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SPATIO-TEMPORAL ANALYSIS OF DROUGHT OCCURRENCE AND INTENSITY IN NORTHWEST ZONE OF NIGERIA

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Abstract

This study assesses 'the spatio-temporal analysis of the occurrence and intensity of drought in Northwest zone of Nigeria'. The zone is prone to drought occurrence, characterized by various intensities. Monthly rainfall data spanning a period of 60 years was employed (that is, 1956-2015) from six meteorological stations scattered over the zone. Besides, the standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics were used to test for the normality in the seasonal (April to October) rainfall series for each of the stations. Also, the Normalized Rainfall Index (NRI) was used to determine the occurrence and intensity of drought in the zone. It was revealed that the study area has experienced mild, moderate and severe droughts. Similarly, drought years were identified within the study period using NRI, the drought years identified include: 11 years of mild drought (in Gusau); 9 years of moderate droughts (in Gusau) and 1 year of severe drought (in Gusau) while, Sokoto experienced, 10 years of mild drought, 6 year of moderate drought and 4 years of severe drought. Also,

Kano experienced 14 years of mild drought, 7 years of moderate drought and 3 years of severe drought. Katsina on the other hand experienced 8 years of mild drought, 9 years of moderate drought and 4 years of severe drought. Kaduna too experienced 8 years of mild drought, 5 years of moderate drought and 6 years of severe drought. Finally, Yelwa experienced 6 years of moderate drought and 3 years of severe drought. The study recommends the need for a close monitoring over this zone in order to identify its onset, intensity, cessation, duration and spatial extent as well as its frequency in a timely manner for its proper management, among others were the mitigating measures recommended.

Keywords: Occurrence, Normalized Rainfall Index, Intensity, Moderate and Severe drought

Introduction

Drought occurs in virtually all climates. Unlike hurricanes which are easily identified and straight forward to classify in terms of wind speeds, droughts are much tougher to define. Drought is an insidious hazard on nature (National Drought Mitigation Centre [NDMC], 2016). Drought means different things to various people, depending on their specific interest (Abaje, Ati and Iguisi, 2011). It is often referred to as a "creeping phenomenon" and its impact vary from region to region (Larry, 2014). Drought can therefore be difficult for people to understand. It is equally difficult to define (NDMC, 2016).

Thus, there is no agreed definition of drought. Specialists who have differing perspectives have suggested at least 150 different definitions (Wilhite, 2000). For instance according to U.S. National Weather Service [NWS], (2008), drought is "a period of abnormally dry weather which persists long enough to produce a serious hydrologic imbalance". However, in the most general sense, drought originated from a deficiency of precipitation over an extended period of time – usually a season or more – resulting in a water shortage for some activity, group or environmental sector (NWS, 2008; NDMC, 2016).

In addition, based on disciplinary perspectives and interest, the following drought types were identified: meteorological, agricultural, hydrological and socio-economic/famine droughts (Keith, 2002; Ayoade, 2004; Richard, Lindley, George and Richardson, 2004; Arvind, 2006). The frequency of occurrences of extreme weather events such as floods, hurricanes, blizzards, droughts and heat and cold waves experienced in different parts of the world in recent years and the devastating effects of these severe weather events on human lives and property as well as national economies, constitute the most important environmental problem that mankind faces (Faniran, 1992; Ayoade, 2005; USAID, 2007).

Background of the Research

Extreme weather and climate events have attracted considerable attention in recent years because of the large losses of life as well as tremendous increase in economic losses caused by the extreme events (Easterling et al., 2000). Evidence is emerging that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). Boko et al., (2007) predicted that Africa is likely to warm across all seasons during this century with annual mean surface air temperatures expected to increase between 3^0C and 4^0C by 2099, roughly 1.5 times the average global temperatures. Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5-20 percent from December to February, and decrease rainfall by 5-10 percent from June to August by 2050 (Hulme, Doherty, Ngara, New and Lister, 2001; IPCC, 2007). Fluctuations of climatic elements, particularly rainfall in northern Nigeria is not new especially in the north western ecological zone which comprises the northern Guinea, and Sudan-Sahel ecological zones of West Africa (Asiedu, 1992; Abdulkarim, Oladipo and Balarabe, 2015).

Available literature on Nigeria shows the existence of spatial differences in the nature of disasters (Daura, 2014). While oil and gas pollution is largely a Niger Delta problem, drought and quelea birds infestation occur in the Northwest zone (National Emergency Management Agency [NEMA], 2012; Daura, 2014). Literature has also shown that the Sahel and Sudan savanna are drought prone areas. Several studies in the Northern Regions have indicated that the onset in raining season is highly variable and unpredictable (Hassan and Abdulhameed, 2012).

Drought is not a recent phenomenon in Nigeria. Historical records indicate that drought has occurred frequently in the past. Some of these droughts were severe and accompanied by famines, arising from crop failures. Drought-induced famines compelled people in the past to abandon their settlements and resettle where agricultural conditions were more favourable (Ayoade, 1988). It has been quantified that in 1987, about 5 million metric tonnes of grains (valued at about $400 million) were reportedly lost to drought (Oladipo, 1993). Similarly, an analysis of drought during 1900 – 2013 indicated that the severe droughts in Sahel (during; 1910's, 1940's, 1960's, 1970's and 1980's) caused huge socio-economic and environmental impacts in the region (Masih, Maskey, Musa and Trambauer, 2014). In addition, Zeng (2003) concluded that between 1968 and 1972, the Sahelian area of Africa experienced one of the worst droughts in living memory.

Study Area

Northwest zone of Nigeria is located between Latitudes 9^o 02^1N and 13^o 58^1N and Longitudes 3^o 08^1E and 10^o 15^1E (Fig.1). The area so defined covers a land area approximately 212,350km^2 (Table 1). Northwest zone of Nigeria shares borders with Niger Republic in the northern part,

Benin and Niger Republic in the Western part, Niger State and FCT to the south, and Yobe, Bauchi and Plateau States to the East.

The climate of Northwest zone of Nigeria is the tropical wet-and-dry type (Koppen's Aw climate). The wet season lasts from April through October with a peak in August, while the dry season extends from November of one calendar-year to April of the next (Abaje et al., 2012). The annual average rainfall varies from about 1733 mm at the extreme southern part of the zone to about 600 mm at the extreme northern part (Abaje et al., 2016). The rainfall intensity is very high between the months of July and August (ranging from 60 mm hour^{-1} to 99 mm hour^{-1}) (Oladipo, 1993). The pattern of rainfall in this region is highly variable in spatial and temporal dimensions with an inter-annual variability of between 15 and 20% (Oladipo, 1993; Abaje, 2016).

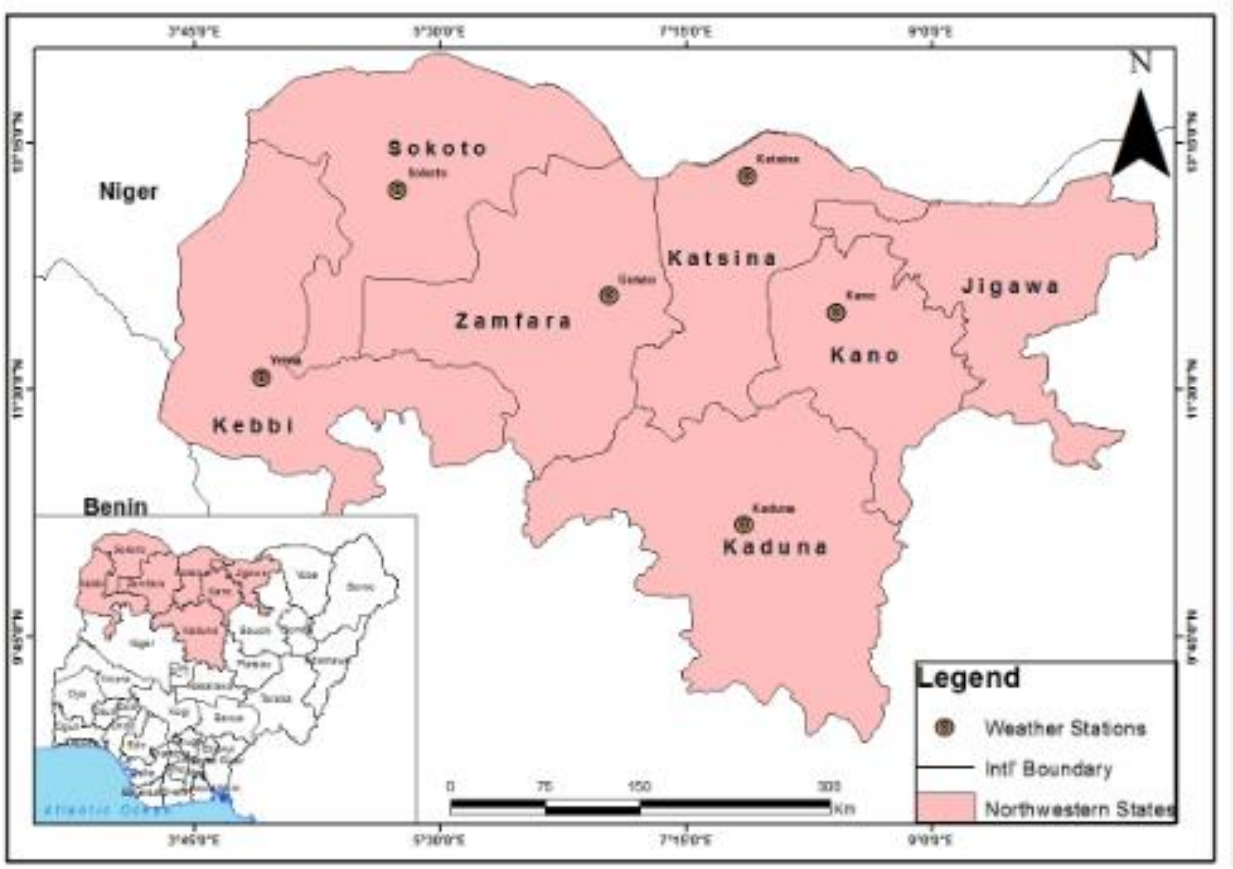


Figure 1: Study Area

The climate is dominated by the influence of the relative warm and moist tropical maritime (mT) air mass, which originates from the Atlantic Ocean associated with Southwest winds in Nigeria; and the relatively cool, dry and stable tropical continental (cT) air mass that originates from the Sahara Desert and is associated with the dry, cool and dusty Northeast Trades known as the Harmattan (Odekunle, 2010; Abaje *et al*, 2015). These two air masses (mT and cT) meet

along a slanting surface called the Intertropical Discontinuity (ITD). The movement of the ITD northwards across northern part of this zone in August (around latitude 21 to 22°N) marks the height of the rainy season in the whole zone while its movement to the southernmost part around January/February (approximately at 6°N) marks the peak of the dry season in the zone (Abaje *et al*, 2017). The movement of the ITD is very irregular, varying according to the season from 2° to 5.6° of latitude per month, and the southward retreat of the ITD is faster than its northward advance. While the northward advance is at the rate of about 160 km per month, that of the southward retreat is at about 320 km per month (Ayoade, 2005). This accounts for the rather gentle onset of the rainy season in the zone and its rather abrupt end (Abaje, 2016). The highest average air temperature normally occurs during the hot season (March to May) while the lowest average air temperature occurs during the cold season (December to February) (Abaje et al., 2017).

Table 1: Land Area of Northwest Zone by States

States	**Hectares**	**Square kilometers**	**Acres**	**Square miles**
Jigawa	2,238,700	23,287	5,728,602	9,096.48
Kaduna	4,248,100	42,481	10,450,326	16,594.14
Kano	2,028,000	20,280	4,988,880	7,921.88
Katsina	2,356,100	23,561	5,796,006	9,203.52
Kebbi	3,698,500	36,985	9,098,310	14,447.27
Sokoto	2,782,500	27,825	6,844,950	10,869.14
Zamfara	3,793,100	37,931	9,331,026	14,816.80
Total	21,235,000	212,350	52,238,100	82,949.23

Source: Office of the Surveyor-General

Methodology

A reconnaissance survey was carried out in the study area. The main objective of this visit is to become familiar with the study area. Besides, monthly rainfall data for the period 1956-2015 was obtained from Nigerian Meteorological Agency. The data were collected from six synoptic stations in the Northwest zone of Nigeria (that is, Kano, Gusau, Sokoto, Katsina, Kaduna and Yelwa), (Table 2).

Table 2: Metrological Stations in the Northwest Zone of Nigeria

Stations	Station no.	Latitude	Longitude	Altitude	Period	No. of years
Kano	1206.03	12°03′N	08°32′E	475.80m	1956-2015	60
Gusau	1206.14	12°10′N	06°42′E	468.00m	1956-2015	60
Sokoto	1205.51	12°55′N	05°12′E	309.00m	1956-2015	60
Katsina	1307.04	13°01′N	07°41′E	516.63m	1956-2015	60
Yelwa	1004.54	10°53′N	04°45′E	224.00m	1956-2015	60
Kaduna	1007.34	10°36′N	07°27′E	644.96m	1956-2015	60

Source: Nigeria meteorological agency (NIMET).

These stations were selected because they are in the drought prone areas of the region (Abaje, 2010). These stations were chosen based on the following criteria:

1. They are synoptic stations.
2. They are evenly distributed in the area.
3. All the stations have long period of recorded rainfall data that cover the period of study.
4. The stations have no significant missing rainfall records during the period of study.
5. The stations have not been relocated since their establishment.
6. The data were tested and found to be normally distributed.

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) was used to test for the normality in the seasonal (April to October) rainfall series for each of the stations. These are the months during which most of the stations in the region receive over 85% of their annual rainfall totals (Oladipo, 1993). The standardized coefficient of Skewness (Z_1) was calculated using:

$$Z_1 = \left[\left(\sum_{i-1}^{N}(xi - \bar{x})^{3/N}\right) \Big/ \left(\sum_{i-1}^{N}(xi - \bar{x})^{2/N}\right)\right] \Big/ \left(\frac{6}{N}\right)^{1/2} \quad \text{----------Equation (1)}$$

and the standardized coefficient of Kurtosis (Z_2) was determined by:

$$Z_2 = \left[\left(\sum_{i-1}^{N}(xi - \bar{x})^{4/N}\right) \Big/ \left(\sum_{i-1}^{N}(xi - \bar{x})^{2/N}\right)^2\right] - 3 \Big/ \left(\frac{24}{N}\right)^{1/2} \quad \text{----------Equation (2)}$$

Where $\bar{x}$ is the long term mean of X_i values and N is the number of years in the sample.

In this study, meteorological indication was used in depicting periods of different drought frequencies and intensities in the study area. This method was based only on rainfall input. This is because rainfall has been considered as the most important variable in drought indices that also include data of temperature or evapo-transpiration. Moreover, rainfall is the variable that mainly determines the duration, magnitude and intensity of drought (Oladipo, 1985; Keyantash and Dracup, 2002; Vicente-Serrano and L'opezMoreno, 2005). The choice of this method is justified enough when one considers the fact that it is only rainfall records that are available in many parts of the study area. This method is:

(i) Normalized Rainfall Index (NRI): The normalized rainfall index is a measure of intensity of drought using annual or seasonal rainfall totals and the standard deviation to indicate the shortage of water of any given season. The normalized rainfall index for a given station as defined by Turkes (1996) was computed as:

$$A_{sy} = \frac{R_{sy} - \bar{R}_s}{S_s} \quad \text{----------Equation (5)}$$

Where: R_{sy} = the rainfall total for the stations during a year (or a season).

$\bar{R}_s$ = the long term mean (of the period specified for the station) and,

S_s = standard deviation of the annual (or seasonal) rainfall total for that station.

This was achieved using description and classifications of index as defined by Turkes (1996). This is shown in Table 3.

Table 3: NRI Classification Values

Limit of Index	Character of Rainfall
1.76 or more	Extremely wet
1.31 to1.75	Very wet
0.86 to 1.30	Moderately wet
0.51 to 0.85	Mildly wet
0.50 to -0.50	Near normal
-0.51 to 0.85	Mild drought
-0.86 to 1.30	Moderate drought
-1.31 to 1.75	Severe drought
-1.76 or less	Extreme drought

Source: Turkes, (1996)

In this very study, a modified classification of NRI was therefore adopted. This is because extreme values, that is, greater than or equal to 1.76, and less than or equal to -1.76 for NRI values. These are infrequent throughout the period of study. Previous studies from Oladipo (1993), Abaje (2010), Abaje, Ati and Iguisi (2012) lend credence to this fact. These modified classifications are presented in Table 4.

Table 4: Modified Classes of NRI Values

Index	Character of Rainfall
1.31 or more	Very wet
0.86 to 1.30	Moderately wet
0.51 to 0.85	Mildly wet
0.50 to -0.50	Near Normal
0.50 to -0.85	Mild drought
-0.86 to -1.30	Moderate drought
-1.31 or less	Severe drought

Source: Abaje (2010)

Results and Discussion

The results of the standardized coefficient of Skewness (Z_I) and Kurtosis (Z_2) for the six stations are presented in Table 5. The results of Z_1 and Z_2 for the stations revealed that all the stations were accepted as normal at 95% confidence level. Therefore, no transformation was made to the rainfall series.

Table 5: Standardized coefficients of skewness and kurtosis for the six meteorological stations

Statistics/stations	Kano	Gusau	Sokoto	Katsina	Yelwa	Kaduna
Skewness	0.78	1.21	0.74	0.20	0.51	1.26
Kurtosis	0.12	1.84	1.19	-0.36	2.19	4.61

Source: Fieldwork (2017)

Similarly, the occurrence and intensity of drought are expressed in terms of drought index. The results of analysis of Normalized Rainfall Index (NRI) for the 6 stations in the study area are presented in Tables: 6-11 and graphically in figures 2 (a-f).

Table 6: Kaduna NRI Results

Intensity	Index	Drought year	Freq of occurrence	%
Very wet	1.33 or more	1966, 2013, 2014, 2015	4	6.67
Moderately wet	0.86 to 1.30	1962, 1963, 1969, 1974, 1978, 2003,2004,2012,	8	13.33
Mildly wet	0.51 to 0.85	1968, 1975, 1991, 2011	4	6.67
Near normal	0.50 to -0.85	1957, 1960, 1964, 1965, 1967, 1971, 1972, 1973, 1979, 1980, 1981, 1982, 1984, 1985, 1987, 1988, 1993, 1996, 1997, 1999, 2000, 2001, 2002, 2009, 2010	25	41.67
Mild drought	0.50 to -0.85	1959, 1970, 1977, 1986, 1992, 1994, 1995, 1998	8	13.33
Moderate drought	-0.86 to -1.30	1958, 1961, 1989, 1990, 2005	5	8.33
Severe drought	-1.31 or less	1956, 1976, 1983, 2006, 2007, 2008	6	10.00
Source: Fieldwork (2017)			Total: 60	100.00

Table 7: Kano NRI Results

Intensity	Index	Drought year	Freq of occur.	%
Very wet	1.31 or more	1961, 1998, 1999, 2001, 2003, 2005, 2012, 2014	8	13.33
Moderately wet	0.86 to 1.30	1978, 1997, 2004, 2006	4	6.67
Mildly wet	0.51 to 0.85	1962, 1996, 2000, 2007, 2011	5	8.33
Near normal	0.50 to -0.50	1957, 1958, 1959, 19645, 1966, 1968, 1969, 1970, 1977, 1980, 1988, 1991, 1992, 1993, 2002, 2008, 2010, 2013, 2015	19	31.67
Mild drought	0.50 to -0.85	1956, 1960, 1963, 1964, 1967, 1971, 1975, 1979, 1985, 1986, 1989, 1994, 1995, 2009	14	23.33
Moderate drought	-0.86 to -1.30	1972, 1974, 1976, 1981, 1982, 1987, 1990	7	11.67
Severe drought	-1.31 or less	1973, 1983, 1984	3	5.00
Source: Fieldwork (2017)			Total: 60	100 %

Table 8: Yelwa NRI Results

Intensity	Index	Drought year	Freq of occurrence	%
Very wet	1.31or more	1962, 1963, 1994, 1999, 2008	5	8.33
Moderately wet	0.86 to 1.30	1959, 1995, 2001, 2009	4	6.67
Moderately wet	0.86 to 1.30	1959, 1995, 2001, 2009	4	6.67
Mildly wet	0.51 to 0.85	1964, 1976, 1977, 1978, 1988, 1991, 1996, 1998, 2010, 2012, 2014	11	18.33

Near normal	0.50 to -0.50	1956, 1957, 1958, 1960, 1961, 1965, 1969, 1970, 1971, 1972, 1974, 1975, 1979, 1981, 1982, 1984, 1986, 1988, 1989, 1992, 1993, 1997, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2011, 2015	31	51.67
Mild drought	0.50 to 0.85	-----	0	0.00
Moderate drought	-0.86 to -01.30	1967, 1973, 1985, 1987, 1990, 2013	6	10.00
Severe drought	-1.31 or less	1966, 1968, 1983	3	5.00
Source: Fieldwork (2017)		Total: 60		100.00

Table 9: Katsina NRI Results

Intensity	Index	Drought year	Freq of occurrence	%
Very wet	1.31 or more	1957, 1958, 1959, 1964, 2010	5	8.33
Moderately wet	0.86 to 1.30	1961, 1979, 1980, 2003	4	6.67
Mildly wet	0.51 to 0.85	1963, 1965, 1966, 1969, 1970, 2001, 2002, 2004, 2005, 2006, 2007, 2012, 2013	13	21.67
Near normal	0.50 to -0.50	1956, 1960, 1962, 1967, 1974, 1975, 1976, 1977, 1978, 1981, 1986, 1989, 1990, 2000, 2008, 2011, 2015	17	28.33
Mild drought	0.50 to –0.80	1968, 1971, 1982, 1988, 1994, 1996, 1997, 2014	8	13.33
Moderate drought	-0.86 to -1.30	1972, 1973, 1983, 1984, 1985, 1987, 1995, 1998, 2009	9	15.00
Severe drought	-1.31 or less	1991, 1992, 1993, 1999	4	15.00
Source: Fieldwork (2017)		Total: 60		100.00

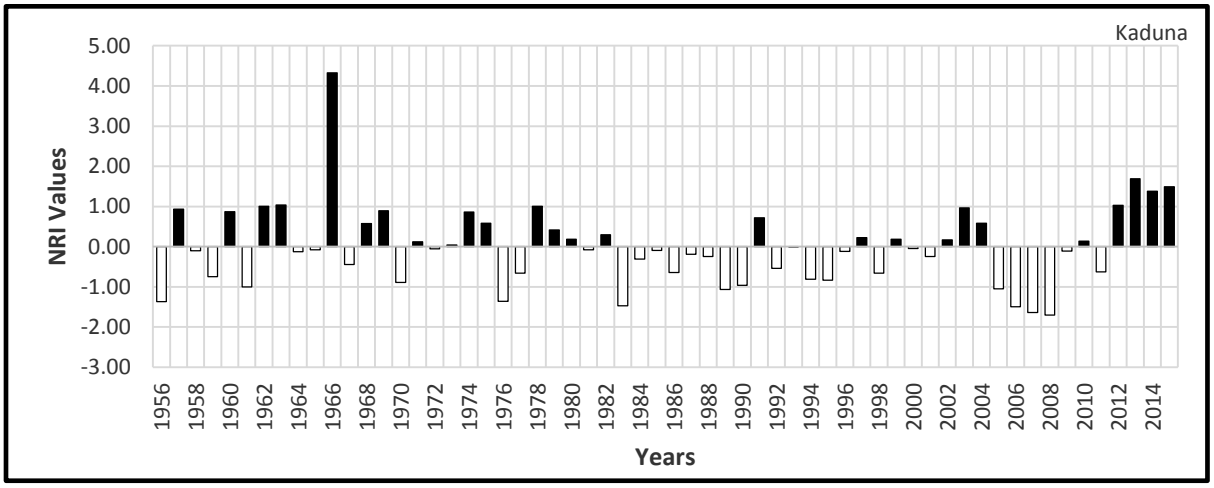
Table 10: Sokoto NRI Results

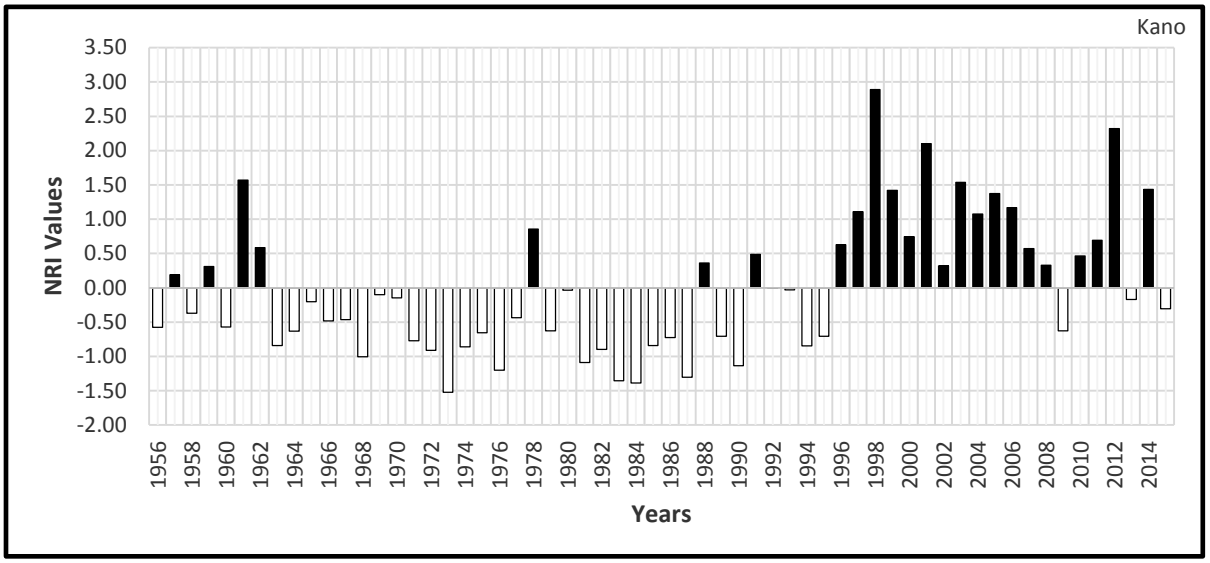
Intensity	Index	Drought year	Freq of occurrence	%
Very wet	1.31 or more	1957, 1958, 1960, 1965, 1976, 1998, 2010, 2014	8	13.33
Moderately wet	0.86 to 1.30	1963, 1977, 2003	3	5.00
Mildly wet	0.51 to 0.85	1991, 1994, 2001, 2002, 2006	5	8.33
Near normal	0.50 to -0.50	1956, 1961, 1962, 1964, 1966, 1969, 1970, 1978, 1979, 1983, 1988, 1989, 1990, 1993, 1996, 1997, 1999, 2000, 2004, 2005, 2007, 2009, 2012, 2013	24	40.00
Mild drought	0.50 to -0.85	1959, 1967, 1972, 1975, 1980, 1981, 1982, 1992, 2011, 2015	10	16.67
Moderate drought	-0.86 to -1.30	1971, 1974, 1984, 1986, 1995, 2008	6	10.00
Severe drought	-1.31 or less	1968, 1973, 1985, 1987	4	6.67
Source: Fieldwork (2017)			Total: 60	100.00

Table 11: Gusau NRI Results

Intensity	Index	Drought year	Freq of occurrence	%
Very wet	1.31 or more	1957, 1992, 1993, 1994, 2003	5	8.33
Moderately wet	0.86 to 0.85	1958, 1959, 1962, 1963, 1978, 1979, 1996	7	11.67
Mildly wet	0.51 to 0.85	1966, 1968, 1998, 2009, 2015	5	8.33
Near normal	0.50 to 0.50	1960, 1961, 1964, 1967, 1969, 1974, 1975, 1976, 1980, 1983, 1985, 1988, 1989, 1991, 1999, 2000, 2002, 2005, 2006, 2008, 2010, 2012	22	36.67
Mild drought	0.50 to 0.85	1956, 1965, 1970, 1971, 1977, 1981, 1982, 1986, 1995, 1997, 2007	11	18.33

Moderate drought	-0.86 to -1.30	1972, 173, 1987, 1990, 2001, 2004, 2011, 2013, 2014	9	15.00
Severe drought	-1.31 or less	1984	1	1.67
Source: Fieldwork (2017)			Total: 60	100.00





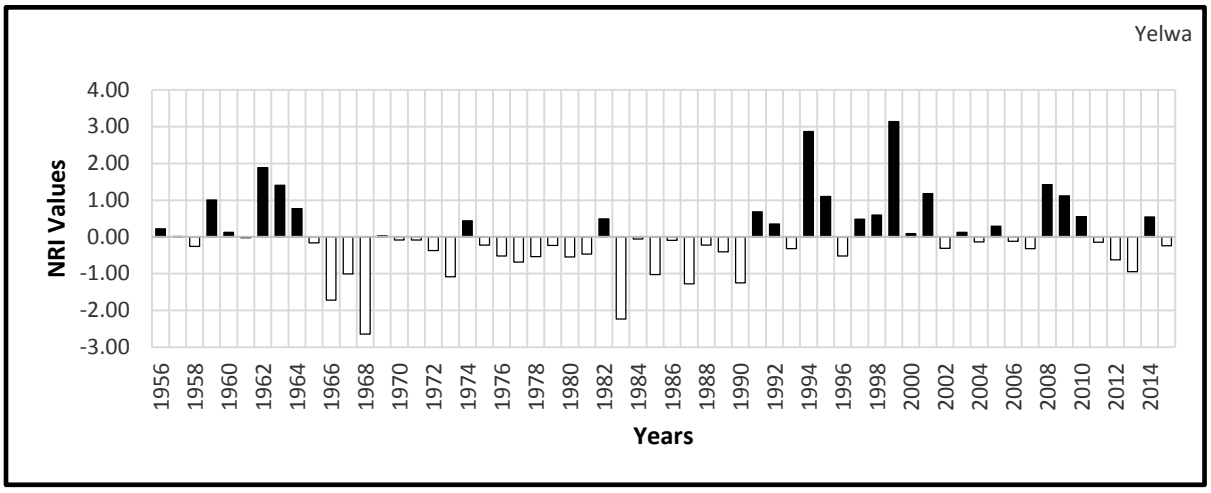
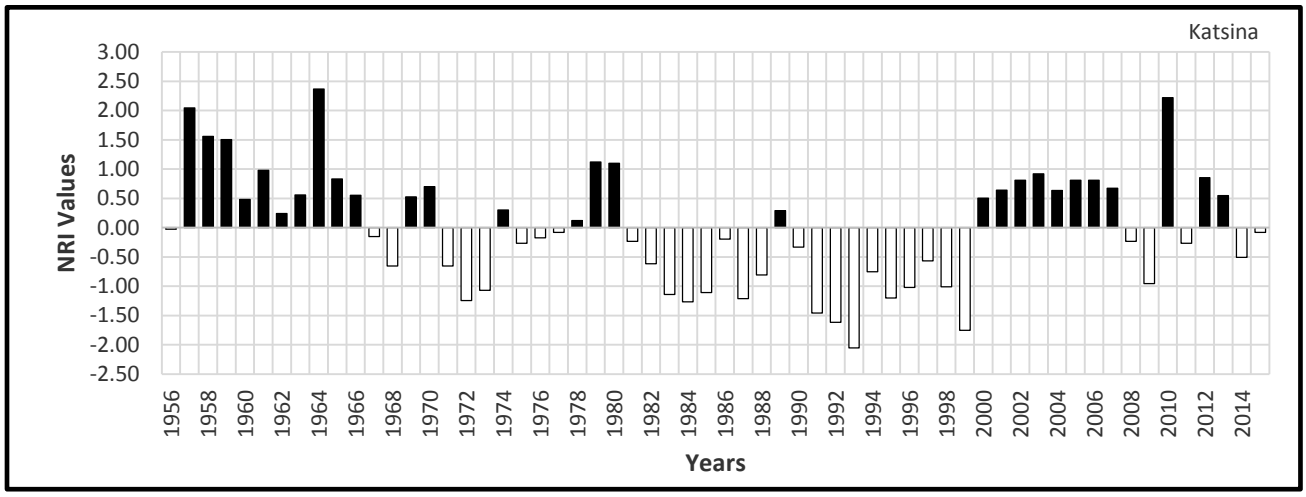


Fig. 2: Occurrence and intensity of drought in Northwest zone of Nigeria: Kaduna, Kano and Yelwa



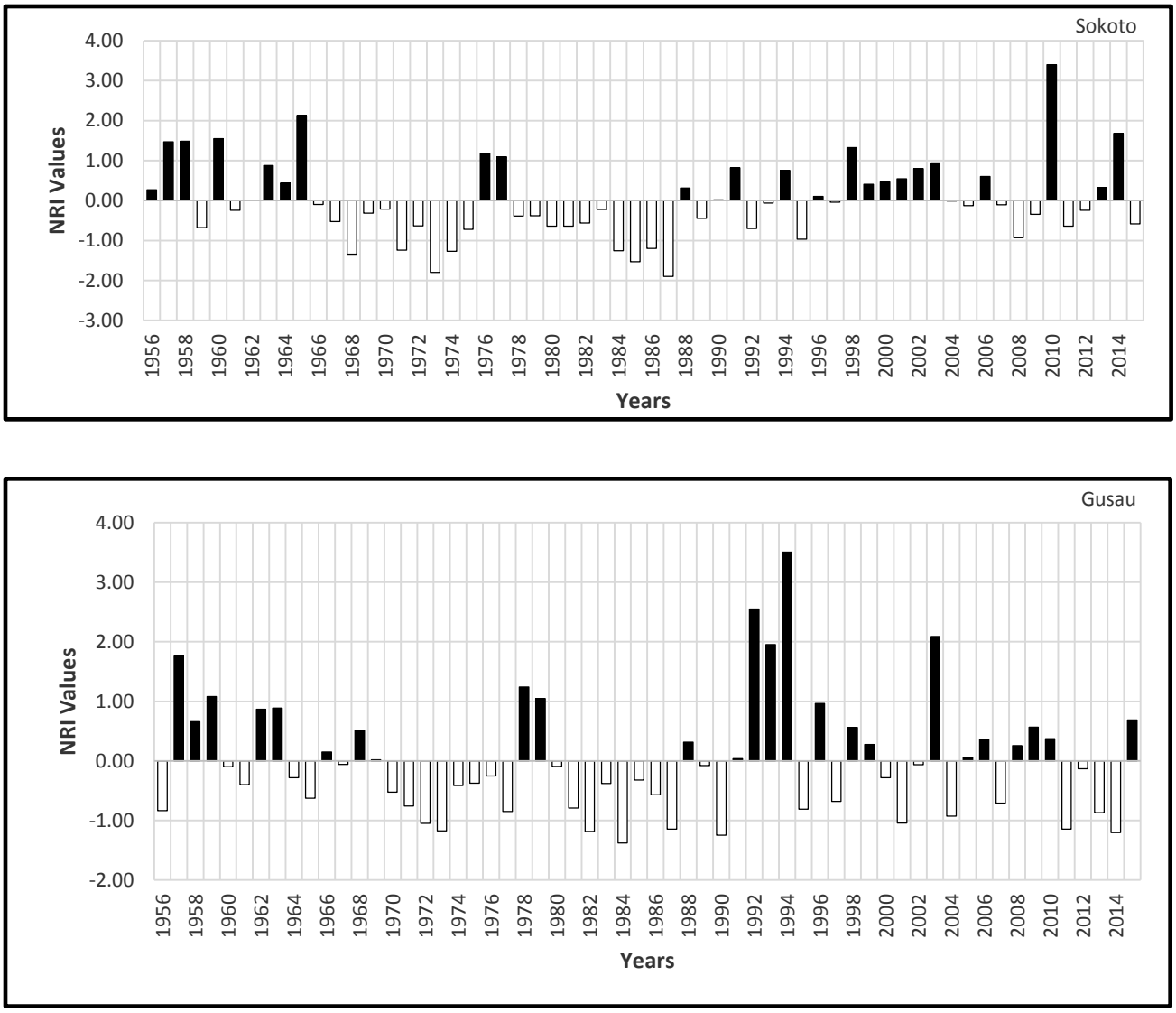


Fig. 2: Occurrence and intensity of drought in Northwest zone of Nigeria: Katsina, Sokoto and Gusau (Continued)

The results show that the zone is generally replete with severe and prolonged drought events. Mild to severe drought conditions existing over this zone (Tables: 6 -11) and graphs 2 (a-f). For instance, it could be seen that between1956-1960 this zone experienced normal to very wet conditions. The only exception during this period was Kaduna and Kano that experienced severe and moderate drought 1956 and 1958 respectively. Interestingly the extreme northern part of the study area (Sokoto, Gusau and Katsina) that was expected to be affected by drought, had very wet moisture condition during this period.

Similarly, the 1960s generally experienced normal to very wet conditions in this zone. ExceptsYelwa and Sokoto that were affected by severe droughts in 1966 and 1968. Mild drought occurred in Kano (1963, 1964 and 1967). Furthermore, between: 1971 to 1977 mild, moderate and severe drought affected almost all the parts of the zone. The drought hitted the highest point in 1973. During this period the whole zone was affected by drought conditions except Sokoto that experienced very wet moisture in 1976 and 1977. However, by 1978-1979 normal conditions returned to the environment. But, between 1980 and early 1990s were characterized by more widespread drought in the zone. With the exception of Sokoto (1991) and Gusau (1992, 1993, and 1994) that experienced wet moisture within this period. And near, normal to very wet conditions dominated the other half of the 1990s. Early 2000s generally experienced near normal to very wet conditions, except Gusau that experienced moderate drought in 2001 and 2004. Thus, between 2005-2015 mild, moderate and severe droughts were experienced in Gusau (2007, 2011, 2013, and 2014) Sokoto (2008), Yelwa (2013), Katsina (2009) and Kaduna (2006, 2005, 2006, 2007, and 2008). It is noteworthy that near normal to very conditions dominated 2010-2015 in the zone. Except Gusau that was affected by drought 2011, 2013 and 2014. And, Yelwa was also affected by drought in 2013.

Furthermore, the results revealed that out of the last 60 years in which this study was done (1956-2015), Kaduna experienced drought (Mild, Moderate and Severe) for 19 years representing 31.66 percent of the study period (Tables: 6-11). Also, Kano experienced drought for 24 years representing 40 percent of the study period. Besides, Yelwa experienced drought for 9 years out of the 60 years in which the study was done representing 15 percent. Similarly, Katsina and Gusau experienced droughts (Mild, Moderate and Severe) for 21 years out of the 60 years in which the study was done representing 35 percent each, though, with variations in the number of severe and mild droughts occurrence. Sokoto on the other hand, experienced drought for the periods of 20 years out of the 60 years study period.

Thus, it could be concluded particularly in this zone that the occurrence of droughts in this zone already has a long history, which is not likely to disappear in the near future. These findings correspond with the studies conducted by Imo and Ekponyong (2011) who observed that in the last 40 years, this zone has witnessed severe drought. Also studies by Adefolalu (1985), Adefolalu (1986), Tarhule and Woo (1998) revealed recurrence, persistence and periodicity of droughts (in one form or the other) in Northwest zone of Nigeria.

CONCLUSION

Drought is part of the environment. It occurs in every part of the globe and adversely affects the lives of a large number of people, causing considerable damage to economies, the environment and property. It also affects countries or zones differently, having a greater impact on countries or zones with poor economic conditions. One of the negative features of

North Western zone of Nigeria is the periodic occurrence of meteorological drought. The most frequent source of this phenomenon has been attributed to the occurrence of long-term rainless periods.

Since droughts are more frequent in this zone, there is need for a close monitoring over this zone in order to identify its onset, intensity, cessation, duration and spatial extent as well as its frequency in a timely manner for its proper management. In rain fed agriculture, the frequency of occurrence and duration of dry spells have an important bearing on the growth of crops. Some crops are highly sensitive to moisture stress and wither away if the moisture is not replenished in time. This can lead to partial and in some cases total failure of the crop. A single irrigation at such critical times can save the crops from total failure. Thus, farmers should be enlightened about water harvesting technology. This involves collecting and storing major parts of rain fall so that a crop life saving irrigation could be given. Immediately after planting, a light irrigation should be given to raise soil water level and aid germination. Irrigation may be required to enhance seeding emergence in soils that water is not easily available. This would be useful especially in replenishing depleted water reserves in the soil.

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