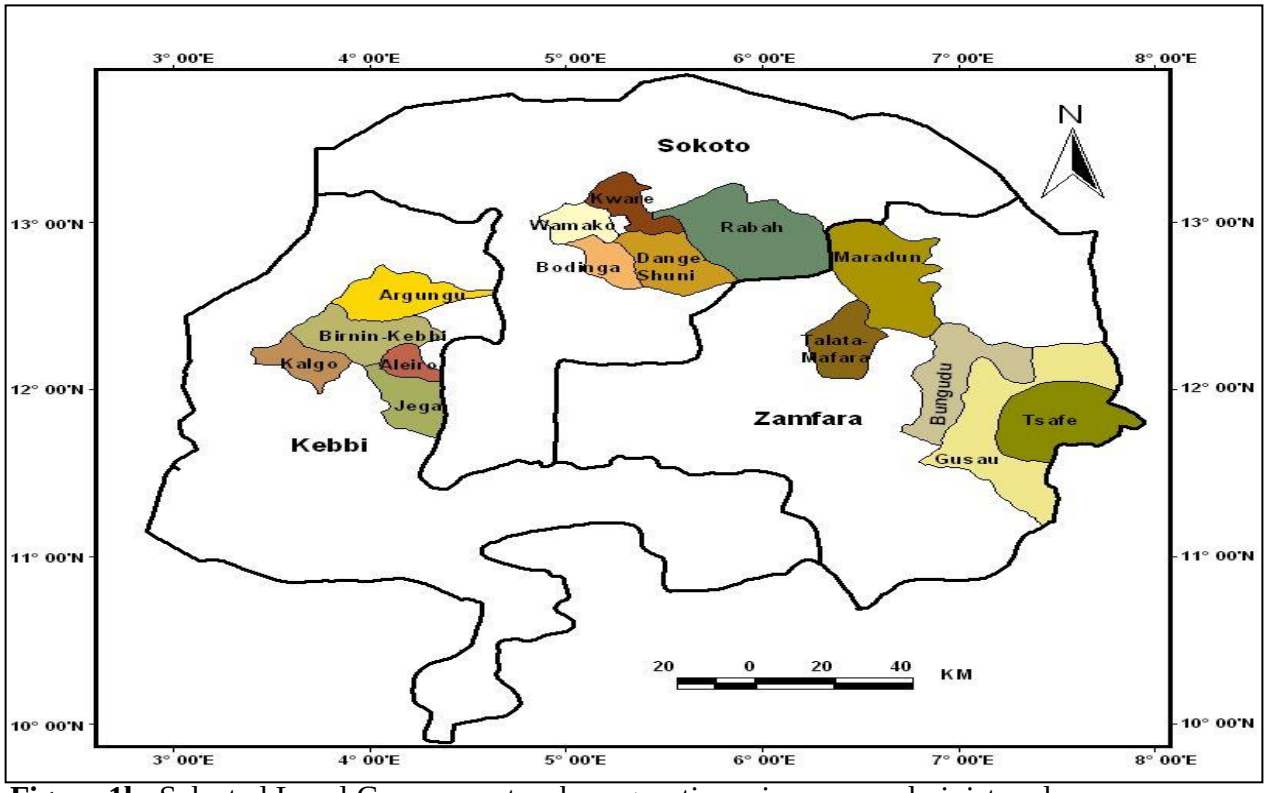


Figure 1b: Selected Local Governments where questionnaires were administered

Cluster sampling technique was employed in this study due to its advantages over other methods. It is less expensive, quicker and easy to be used from practicality viewpoint; the most time-efficient and cost-efficient probability design for large geographical areas; and the larger sample size can be used due to increased level of accessibility of prospective sample group members (Jackson, 2011). Besides, it may combine the advantages of both random sampling as well as stratified sampling.

Rainfall data were retrieved from the archives of the Nigerian Meteorological Agency (NIMET; Oshodi, Lagos State) from 1970 to 2009. The data were collected for Sokoto, Gusau and Yelwa – the synoptic stations in the study area (Table 2).

Table 2: The location characteristics of the synoptic stations used in the study

Station	Lat. (^{o}N)	Long. (^{o}E)	Altitude (m)
Sokoto	13.01	05.15	350
Gusau	12.10	06.42	463
Yelwa	10.53	04.45	243

Data were analysed using frequency, percentages, standardized anomaly index and cumulative index analysis. Frequency and percentages was employed for analysing farmer's responses, standardized anomaly index (SAI) for rainfall anomaly while the cumulative index analysis was used to determine the onset, retreat and length of growing season rainfall in the study area. Cumulative index analysis is expressed as:

$$C.I = \frac{D\,(51-AP)}{RN}$$

Where: C.I is the cumulative Index analysis, D is the number of days in that month, AP is the
total accumulation of rain before 51mm rainfall has been reached, RN is the total rainfall in that month. Rainfall onset is the time at the commencement of the wet season when the soil contains adequate moisture to sustain crop growth or a time when 51mm of rains is expected (Adejuwon, 2008).

In this study, SAI was employed to determine the annual rainfall departure from normal. Ologunorisa and Adejuwon (2010) reported that the indices near zero indicate normal rainfall, while those substantially above or below zero indicate relatively wet or dry conditions. SAI was used because it provides more information about the magnitude of the anomalies due to removal of influences of dispersion.

For each station i, annual rainfall ri is normalized to produce a series of annual departure as follows:

$$x_{ij} = (r_i - r_{ij})/\acute{O}_i \quad \text{.....(1)}$$

Where:

xij = the transformed annual rainfall departure for station i in the year j

rij = annual rainfall for station i in the year j.

ri = mean annual rainfall at station i average over the entire length of record = $n1\text{-}1\sum$ rij

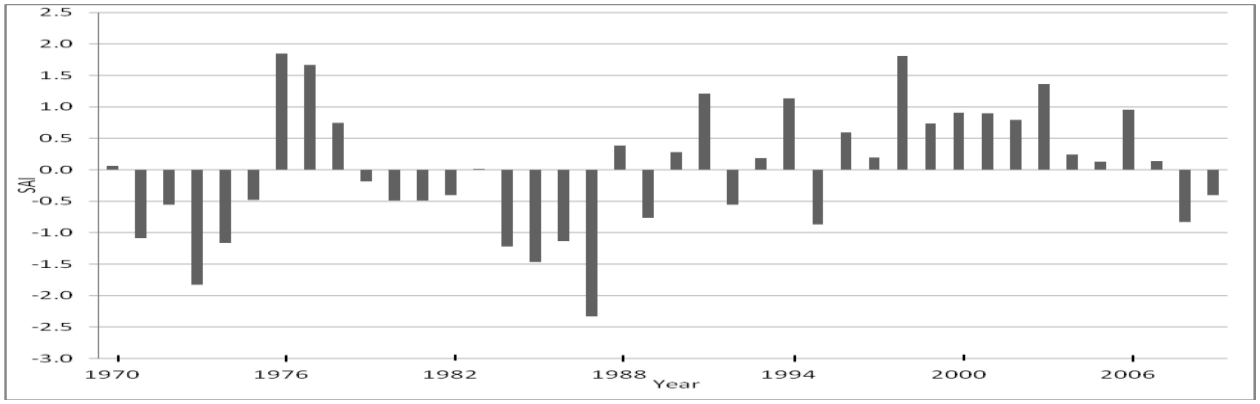
ni = number of record years for station i

Ó = the standard deviation of the annual rainfall at station i

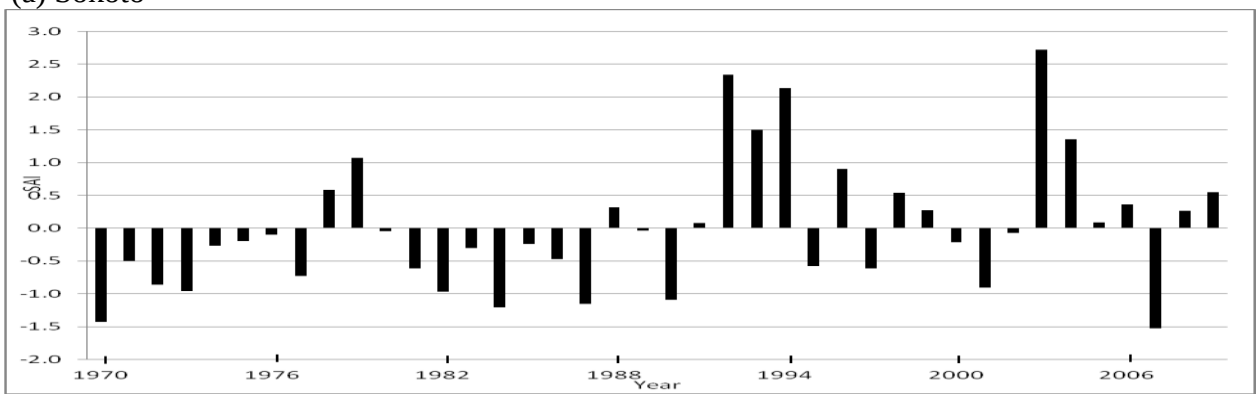
RESULTS

The annual rainfall anomalies in Sokoto-Rima River Basin are shown in Figure 2. A total of 42 droughts (Sokoto – 13, Gusau – 16, Yelwa – 13) were recorded out of the total 60 years from 1970 to 1989. The wetter years from 1990 to 2009 showed a total of 39 years (Sokoto – 16, Gusau – 13, Yelwa – 10) of excess rainfall.

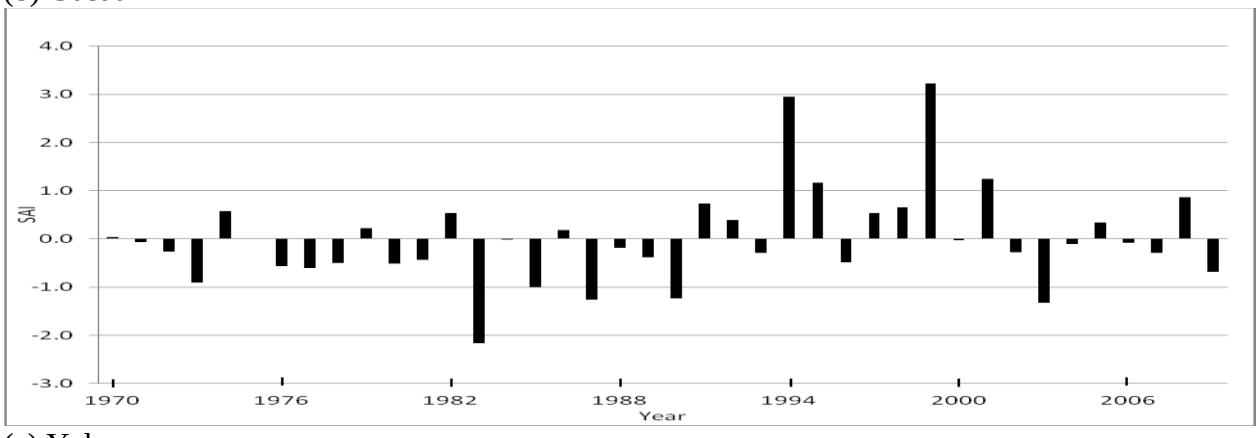
Responses from the respondents on rainfall commencement ranged from 0.2% in December and March/April to 55.1% in April in 1970's, and 0.2% in August to 43.3% in May in 2000's (Table 3). Table 4 showed the onset, retreat and length of growing season in Sokoto-Rima River Basin (1970-2009). Onset of rainfall varied from May 1 at Yelwa to June 2 at Sokoto, while the retreat of rainfall ranged from September 3 at Gusau to October 29 at Yelwa. However, the length of the growing season varied from 131 days at Sokoto to 182 days at Yelwa.



(a) Sokoto



(b) Gusau



(c) Yelwa

Figure 2: Rainfall anomalies in the Sokoto-Rima River Basin from 1970 to 2009

Table 3: Rainfall commencement in Sokoto-Rima River Basin

Months	Rainfall Onset in 1970's	Percentage	Rainfall Onset in 2000's	Percentage
March	92	20.4	-	-
April	248	55.1	109	24.2
May	8	1.8	195	43.3
June	59	13.1	64	14.2
July	39	8.7	15	3.3
August	-	-	1	0.2
December	1	0.2	-	-
March/April	1	0.2	2	0.4
April/May	-	-	7	1.6
May/June	-	-	57	12.7
No idea	2	0.4	-	-
Total	450	100.0	450	100.0

Source: Authors fieldwork (2009)

Table 4: Onset, retreat and length of growing season in Sokoto-Rima River Basin (1970-2009)

Station	Onset Dates	Retreat	Length of Growing Season
Sokoto	June 2	Sep 10	131 days
Gusau	May 13	Sep 3	143 days
Yelwa	May 1	Oct 29	182 days

DISCUSSION

The result has shown that climate changed from drought prevalent period of the 1970s and 1980s towards wetter years of the 1990s and 2000s. A decreased rainfall and an associated changing climate have been observed in the semi-arid region of Nigeria (Ayoade, 2003; Federal Ministry of Environment-FME, 2003; Adefolalu, 2007; Obioha, 2008). This area experienced declined rainfall since 1941 and suffered prolonged droughts and effective desertification processes since 1960's (FME, 2003; Adejuwon, 2004).

An examination of responses in the study area revealed that 99.2% of the farmers experienced a change in the pattern of rainfall in the past 40 years. When interviewed about the exact month of rainfall commencement, 55.1% of the farmers affirmed commencement of rainfall in April in the 1970s while 43.3% observed rainfall commencement in May in 2000s. Also, 14.2% and 12.7% of the farmers noted that June and May/June was the onset dates in 2000s. This shows an increased dry season and a reduced wet season. The farmers attributed these alterations to changes in climate. Prothero (1962) reported that the rainy season in northwestern Nigeria is from April to September with most rain in July and August, although the length of the rainy season may vary by up to six weeks. The study of Van de Giesen *et al.* (2010) also showed that farmers have experienced shifts in the onset of the wet season from April towards May and sow 10–20 days later than their parents in the Volta Basin, West Africa. The statistical findings revealed that rainfall onset varied from May 1 at Yelwa in latitude 10^{o} 50'N to June 2 at

Sokoto in latitude13^{o} 04'N. The reduction in the duration of rainfall from 131 days at Sokoto to 182 days at Yelwa indicates that the wet season and the planting period reduces from the south to the north. The result obtained is consistent with other studies (Odekunle, 2004; Adefisan and Abatan, 2015) who observed May to June as the onset dates for rainfall in northern Nigeria.

The present study shows a shift of rainfall onset from April to May and an unchanged rainfall retreat, resulting in a reduced agricultural calendar by a month in four decades. Sivakumar's (1992) reported major shifts in the average dates of onset between the two periods 1945-1964 and 1965-1988 in Niger, a part of the Sahelian zone of West Africa that has been affected by drought in a continuum since 1968. Corroborating these findings, Anuforom (2009) observed that late onset is now consistent across many parts of the country, particularly to the North from the dry period 1971-2000.

CONCLUSION

This study has shown that climate changed from drought prevalent period of the 1970s and 1980s towards wetter years of the 1990s and 2000s. It indicated April in the 1970s and May/June in 2000s as the rainfall onset and September as rainfall cessation. The onset of rain varied from May 1 to June 2 and rainfall cessation from September 3 to October 29 while the duration of rainfall for agricultural activities varied from 131 days to 183 days. A shift of rainfall onset from April to May and an unchanged retreat of rainfall (and reduced agricultural calendar by one month) in four decades influenced by natural and human-induced climate change have also been revealed.

RECOMMENDATION

The implication of the shift in the agricultural calendar for sustainable development include altered rainfall patterns that could affect agriculture, water shortages resulting from reduced rainfall period and decline crop yields, especially in the already drought-prone areas and. The solution lies in policymakers delivering a prompt response in terms of provision of irrigation water and improved seedlings that could produce within a short time. The accurate prediction of future climate change will enhance better agricultural planning in the study area.

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