



Drought occurrence in the sub-humid eco-climatic zone of Nigeria

Joseph O. Adejuwon¹ · S. B. Olaniyan¹

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Abstract

This study examined drought occurrence in the sub-humid eco-climatic zone of Nigeria using monthly rainfall data from 13 synoptic stations for the period 1970–2009. Standardized Precipitation Index and descriptive statistics were employed for the study. The result obtained showed 266 drought occurrences, with 65.79, 19.93, 9.77, and 4.51% as mild, moderate, severe, and extreme droughts, respectively. The period 1980–1989 was more prone to drought of different categories while 1990–1999 was wetter than other decades. Drought occurrences ranged from 14 times at Makurdi to 24 times at Bauchi. Severe drought occurred most at Kaduna and Ibi while extreme drought was mostly devastating at Minna. However, Bida was more affected by the combination of severe and extreme droughts than other stations. The result also showed considerable interannual variability characterized by oscillations in drought duration. The duration varied from 1 to 11 years while drought intensity ranged from –0.01 to –3.1.

1 Introduction

Drought is a phenomenon of long-time history that originated from a deficiency of precipitation as a result of water shortage for some activity or group. Drought occurrence becomes imminent when there is persistence dry condition caused mainly by low rainfall or absence of it, therefore resulting in gross water deficit for man, plant, and animal in a given environment at a particular period of time (Wilhite 1993). According to Lugo and Morris (1982), droughts are relatively better documented in sub-humid and semi-arid zones, where humans tend to concentrate. It affects more people than any other hazards (Hangman 1984), with enormous impact on human activities and livelihood. The severe adverse implications for sustainable development include food shortage and food insecurity due to a drop of agricultural production, famine, water scarcity, and loss of human life.

The huge dependence of Africa on agriculture renders the continent vulnerable to impacts of drought. Climate change is likely to exacerbate frequency of drought occurrence, with even greater and sustained negative impacts. Current climate scenarios predict that the driest zones of the world will become even drier,

signaling a risk of persistence of drought in many arid, semi-arid, and dry sub-humid areas, with greater and sustained negative impacts (United Nations Economic and Social Council 2008).

Drought is regional in nature, that is, they are driven by regional climatic conditions. Therefore, their occurrence is related to regional climatic parameters. The most common climatic parameter is mean annual precipitation, which depends on several factors, including latitude, season, orographic factors, proximity to oceans, mesoscale atmospheric circulation, atmospheric pressure, and the character of the earth's surface. Another common climatic parameter is mean annual potential evapotranspiration which depends on net solar radiation, vapor pressure deficit, surface roughness, and a leaf area index (Monteith 1965). It is believed that a characterization in terms of either of these two parameters provides an appropriate framework for the systematic analysis of drought. Therefore, an attempt was made to relate drought characteristics with mean annual rainfall in sub-humid climatic zone of Nigeria.

Previous understandings on drought in the sub-humid eco-climatic zone of the tropical Africa include Viste et al. (2013), Hua et al. (2016), Yagoub et al. (2017), Zeleke et al. (2017), Nakalembe (2018), and Nguimalet (2018). Viste et al. (2013) studied the recent drought and precipitation tendencies in Ethiopia. Hua et al. (2016) determined the possible causes of the Central Equatorial African long-term drought. Yagoub et al. (2017) examined drought cycles pattern in two countries (Sudan and South Sudan) by using Standardized Precipitation Index (SPI). Zeleke et al. (2017) analyzed the trend and periodicity of drought over Ethiopia. Nakalembe (2018)

✉ Joseph O. Adejuwon
adejoseph2003@yahoo.com

¹ Department of Water Resources Management and Agrometeorology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

characterized agricultural drought in the Karamoja sub-region of Uganda with meteorological and satellite-based indices while Nguimalet (2018) compared community-based adaptation strategies for droughts and floods in Kenya and the Central African Republic.

Despite these studies, no research work has been carried out on drought occurrence in the tropical sub-humid eco-climatic zone of Nigeria. This study fills the gap created by insufficient literature on drought occurrence in the zone. The objectives of this paper are to analyze drought occurrence over time in the study area; identify drought categories in the study area; examine the duration and intensity of drought in the study area; analyze decadal differences of drought in the study area; and examine the growth and suppression of drought in the study area.

2 Study area

The sub-humid zone of Nigeria covers 455,000 km² or approximately half of Nigeria and a third of the zone in West Africa. It lies between longitude 3°E and 13°E and latitude 6°N and 12°N (Fig. 1). Most of the Nigerian sub-humid zone lies between the 1000 and 1500 mm isohyets, offering a wide choice of crop options. Rainfall is governed by the annual passage of the Intertropical Discontinuity (ITD), the meeting

point of a dry northeastern low-pressure air mass and a moist southwestern high-pressure air mass. The northeastern movement of the ITD and the rain-bearing winds that accompany it marks the onset of the rainy season. Its southwestward movement and the accompanying cold North East trade winds known as “hamattan” blowing from the Sahara Desert mark the beginning of the dry season. Annual rainfall and its reliability decrease from the south northwards.

The northern part of the zone has unimodal rainfall distribution in which rains increase in frequency and amount, beginning in May and peaking in August. In the southern part, the rainfall pattern is bimodal, the first peak occurring in June–July, and the second in September, with August relatively dry. Variations in annual rainfall make it difficult to draw a strict geographical boundary between these two distribution patterns. Much of the sub-humid zone is transitional between unimodal and bimodal rainfall distribution. The rains are expected to reach the southern boundary of the sub-humid zone at the beginning of March, and the northern boundary 2 months later (Walter 1968). At the northern boundary, the rainy season normally ends in early October and at the southern boundary 6 weeks later. The expected duration of the wet season in the sub-humid zone ranges from 5 months in the north to more than 8 months in the south. Nevertheless, the season (April to October) is invariably punctuated by dry

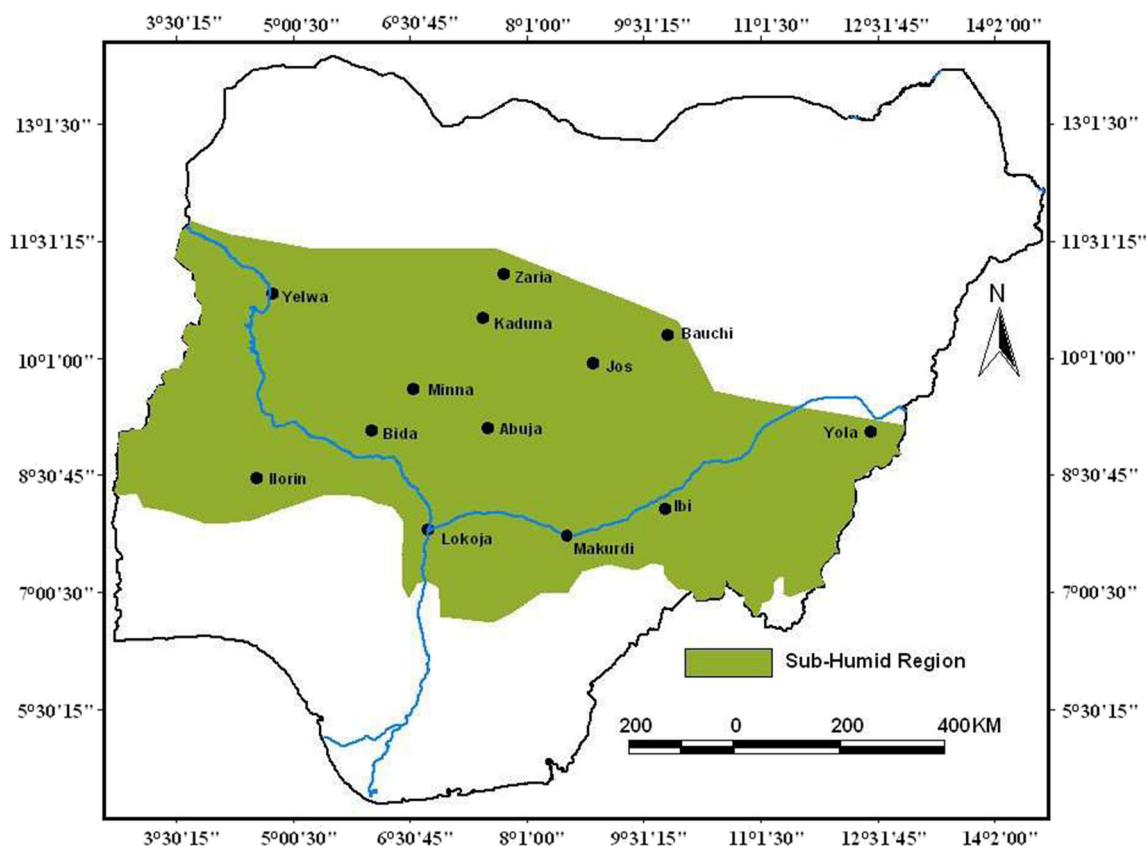


Fig. 1 Map of Nigeria showing the study locations in the sub-humid eco-climatic zone

spells, the length of which varies from a few days to a few weeks. Evapotranspiration exceeds rainfall north of latitude 7°30'N (Kowal and Knabe 1972), although almost everywhere in the zone there appears to be a period of water surplus in the year when rainfall exceeds evapotranspiration. Rainfall is usually torrential, 25 to 50 mm or more often falling within 1 h. Measurement of infiltration or rainfall acceptance on a ferruginous soil type using catchment gauges gave an average ultimate infiltration of 24 mm/h. Rainfall exceeding this rate can cause serious erosion and runoff. High humidity and concentrated rainfall during the growing season are conducive to pathogen survival and transmission. The dry season, on the other hand, is severe and the vegetation becomes parched and easily combustible.

3 Methodology

3.1 Data collection

Monthly rainfall data for 13 stations in the sub-humid zone of Nigeria from the period 1970 to 2009 (40 years) was sourced from the archives of the Nigeria Meteorological Agency (NIMET), Oshodi, Lagos State, Nigeria. The stations were shown in Table 1. The British standard dines titling siphon rain gauge rainfall recorder was used in recording the data in this station by NIMET observers. The stations were not affected by site relocation.

3.2 Data analysis

Drought was analyzed using descriptive statistics such as totals, frequency, and percentages and the SPI method. The following procedure was followed for SPI:

Table 1 The location characteristics of the synoptic stations used in the study

Station	Lat. (°N)	Long. (°E)	Altitude (m)
Yelwa	10.53	04.45	244
Bida	09.06	06.06	111
Kaduna	10.36	07.27	616
Lokoja	07.48	06.44	67
Zaria	11.08	07.41	644
Ibi	08.11	09.45	105
Minna	09.37	06.12	272
Yola	09.14	12.28	192
Ilorin	08.29	04.35	310
Bauchi	10.17	09.49	622
Abuja	09.07	7.48	476
Makurdi	07.44	08.32	89
Jos	09.52	08.54	1191

- Calculate the long-term mean and standard deviation over the study period for each station.
- Calculate SPI values for each year over the study period.
- Then calculate drought occurrence, duration, and intensity.

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee 1997). Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. McKee et al. (1993) used the classification system shown in the SPI values table to define drought intensities resulting from the SPI. McKee et al. (1993) also defined the criteria for a drought event for any of the time scales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive (Table 2).

The SPI for each station was determined using the equation below:

$$SPI = (X_{ik} - X_i) / \sigma_i$$

where σ_i = standardized deviation for the i th station, X_{ik} = rainfall for the i th station and k th observation, and X_i = mean rainfall for the i th station. All negative SPI values are taken to indicate the occurrence of drought, while all positive values show no drought.

The SPI was adopted for this study because of its advantages over other indices, particularly the Palmer Drought Severity Index (PDSI). It is flexible, i.e., it can be computed for different time scales, can provide early warning of drought, and helps assess drought severity. The SPI is versatile, i.e., adapted to many functions (McKee et al. 1993). It is less complex than the PDSI and many other indices. It is spatially consistent: it allows for comparisons between different locations in different climates, and its probabilistic nature gives it historical context, which is well suited for decision-making

Table 2 Standardized precipitation index values and categories (Adapted from McKee et al. 1993)

SPI values	Categories
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

(World Meteorological Organization 2012). It is preferred to the PDSI, which is only good for large areas of uniform topography. The SPI has the advantage of identifying emerging droughts months sooner than the PDSI. PDSI is not as comparable across regions as the SPI, and it lacks multi-timescale features of indices like the SPI (Dai and National Center for Atmospheric Research Staff 2017).

4 Result

4.1 Drought occurrences

Occurrence of drought in the sub-humid eco-climatic zone of Nigeria from 1970 to 2009 is summarized in Table 3. Drought occurred 266 times in the zone during the study period. This ranged from 57 times in 1990–1999 to 87 times in 1980–1989, respectively. The events also varied from 14 times at Makurdi to 24 times at Bauchi. On decadal basis, the drought events ranged from twice at Makurdi and Kaduna to 7 times at Yelwa in 1970–1979, 3 times at Ilorin to 10 times at Minna in 1980–1989, twice at Makurdi to 6 times at Bida and Zaria in 1990–1999, and twice at Minna and Bauchi to 7 times at Ibi in 2000–2009, respectively.

4.2 Categories of drought

Table 4 shows occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 1970 to 2009. The categories followed a decreasing order from 175 times as mild to 12 times as extreme during the period of study. Seven out of the 13 stations experienced extreme drought events and most of them concentrated in the southern part of the study area, while others are found scattered in the northern part. The 11

stations that experienced severe drought are found in all parts of the study area. Mild drought varied from 9 times at Ilorin to 17 times at Bauchi and Jos, while moderate, severe, and extreme drought events ranged from once at Markurdi to 8 times at Zaria, once at Makurdi to 4 at Kaduna and Ibi, and once at Jos to 3 times at Minna, respectively.

In the first decade (1970 to 1979), the zone experienced 42 mild droughts, 12 moderate droughts, 5 severe droughts, and an extreme drought event, respectively (Table 5). Mild drought was highest in Yelwa, while moderate drought was highest in Bida, Yola, Ilorin, and Bauchi with two occurrences each. Severe drought only occurred once in few stations while only Bida experienced extreme drought during the study period.

Drought ranged from 7 extreme droughts to 53 mild drought events during the second decade (1980–1989) (Table 6). Mild drought was highest at Minna and least at Ilorin, while Abuja and Zaria experienced the highest number of moderate drought events. Severe drought varied from one to two times in some of the stations, while Minna experienced the highest number of extreme drought events.

The third decade (1990–1999) experienced 42 mild drought, 12 moderate drought, 1 severe drought, and 2 extreme drought events, respectively (Table 7). Mild drought event varied from an event at Yelwa to five times at Zaria, while Yelwa and Lokoja recorded the highest number moderate drought events. The only severe drought occurred at Bida while that of extreme drought event occurred at Ilorin and Jos, respectively.

Mild, moderate, severe, and extreme drought events occurred 37, 13, 10, and 2 times in the fourth decade (2000–2009) (Table 8). Mild drought events were highest at Jos while moderate drought was highest at Zaria. Less than half of the stations experienced severe drought which ranged from one to

Table 3 Drought occurrence in the sub-humid eco-climatic zone of Nigeria from 1970 to 2009

S/No.	Station	1970–1979	1980–1989	1990–1999	2000–2009	Total
1	Yelwa	7	8	3	4	22
2	Bida	5	6	6	5	22
3	Kaduna	2	6	5	5	18
4	Lokoja	6	8	5	4	23
5	Zaria	6	7	6	4	23
6	Ibi	5	7	4	7	23
7	Minna	5	10	5	2	22
8	Yola	6	6	4	5	21
9	Ilorin	6	3	4	4	17
10	Bauchi	6	9	4	5	24
11	Abuja	–	6	4	6	16
12	Makurdi	2	5	2	5	14
13	Jos	4	6	5	6	21
	Total	60	87	57	62	266

Table 4 Occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 1970 to 2009

Station	Near normal	Moderate drought	Severe drought	Extreme drought	Total
Yelwa	16	5	0	1	22
Bida	13	4	3	2	22
Kaduna	10	4	4	0	18
Lokoja	13	6	3	1	23
Zaria	13	8	2	0	23
Ibi	16	3	4	0	23
Minna	16	2	1	3	22
Yola	13	4	2	2	21
Ilorin	9	4	2	2	17
Bauchi	17	4	3	0	24
Abuja	11	5	0	0	16
Makurdi	11	1	2	0	14
Jos	17	3	0	1	21
Total	175	53	26	12	266

three occurrences. The two extreme drought events during the decade occurred at Yola and Ilorin, respectively.

4.3 Drought intensity

Drought intensity ranged from -0.01 to -3.1 on SPI scale during the period of investigation (Table 9). It ranged from -0.01 to -2.3 in 1970–1979, -0.1 to -2.2 in 1980–1989, -0.01 to -2.2 in 1990–1999, and -0.01 to -3.1 in 2000–2009. Drought is more intense in the eastern part of the study area than the other areas.

4.4 Drought duration

Drought duration is depicted in Fig. 2. Drought duration varied from 1 to 3 years in Yola and Makurdi, 1 to 4 years in

Yelwa, Bida, Ilorin, Abuja, and Jos, 1 to 5 years in Kaduna, Zaria, and Ibi, 1 to 7 years in Lokoja, 1 to 10 years in Bauchi, and 1 to 11 years in Minna.

Severe and extreme drought years in most stations were followed by either wet/very wet years or reduced drought and wet years in a continuum. Very wet and/or extremely wet years vary from 1 to 3 years in the study area during the period of study. Drought varied from 14 years at Markurdi to 24 years at Bauchi, while wet period ranged from 16 years at Bauchi to 23 years at Ilorin.

4.5 Drought variation

Figure 2(a–m) showed the drought variation in the study area. Half of the entire study period was dominated by mild drought in Yelwa (Fig. 2a). Years 1973, 1985,

Table 5 Occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 1970 to 1979

Station	Near normal	Moderate drought	Severe drought	Extreme drought	Total
Yelwa	6	1	0	0	7
Bida	2	2	0	1	5
Kaduna	1	1	0	0	2
Lokoja	4	1	1	0	6
Zaria	4	1	1	0	6
Ibi	4	0	1	0	5
Minna	4	0	1	0	5
Yola	4	2	0	0	6
Ilorin	4	2	0	0	6
Bauchi	3	2	1	0	6
Abuja	–	–	–	–	–
Makurdi	2	0	0	0	2
Jos	4	0	0	0	4
Total	42	12	5	1	60

Table 6 Occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 1980 to 1989

Station	Near normal	Moderate drought	Severe drought	Extreme drought	Total
Yelwa	5	2	0	1	8
Bida	4	1	0	1	6
Kaduna	4	1	1	0	6
Lokoja	4	1	2	1	8
Zaria	3	3	1	0	7
Ibi	5	0	2	0	7
Minna	6	1	0	3	10
Yola	3	1	1	1	6
Ilorin	2	0	1	0	3
Bauchi	6	1	2	0	9
Abuja	3	3	0	0	6
Makurdi	4	1	0	0	5
Jos	5	1	0	0	6
Total	54	15	10	7	87

1987, and 1990 were moderate drought years while that of 1983 was extreme. Twenty-four of the 40 years studied were characterized by drought of different intensity at Bida. About half of the drought was mild, while 1970, 1979, 1982, and 1992 were moderate drought years. The droughts were severe in 1998, 2002, and 2003 but extreme in 1972 and 1983, respectively (Fig. 2b). Kaduna was dominated by mild to moderate drought. However, the drought of 1983, 2006, 2007, and 2008 was severe (Fig. 2c). There was 23 years of drought in Lokoja, Zaria, and Ibi, respectively (Fig. 2d–f). Years 1977, 1982, and 1983 were severe drought years at Lokoja while Zaria was characterized by severe drought in 1975 and 1989 as well as extreme drought in 1983. At Ibi, drought was severe in 1973, 1979, 1983, and 2003. Out

of the 22 years of drought at Minna, 16 were mild. Though, 1981 and 1993 were moderate drought years, severe drought occurred in 1973, while 1983, 1984, and 1987 were characterized by extreme drought events (Fig. 2g). Yola and Ilorin were characterized by mild and moderate drought until 1987 when severe drought occurred at Yola and 1989 and 2002 at Ilorin. Extreme drought occurred in 1989 and 2008 at Yola and 1990 and 2001 at Ilorin, respectively (Fig. 2h, i). Bauchi drought was severe in 1973, 1985, and 1987 but dominated by mild and moderate drought for 21 years (Fig. 2j). Mild and moderate drought categories were prevalent at Abuja, Makurdi, and Jos (Fig. 2k–m). The occurrence of extreme drought in 2003 and severe drought in 2005 at Markurdi as well as extreme drought in Jos in 1995 were the only exceptions.

Table 7 Occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 1990 to 1999

Station	Near normal	Moderate drought	Severe drought	Extreme drought	Total
Yelwa	1	2	0	0	3
Bida	4	1	1	0	6
Kaduna	4	1	0	0	5
Lokoja	3	2	0	0	5
Zaria	5	1	0	0	6
Ibi	3	1	0	0	4
Minna	4	1	0	0	5
Yola	3	1	0	0	4
Ilorin	2	1	0	1	4
Bauchi	4	0	0	0	4
Abuja	4	0	0	0	4
Makurdi	2	0	0	0	2
Jos	3	1	0	1	5
Total	42	12	1	2	57

Table 8 Occurrence of drought categories in the sub-humid eco-climatic zone of Nigeria from 2000 to 2009

Station	Near normal	Moderate drought	Severe drought	Extreme drought	Total
Yelwa	4	0	0	0	4
Bida	3	0	2	0	5
Kaduna	1	1	3	0	5
Lokoja	2	2	0	0	4
Zaria	1	3	0	0	4
Ibi	4	2	1	0	7
Minna	2	0	0	0	2
Yola	3	0	1	1	5
Ilorin	1	1	1	1	4
Bauchi	4	1	0	0	5
Abuja	4	2	0	0	6
Makurdi	3	0	2	0	5
Jos	5	1	0	0	6
Total	37	13	10	2	62

5 Discussion

Drought occurrences prevailed for more than half of the 40 years studied in most of the stations. The occurrences varied from 14 times at Markurdi to 24 times at Bauchi during the period of investigation. Okorie (2003) reported that drought incidence is not new in the sub-Saharan zone of Nigeria, considering the fact that the entire Sahel zone is susceptible to climatic anomalies. He later concluded that drought threatened the zone for many years but there was dramatic decline in the occurrence towards the end of the last decade, 1990–1999. The present study in the sub-humid zone of Nigeria corroborates his finding, as the decade 1990–1999 actually recorded the least number of drought events with 57 (21.43%) occurrences. The study also revealed that the decline in drought occurrences was not particular to any decade. The

first decade (1970–1979) and third decade (1990–1999) recorded less occurrences of drought than the second (1980–1989) and the fourth decades (2000–2009), respectively.

The sub-humid eco-climatic zone of Nigeria was characterized with drought of different categories, ranging from mild to extreme. Mild drought was more common than other drought categories, as it accounted for 65.79% of the droughts in the zone. Moderate, severe, and extreme droughts made up of 19.93, 9.77, and 4.51%, respectively. Severe and extreme droughts were the most devastating of these droughts, as they cause serious damage to agriculture with consequences on the economy. Severe drought occurred in most of the stations, with variation from one to four times. However, extreme drought occurred in seven stations, but was more serious at Bida, where it occurred three times during the study period. The period 1972–1973 as well as 1982–1984 was either

Table 9 Drought intensity on SPI scales in Sokoto-Rima River Basin, Nigeria

Station	Drought intensity				
	1970–2009	1970–1979	1980–1989	1990–1999	2000–2009
Yelwa	−0.01 to −2.2	−0.01 to −1.0	−0.2 to −2.2	−0.4 to −1.3	−0.01 to −0.3
Bida	−0.01 to −2.3	−0.01 to −2.3	−0.1 to −2.1	−0.2 to −1.8	−0.2 to −1.8
Kaduna	−0.1 to −1.9	−0.1 to −1.2	−0.1 to −1.5	−0.1 to −1.4	−0.1 to −1.9
Lokoja	−0.01 to −1.8	−0.1 to −1.5	−0.3 to −1.8	−0.01 to −1.1	−0.4 to −1.4
Zaria	−0.1 to −2.2	−0.1 to −1.7	−0.3 to −2.2	−0.3 to −0.5	−0.3 to −1.3
Ibi	−0.2 to −1.9	−0.3 to −1.6	−0.2 to −1.5	−0.4 to −1.2	−0.3 to −1.9
Minna	−0.1 to −2.8	−0.2 to −1.7	−0.3 to −2.8	−0.1 to −1.2	−0.6
Yola	−0.2 to −3.1	−0.2 to −1.1	−0.2 to −2.8	−0.3 to −1.2	−0.2 to −3.1
Ilorin	−0.1 to −2.5	−0.1 to −1.4	−0.3 to −1.5	−0.3 to −2.1	−0.9 to −2.5
Bauchi	−0.2 to −1.7	−0.3 to −1.6	−0.3 to −1.8	−0.5 to −0.9	−0.2 to −1.0
Abuja	−0.1 to −1.4	–	−0.3 to −1.2	−0.1 to −1.2	−0.2 to −1.4
Makurdi	−0.3 to −1.8	−0.3 to −1.3	−0.3 to −1.4	−0.4 to −0.7	−0.4 to −1.8
Jos	−0.01 to −2.2	−0.4 to −0.9	−0.1 to −1.0	−0.4 to −2.2	−0.1 to −1.2

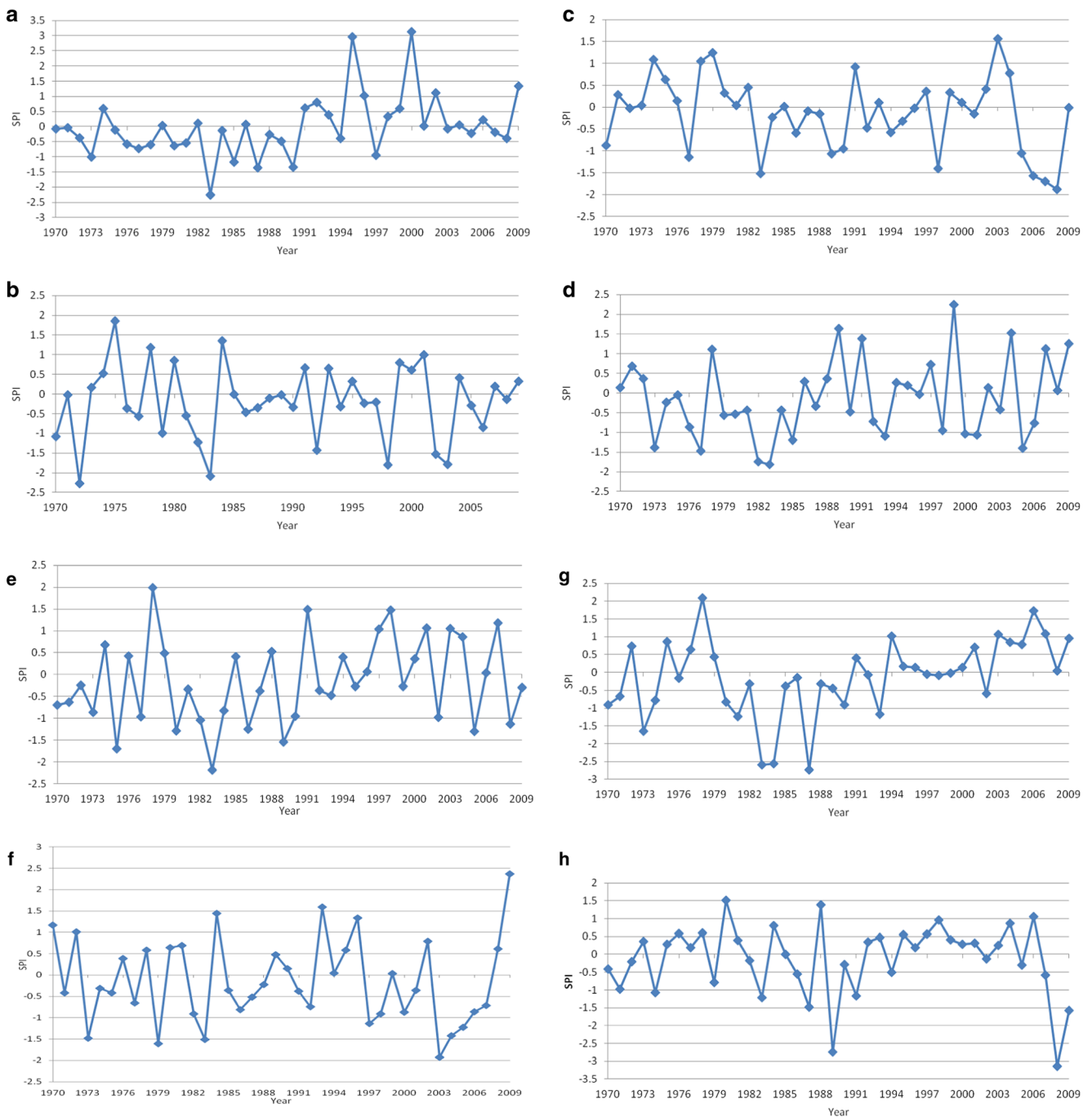


Fig. 2 a Standardized Precipitation Index (SPI) showing drought duration and intensity in Yelwa. b SPI showing drought duration and intensity in Bida. c SPI showing drought duration and intensity in Kaduna. d SPI showing drought duration and intensity in Lokoja. e SPI showing drought duration and intensity in Zaria. f SPI showing drought duration and intensity in Ibi. g SPI showing drought duration and intensity in Minna. h SPI showing drought duration and intensity in

Yola. i SPI showing drought duration and intensity in Ilorin. j SPI showing drought duration and intensity in Bauchi. k SPI showing drought duration and intensity in Abuja. l SPI showing drought duration and intensity in Makurdi. m SPI showing drought duration and intensity in Jos. a–m SPI showing drought duration and intensity in the sub-humid eco-climatic zone of Nigeria

severe or extreme drought year in most stations, especially Yelwa, Bida, Minna, Kaduna, Lokoja, Zaria, and Ibi. This period marked the time of serious drought problem in the northern part of Nigeria (New Nigerian Newspaper, 26/11/73, 15/12/73; Apeldoorn 1977; Mijindadi and Adegbehin

1991). Besides, 2002 to 2003 and 2007 to 2008 were either severe or extreme drought years at Bida, Ibi, Yola, Ilorin, and Markurdi.

The study revealed no latitudinal progression from the south to the north in the occurrence of drought events. The

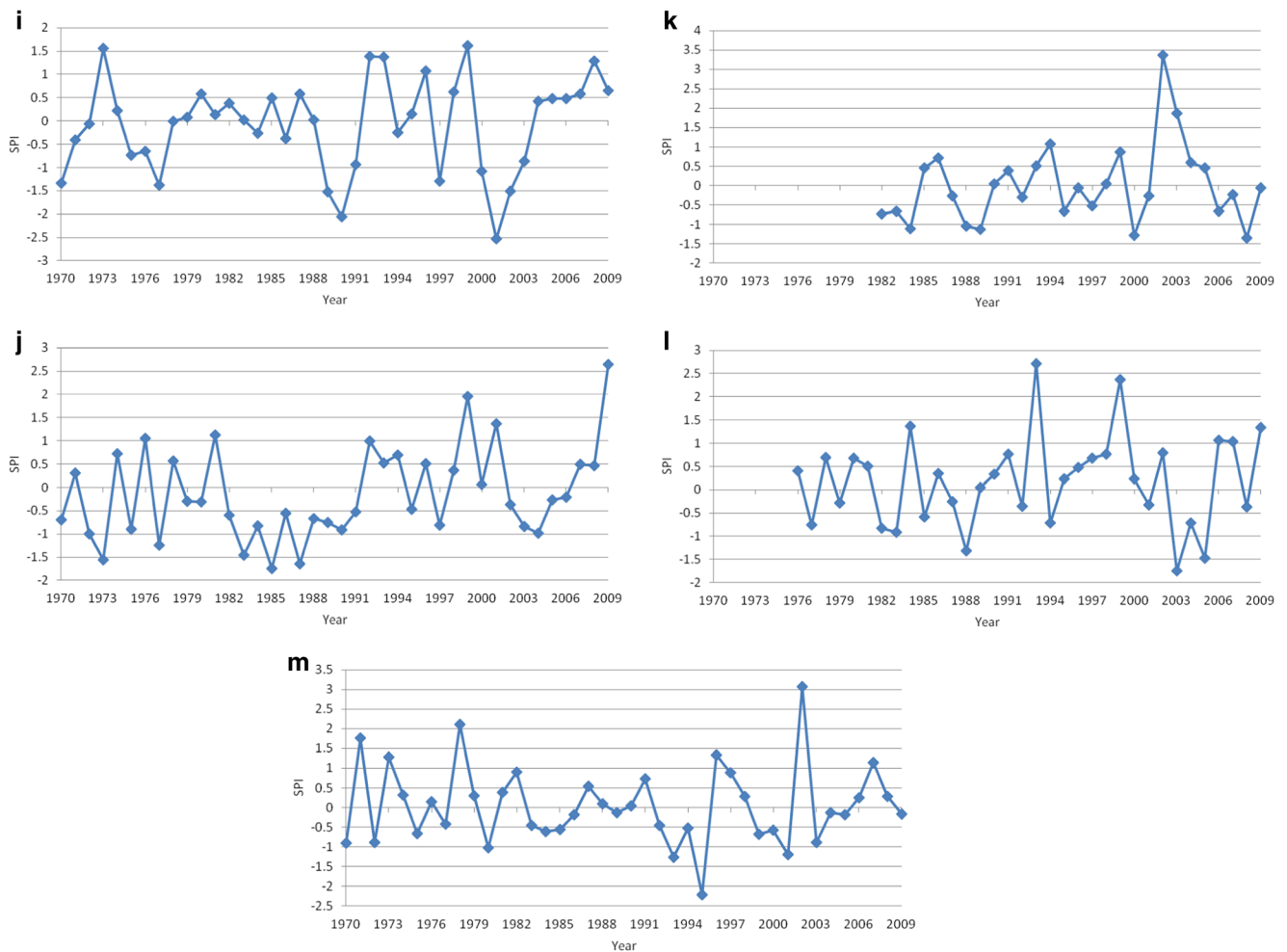


Fig. 2 continued.

notorious drought events occurred more in the southern part of the study area than the northern part. For instance, extreme drought occurred more in the southern stations such as Ilorin, Lokoja, and Bida, while there was no occurrence of severe drought in Yelwa and Jos, and extreme drought in Kaduna, Zaria, and Bauchi in the north. It worthy of note that Abuja and Markurdi that recorded less number of drought occurrences lacked complete data.

Drought was most prevalent in the zone in the second decade (1980 to 1989). The decade recorded 32.71% of drought events and was mostly affected by all categories of drought. Besides, most stations were devastated during this decade, as it recorded 38.46% of the severe droughts and 58.33% of the extreme drought events. Apart from 1982 to 1984 when these droughts affected most stations, 1985 and 1987 at Bauchi, 1987 in Minna and Yola, as well as 1989 in Zaria were either severe or extreme drought years. In particular, the three extreme droughts of 1983, 1984, and 1987 at Minna were devastating. Drought was also serious in some stations in the fourth decade (2000–2009). For instance, while 2002 to 2003 were two consecutive severe drought years at Bida,

2006, 2007, and 2008 were three consecutive severe drought years at Kaduna.

In most time, severe and/or extreme drought exceeds one decade. This was typical of Makurdi, Bauchi, Ilorin, Ibi, Zaria, Kaduna, and Bida, respectively. For instance, at Bida, the droughts of 1972 and 1983 were extreme, while that of 1998 and 2002 to 2003 were severe. Also, drought experienced growth and suppression in the zone. Examples are the drought of Yola, Ilorin, Bauchi, Markurdi, Jos, and Abuja, respectively. At Yola, there was reduction in rainfall in 1985 when mild drought set in. This later became moderate in 1986 and severe in 1987. The reprieve of 1988 was short-lived as extreme drought set in later in 1989. Besides, the moderate drought of 2007 turned extreme in 2008 and reduced to severe drought in 2009. Also, the drought that started as mild at Ilorin in 1988 became severe in 1989 and later graduated to extreme in 1990. In like manner, the moderate drought of 2000 suddenly turned extreme in 2001 and reduced to severe in 2002, before returning to mild in 2003. The three occurrences of severe drought events at Bauchi were limited to the earlier two decades (1970–1979 and 1980–1989). While the only severe

drought of the first decade occurred in 1973, the remaining two occurred in 1985 and 1987, respectively. Since then, drought at Bauchi has been relatively mild. Neither severe nor extreme drought events were witnessed at Markurdi until the third decade. The characteristically mild drought of this location suddenly turned severe in 2003 and 2005, respectively, before returning to normal. Jos was mostly characterized by mild drought, with 18 (81.82%) out of the 22 years as mild. The only extreme drought experienced in Jos occurred in 1995. However, since 1982 when data collection started at Abuja station, the city has never witnessed any severe or extreme drought event. The drought was either mild, graduating to moderate and vice versa.

The result showed considerable interannual variability characterized by oscillations in drought duration. The duration of drought varied from 1 to 11 years in the study area. Drought occupied a long period of years in some of the stations. For instance, drought occurred from 2003 to 2007 at Ibi, 1980–1984 at Zaria, 1986–1990 at Kaduna, 1979–1985 at Lokoja, 1980–1990 at Minna, and 1982–1991 at Bauchi. Drought intensity ranged from -0.01 to -3.1 . Drought was most intense in 1989 in Yola in the study area during the period of study.

Three major factors appear to dominate drought occurrences in the study area: the El Niño/Southern Oscillation (ENSO), Intertropical Convergence Zone (ITCZ), and human activities especially deforestation, overgrazing, and poor cropping methods. The effect of ENSO in altering and changing weather in different parts of the globe is a well-known fact (Ropelewski and Halpert 1987; Kane 1999). Several researches have tried to ascertain connection between drought and ENSO (Nicholson 1981; Shukla and Paolino 1983; Ropelewski and Halpert 1987, 1996; Rasmusson and Mo 1993; Reason and Mulenga 1999; Shewale and Rase 2000; Reason and Rouault 2002; Nazemosadat and Ghasemi 2004; Anreoli and Kayano 2005; Wu et al. 2003), etc. The extensive drought the globe experienced in 1970s, 1980s (especially 1972, 1982, 1987), and so on have been ascribed to the presence of ENSO. El Niño is an abnormal increase in surface water temperature of the coast of South American and it is associated with major changes in the ocean/atmospheric system across the entire tropical Pacific and global perturbations of climate and perhaps changes of climatic regime (Gribbin 1978) while Southern Oscillation is an inverse variation of pressure between the Indian and Pacific oceans in the tropics (Parker 1982). The ENSO being a global event is believed to affects small areas (Abigail et al. 2002) as well as extensive areas, far removed from the center of action.

Investigations on the reduction of rainfall in the semi-arid zone south of Sahara were seen as a function of equatorial displacement of ITCZ (Ilesanmi 1971; Kraus 1977; Nicholson and Grist 2001; Doherty et al. 2012; Lucio et al. 2012; Nicholson 2013; Schneider et al. 2014). Bryson (1973), Brooks (2004), Tourre et al. (2006), and Paz et al. (2008)

related Sahelian drought to a southward displacement of the Northern Hemisphere subtropical anticyclones (and other climatic features). It also includes variable convective activity due to changes of the surface temperature and strength or convergence, or changes of the slope of the ITCZ (Nicholson 1979; Nolan et al. 2007; Vondou 2012). Hastenrath and Greischar (1993) and Hastenrath and Droyan (1993) revealed that enhanced northward temperature increase in the tropical Atlantic is accompanied by a stronger meridional pressure gradient and an accelerated southerly wind component, which are representative of a northward displacement of the ITCZ.

The underlying cause of most droughts in a region can be related to changing weather patterns manifested through the excessive build up of heat on the earth's surface, meteorological changes which result in a reduction of rainfall, and reduced cloud cover, all of which results in greater evaporation rates (Dai 2011). Droughts are exacerbated by human activities such as deforestation, overgrazing, urbanization, industrialization, and poor cropping methods, which reduce water retention of the soil, and improper soil conservation techniques, which lead to soil degradation (Adejuwon 2000; Dai 2011). The modification of the land surface therefore has impact on the atmosphere by changing its lower and surface physical properties. Human activities were recognized by SMIC Report (1971) to have significantly altered the global land surface. There is widespread belief that extensive irrigation augments rainfall, large-scale deforestation inadvertently alters rainfall pattern, rainfall could be enhanced by intentional modification of the land surface (e.g., irrigation or deforestation), soil moisture exerts a significant influence on large scale air temperature fields, and that surface effects have played a critical role in maintaining the drought that plagued Sahelian Africa for nearly two decades (Nicholson 1985). Schmid (1998) established that the recent severe drought events are signs that climate had already changed owing to human impacts.

6 Conclusion

The study has shown that drought category in sub-humid ecological zone of Nigeria over the study period followed a decreasing order in occurrence from mild to extreme. The period 1980–1989 was more prone to drought while 1990–1999 was wetter than other decades. Drought occurrences varied from 14 times at Makurdi to 24 times at Bauchi. Severe drought occurred most at Kaduna and Ibi while extreme drought was mostly devastating at Minna. The result also showed considerable interannual variability characterized by oscillations in drought duration. Drought intensity ranged from -0.01 to -3.1 , while the duration varied from 1 to 11 years. Since drought is associated with hardship, the study suggests

drought planning, forecasting, and preparation to mitigate drought impacts.

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