Global Journal of human social science
Geography, Geo-Sciences & Environmental
Volume 13 Issue 2 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-460X & Print ISSN: 0975-587X

Droughts in the Sudano-Sahelian Ecological Zone of Nigeria: Implications for Agriculture and Water Resources Development

By Dr. Abaje, I.B., Ati, O.F., Iguisi, E.O. & Jidauna, G.G.
Federal University, Dutsin-ma,Katsina State, Nigeria

Abstract - This study evaluates the extent and degree of severity of droughts in the Sudano-Sahelian Ecological Zone of Nigeria using rainfall data spanning a period of 60 years (1949-2008) for eight meteorological stations in the zone. The Normalized Rainfall Index was used in depicting periods of different drought intensities in the region. The results revealed that the zone was characterized by larger extent of severe drought since the beginning of 1968 through the early 1970s, and then the 1980s in which the drought was so severe than any other decade in the study period. The late 1990s and the 2000s on the other hand have been witnessing a decrease in the number of drought occurrences in the zone. The mean absolute probability of mild, moderate and severe droughts for the zone was 0.13 (recurrence interval of 7.7 years), 0.11 (recurrence interval of 9.1 years), and 0.08 (recurrence interval of 12.5 years) respectively.

Keywords : *drought probability, normalized rainfall index, recurrence interval, severe drought.*

GJHSS-B Classification : *FOR Code: 050299, 920407*

DROUGHTSINTHESUDANOSAHELIAN ECOLOGICALZONEOFNIGERIAIMPLICATIONSFORAGRICULTUREANDWATERRESOURCESDEVELOPMENT

Strictly as per the compliance and regulations of:

Droughts in the Sudano-Sahelian Ecological Zone of Nigeria: Implications for Agriculture and Water Resources Development

Abaje, I.B. [α], Ati, O.F. [σ], Iguisi, E.O. [ρ] & Jidauna, G.G. [ω]

Abstract - This study evaluates the extent and degree of severity of droughts in the Sudano-Sahelian Ecological Zone of Nigeria using rainfall data spanning a period of 60 years (1949-2008) for eight meteorological stations in the zone. The Normalized Rainfall Index was used in depicting periods of different drought intensities in the region. The results revealed that the zone was characterized by larger extent of severe drought since the beginning of 1968 through the early 1970s, and then the 1980s in which the drought was so severe than any other decade in the study period. The late 1990s and the 2000s on the other hand have been witnessing a decrease in the number of drought occurrences in the zone. The mean absolute probability of mild, moderate and severe droughts for the zone was 0.13 (recurrence interval of 7.7 years), 0.11 (recurrence interval of 9.1 years), and 0.08 (recurrence interval of 12.5 years) respectively. The implications for agriculture and water resources include: reduction in weight and increased deaths of livestock, food shortages, and soil depletion, the existence of few rivers and streams, and the lowering of the water table. The study recommends the adoption of better herds management practices to include: the reduction in herd numbers, strategic weaning of calves, herd segregation, and parasite control. The establishment and improvement of early warning systems, analysis of observed climatic data, the establishment of Drought and Flood Research Centers in all the universities of the zone among others were the mitigating measures recommended.

Keywords : drought probability, normalized rainfall index, recurrence interval, severe drought.

I. Introduction

Drought is one of the most important natural disasters that show its influences slowly by time. It is one of the costliest natural disaster of the world and affects more people than any other natural disaster (Loukas and Vasiliades, 2004; Bacanli *et al.*, 2008). It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate (NDMC, 2006).

There is no universally accepted definition of drought due to the wide variety of sectors affected by drought, its diverse geographical and temporal distribution and the demand placed on water supply by human-use systems (Loukas and Vasiliades, 2004). Based on the nature of the water deficit, many authorities such as Ayoade (1988, 2004), Barry and Chorley (2003), Okorie, (2003), AMS (1997, 2004), Loukas and Vasiliades (2004), NDMC (2006), and Trenberth *et al.* (2007) amongst others inclusively defined four types of droughts: a) the meteorological drought which is defined as a lack of precipitation over region for a period of time, b) the hydrological drought which is related to a period with inadequate surface and subsurface water resources to supply established water uses of a given water resources management system, c) the agricultural drought, which, usually, refers to a period with declining soil moisture and consequent crop failure without any reference to surface water resources, d) the socio-economic drought which is associated to the failure of water resources systems to meet the water demands and thus, associating droughts with supply of and demand for an economic good (water).

One characteristic seems to be common with all the definitions: drought is caused by a deficiency in precipitation for a fairly long period of time. This may cause widespread crop failure, death of livestock, water shortages, famine and other hardships that may result in the loss of human lives.

Drought is an inherent characteristic of Africa. One-third of the people in Africa live in drought-prone areas and are vulnerable to the impacts of droughts (Bates *et al.*, 2008). Since the devastating Sahelian drought of the early 1970s, drought has reoccurred in many parts of Africa (Oladipo, 1993). In West Africa, a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20–40% in the period 1968–1990 as compared with the 30 years between 1931 and 1960 (Nicholson *et al.*, 2000; Chappell and Agnew, 2004; Dai *et al.*, 2004).

The Sudano-Sahelian Ecological Zone (SSEZ) suffered from seasonal and inter-annual climatic variability, and there have been droughts and effective desertification processes, particularly since the 1960s (FRN, 2003). The Sahelian droughts of the 1970s and the 1980s ravaged this zone and left farmers impoverished (Ati *et al.*, 2007). It has also been noted that the frequent occurrences of drought in this zone is

Author α σ ω : Department of Geography and Regional Planning, Federal University, Dutsin-Ma, P.M.B. 5001, Dutsin-Ma, Katsina State, Nigeria. E-mail : abajebest@yahoo.com
Author ρ : Department of Geography, Ahmadu Bello University, Zaria, Nigeria.

responsible for the social backwardness and general poor quality of life especially among the less privileged ones (Alatise and Ikumawoyi, 2007). The situation is being aggravated by the increase in human population, which appears to be stressing the natural support system (FRN, 2005).

Since drought is an extreme weather event, appropriate techniques should therefore, be applied to determine its occurrence based on relevant data in order to ameliorate its impact on the people of Nigeria with particular reference to the SSEZ. This study, therefore, examines the extent and degree of severity of drought in the zone. It discusses the implications of the occurrence of droughts for agriculture and water resources development, and also recommends possible solutions based on the findings.

II. Study Area

The SSEZ is located in northern Nigeria between latitude 10^{0}N and 14^{0}N and longitude 4^{0}E and 14^{0}E (Fig. 1). This zone occupies almost one-third of the total land area of the country. It stretches from the Sokoto plains through the northern section of the high plains of Hausaland to the Chad Basins (Odekunle *et al*., 2008).

The climate of the zone is the tropical wet and dry type, classified by Koppen as Aw. The zone has an average annual rainfall of about 500 mm in the extreme northeastern part to 1000 mm in the southern sub-region (Abaje *et al,* 2012a&b). The rainfall occurs between the months of April to October with a peak in August. The pattern of rainfall in the zone is highly variable in spatial and temporal dimensions with inter-annual variability of between 15 and 20%. As a result of the large inter-annual variability of rainfall, this zone is subject to frequent dry spells which can result in severe and widespread droughts (Oladipo, 1993; FRN, 2000; Okorie, 2003).

The geology, relief and geomorphological processes that shaped the landforms have greatly influenced the soils (FRN, 2000). More than half of the region is covered by ferruginous tropical soils which are heavily weathered and markedly laterized (Oladipo, 1993; FRN, 2000). They are mostly formed on granite and gneiss parent materials, and on aeolian and many sedimentary deposits (Abaje, 2007). The vegetation is the Savanna type consisting of Sudan and Sahel with the density of trees and other plants decreasing as one move northwards (Abaje, 2007). These two zones (Sudan and Sahel) are together referred to as the SSEZ. This zone has been described by many researchers as the Nigerian dry-land, containing most of the range-land of the country. It constitutes the main source of fodder and grazing land for livestock, and therefore supports large numbers of cattle and other domestic animals. Donkeys and camels are very characteristic of this zone (FRN, 2000).

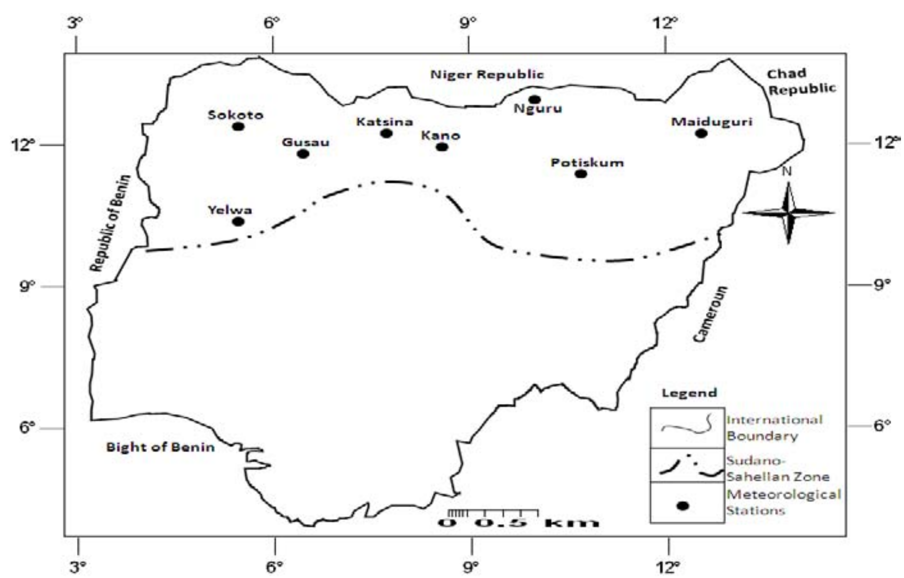

Figure 1 : The Sudano-Sahelian Ecological Zone of Nigeria (Extracted from Iloeje, 1982)

III. Materials and Methods

Rainfall data spanning a period of 60 years (1949-2008) was used in this study (Table 1). The data were sourced from the archive of Nigerian Meteorological Agency (NIMET), Oshodi-Lagos. The data were collected at eight synoptic meteorological stations in the SSEZ of Nigeria-Yelwa, Potiskum, Maiduguri, Kano, Gusau, Sokoto, Nguru, and Katsina. These stations were selected based on the following criteria: 1) they are evenly distributed, 2) all the stations have long period of recorded rainfall data that cover the period of study, 3) they have not been affected by site relocation since their establishment, and 4) the data were tested and found to be normally distributed.

Table 1 : Eight Meteorological Stations in the Sudano-Sahelian Ecological Zone

Station	Station No.	Latitude	Longitude	Altitude	Period	No. of years
Yelwa	1004.54	$10^0$53'N	$04^0$45'E	224.00m	1949-2008	60
Potiskum	1111.40	$11^0$43'N	$11^0$07'E	487.68m	1949-2008	60
Maiduguri	1113.50	$11^0$51'N	$13^0$05'E	348.00m	1949-2008	60
Kano	1208.03	$12^0$03'N	$08^0$32'E	475.80m	1949-2008	60
Gusau	1206.14	$12^0$10'N	$06^0$42'E	468.00m	1949-2008	60
Sokoto	1205.51^A	$12^0$55'N	$05^0$12'E	309.00m	1949-2008	60
Nguru	1210.52^E	$12^0$58'N	$10^0$28'E	341.00m	1949-2008	60
Katsina	1307.04	$13^0$01'N	$07^0$41'E	516.63m	1949-2008	60

Source : Nigerian Meteorological Agency (NIMET), Oshodi-Lagos.

a) *Test for Normality*

The standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) statistics as defined by Brazel and Balling (1986) were 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. The standardized coefficient of Skewness (Z_1) was calculated as:

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

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

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

Where $\bar{x}$ is the long term mean of x_i values, and N is the number of years in the sample. These statistics were used to test the null hypothesis that the individual temporal samples came from a population with a normal (Gaussian) distribution. If the absolute value of Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at the 95% confidence level.

b) *Drought Indexing*

The Normalized Rainfall Index (NRI) as defined by Türkes (1996) was used in depicting periods of different drought intensities in the region. This index uses annual or seasonal rainfall totals and the standard deviation to indicate the shortage of water of any given season. The Index for a given station is computed as:

$$A_{sy} = \frac{R_{sy} - \bar{R}_s}{S_s}$$

Where: *Rsy* = the rainfall total for the station *s* during a year (or a season)

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

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

In this very study, a modified classification of NRI was adopted. This is because extreme values, that is, greater than or equal to 1.76 and less than or equal to -1.76 are very infrequent throughout the period of study. This modified classification is presented in Table 2.

Table 2 : 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
-0.51 to -0.85	Mild drought
-0.86 to -1.30	Moderate drought
-1.31 or less	Severe drought

c) *Drought Probabilities and Recurrence Intervals*

The frequencies of occurrence of mild, moderate and severe droughts were then calculated and their absolute empirical probabilities were computed as the ratio of the number of actual occurrences of mild, moderate and severe drought to the number of possible occurrences. From these absolute probability values, drought recurrence intervals (or return periods) were also obtained as their inverse. This technique is computed as:

$$P = \frac{n}{Ny}$$

for absolute probability and

$$Ri = \frac{1}{P}$$

for drought recurrence intervals where:

$P =$ absolute probability of drought;

$n =$ number of occurrences of a given category of drought;

$Ny =$ total number of possible occurrence (the period specified for the station);

$Ri =$ drought recurrence intervals (or return periods).

IV. Results and Discussion

a) Test for Normality

The results of the standardized coefficients of skewness (Z_1) and kurtosis (Z_2) for the eight stations are presented in Table 3. All the stations were accepted as normal at 95% confidence level. Therefore, no transformation was made to the rainfall series.

Table 3 : Standardized Coefficients of Skewness and Kurtosis for the Eight Meteorological Stations

Statistics \ Stations	Yelwa	Potiskum	Maiduguri	Kano	Gusau	Sokoto	Nguru	Katsina
Skewness (Z_1)	0.41	0.10	0.23	0.84	0.76	0.07	0.09	-0.24
Kurtosis (Z_2)	1.80	0.52	0.59	0.48	1.07	-0.50	-0.64	-0.17

b) Occurrence of Drought

The results of analysis of Normalized Rainfall Index (NRI) in the study area are presented graphically in Figure 2 (a-h) for the 8 stations.

The results show that the zone is generally replete with severe and prolonged drought events. Mild to severe drought conditions existed over this zone in 1949. The only exception was Sokoto that experienced very wet condition while mildly wet condition existed in Yelwa.

The 1950s generally experienced normal to very wet conditions in the study area. The only exception in the zone was found at Yelwa when moderate drought affected the area in 1950 and 1952. Interestingly, the extreme northern part of the study area that was expected to be affected by drought, had a normal moisture condition throughout the decade. Nguru that is at the extreme northeastern part of the study area was the wettest in that decade.

The early 1960s featured generally normal to wet conditions, except in 1964 when moderate drought affected the northeastern part of the zone. In contrast, the other half of the 1960s was characterized by some isolated mild to severe droughts that affected different parts of the study area. About 29% of the areas were affected by moderate to severe droughts in 1966 to 1968, but this was replaced by a normal condition in 1969. The year 1968 is often referred to as the beginning of the Catastrophic Sahelian Droughts; but from the results of this analysis, only 38 % of the study area was affected by severe droughts in 1968. This implies that the Catastrophic Sahelian Droughts of 1968-1973 did not start simultaneously in the whole of the region. It started in the northern part of the West African Sahel in 1968 and retreated southwards until 1973 when the whole study area was affected by drought.

The Sahelian droughts of the 1970s were more severe and significant in the zone than those previously discussed. In 1971, mild to moderate drought affected some part of the zone. This drought continued in many areas in 1972 and was severe at Nguru. The drought hit the highest point in 1973 in which the whole study area was affected by 50% of moderate and 50% of severe drought conditions. There was a slight break in the intensity and percentage coverage of drought in 1974-1977, with only Sokoto and Potiskum area affected by severe drought in 1974 and 1977 respectively. By 1978-1979, normal conditions return to the environment.

The 1980s were characterized by more widespread, more severe and more persistent droughts than the decade 1970-1979. This decade (1980-1989) witnessed the persistent of drought in the zone beginning in 1981. It was the decade in which severe drought became more extensive. About 63% of moderate to severe droughts cover the zone in 1981-1987. The year 1987 was the driest in that decade in which about 37.5% and 62.5% of the zone was affected by moderate and severe droughts respectively. In particular, the drought of the 1987 was more severe than the driest year (1973) of the Catastrophic Sahelian Droughts of 1968-1973.

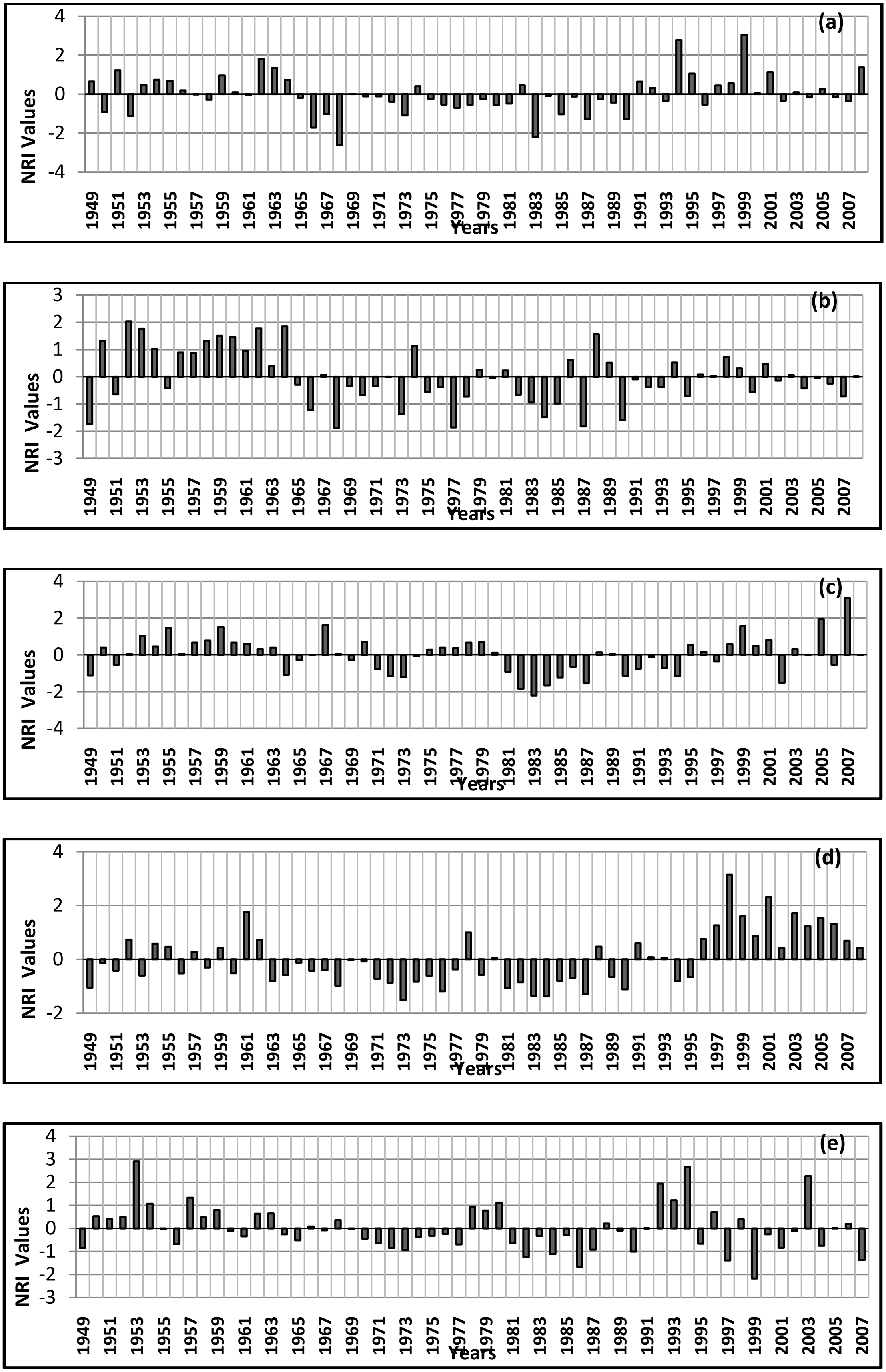

Figure 2 : Normalized Rainfall Index for (a) Yelwa; (b) Potiskum; (c) Maiduguri; (d) Kano; (e) Gusau; (f) Sokoto; (g) Nguru; and (h) Katsina

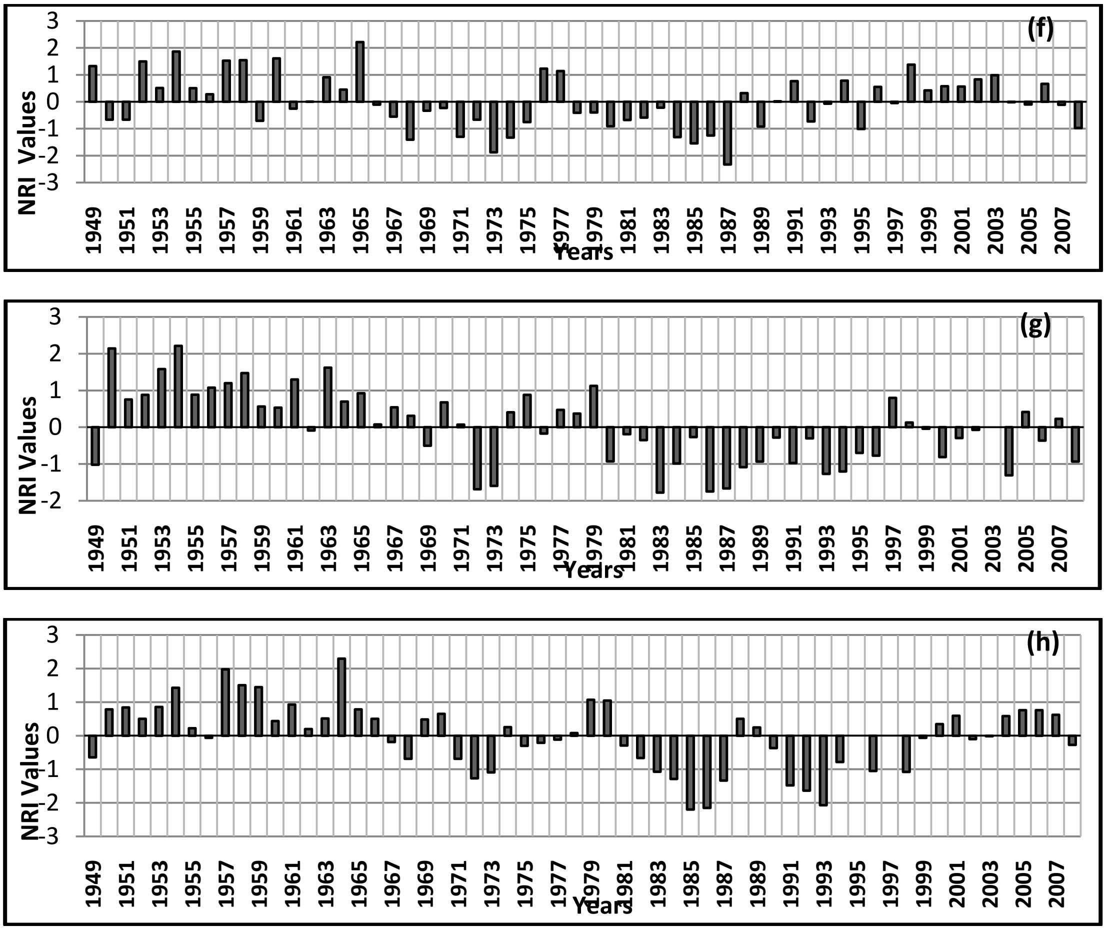

Figure 2 Continued

The first half of the 1990s featured some isolated mild to severe droughts; except 1990 in which 63% of the study area was affected by moderate to severe drought. Surprisingly, the extreme northern part of the zone had a normal moisture condition throughout that year. Contrariwise, the same extreme northern part of the zone was affected by moderate to severe drought in 1991 to 1994. Near normal to very wet conditions of about 78% dominated the other half of the 1990s.

About 85% of the study area during the period 2000-2008 generally experienced near normal to very wet conditions except some isolated mild, moderate and severe droughts that affected about 8%, 3% and 4% of the area respectively. The year 2002 was the driest in the period in which the northeastern part was affected by severe drought. After that normal condition returned in 2003 which is also the wettest year in the period.

Generally, the SSEZ of Nigeria was characterized by larger extent of severe drought since the beginning of 1968 through the early 1970s, and then the 1980s in which the drought was so severe than any other decade in the study period. The year 1987 was the driest in the whole series of drought during the study period followed by 1973 and 1983 in that order. The late 1990s and the 2000s on the other hand have been witnessing a decrease in the number of drought occurrences in the zone. The finding is in agreement with the observation made by Abaje *et al* (2012a) that the SSEZ of Nigeria has been experiencing increasing wetness over the recent years. This may be due to awareness and the general reduction in human activities that causes drought and desertification as a result of the high level of commitment from International Governmental and Non-Governmental Organization such as Intergovernmental Panel on Climate Change (IPCC), United Nations Environment Program (UNEP), and National Drought Mitigation Center (NDMC) amongst others.

c) Frequency of Drought

The absolute probabilities of occurrence of mild, moderate and severe droughts and their respective recurrence intervals were calculated for each station in the study area (Table 4). The values show variation among individual stations. Kano has the highest probability of occurrence of mild drought (0.23) than any other station in the zone with a recurrence interval (or return period) of 4.3 years, while Nguru has the least probability of occurrence of mild drought of 0.07 with a recurrence interval of 14.3 years.

The probabilities of occurrence of moderate drought for the 8 stations show that Nguru has the highest probability of 0.15 with a return period of 6.7 years, followed by a probability of 0.13 each for Maiduguri and Kano with a recurrence interval of 7.7 years.

On the other hand, the probabilities of occurrence of severe drought for the 8 stations revealed Potiskum as having the highest probability of occurrence (0.12) with a recurrence interval of 8.3 years. Sokoto, Nguru and Katsina have a probability of 0.10 each with a recurrence interval of 10 years. The least probability of occurrence of severe drought (0.05) is found in Yelwa and Kano with a return period of 20 years.

Table 4 : Probabilities of Occurrence of Droughts and Recurrence Intervals in Years for the Sudano-Sahelian Ecological Zone of Nigeria

Stations	Mild Drought		Moderate Drought		Severe Drought	
	Probability	Recurrence Interval	Probability	Recurrence Interval	Probability	Recurrence Interval
Yelwa	0.08	12.5	0.12	8.3	0.05	20.0
Potiskum	0.13	7.7	0.05	20.0	0.12	8.3
Maiduguri	0.10	10.0	0.13	7.7	0.08	12.5
Kano	0.23	4.3	0.13	7.7	0.05	20.0
Gusau	0.17	5.9	0.08	12.5	0.07	14.3
Sokoto	0.15	6.7	0.10	10.0	0.10	10.0
Nguru	0.07	14.3	0.15	6.7	0.10	10.0
Katsina	0.08	12.5	0.10	10.0	0.10	10.0
Mean for the Zone	0.13	7.7	0.11	9.1	0.08	12.5

A closer examination of the probabilities of occurrence of severe drought in the zone shows that the extreme northern parts and northeastern parts are more susceptible to severe drought. This is in good agreement with earlier researchers that these areas are more prone to drought and desertification (Oladipo, 1993; FRN, 2000; Ayuba, 2007).

The mean absolute probability of mild drought, moderate drought and severe drought for the zone is 0.13 (recurrence interval of 7.7 years), 0.11 (recurrence interval of 9.1 years), and 0.08 (recurrence interval of 12.5 years) respectively. On the whole, the mean absolute probability of occurrence of drought in the zone is 0.11 with a recurrence interval of 9.1 years. The computed recurrence intervals are also in good agreement with the analyzed data in Fig. 2.

V. Implications for Agriculture and Water Resources Development

Water scarcity due to the occurrence of droughts affects the agricultural outputs of the zone. Food shortages result from an abnormal reduction in crop yield. Irrigation projects which would have served to mitigate these problems are also affected by water shortages as most of the dams dry up during droughts. This implies that agro-allied industries may be affected since their raw materials will be lacking. For example, lower production of cotton, tobacco and groundnuts has made the ginneries and textiles industries, tobacco, and cooking oil companies respectively to resort to importation of their raw materials. This may leads to unemployment because most of these industries/companies have to downsize their work force.

During drought periods, the land is under increased stress from both humans and livestock. This often results in the depletion of the soil. Overgrazing becomes destructive during drought when large areas that would normally have been available for grazing dry up. Animal are force to feed on any available edible vegetation they could find. This may be severe enough to cause severe damage to the environment. Once the precarious equilibrium of the plant communities adapted to the characteristically variable climate is upset by persistent drought, complete ecological recovery may be impossible, even when the rains return. Thus, drought has often been regarded as the major cause of desertification.

The occurrence of droughts in this zone has great implications on the cattle sector. The occurrence of mild drought results in cattle losing weight, whereas the occurrence of severe drought results in increased livestock mortality rates due to scarcity or lack of feed. This affects revenue generation and household income. Subsistence farmers who derive other benefits from cattle such as milking and draught power also suffer losses because the quality and quantity of the milk is reduced and also, the weight and strength of cattle for the purpose of draught power is drastically reduced.

The occurrence of droughts leads to the sustenance of few rivers and streams and the lowering of the water table. This has an implication for developmental projects that depend on water from rivers and ground water sources. The lowering of the water table on the other hand has an implication in digging of wells and construction of bore holes because the water table may never be reached in some places; as a result, there may be scarcity of water especially in rural areas that depend solely on underground and some surface water sources.

VI. Conclusions

Drought 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 regions differently, having a greater impact on countries or regions with poor economic conditions.

Findings revealed that this zone is generally replete with severe and prolonged drought events and that the Catastrophic Sahelian Droughts of 1968-1973 did not start simultaneously in the whole of the region. It started in the northern part of the West African Sahel in 1968 and retreated southwards until 1973 when the whole study area was affected by drought. Findings further revealed that the decade (1980-1989) witnessed the persistent of drought in the zone. It was the decade in which severe drought became more extensive. In particular, the drought of the 1987 was more severe than the driest year (1973) of the Catastrophic Sahelian Droughts of 1968-1973. The late 1990s and the 2000s on the other hand have been witnessing decreasing in the number of drought occurrences in the zone.

The frequency of drought was computed, and the results revealed that the mean probability of mild, moderate, and severe droughts for the zone were 0.13 (recurrence interval of 7.7 years), 0.11 (recurrence interval of 9.1 years), and 0.08 (recurrence interval of 12.5 years) respectively.

a) *Recommendations*

It is a bitter reality that abnormal climatic change such as droughts in the Sudano-Sahelian zone of Nigeria cannot be averted and Man can only take measures to lessen their impacts on various disciplines. Therefore, based on the findings, the following recommendations are made:

Herd management practices are of utmost important in this zone. This is because nearly 70% of Nigerian cattle are concentrated here. The zone supports about two-thirds of the goats and sheep and almost all the donkeys, camels and horses found in the country. Herd management practices to be adopted should include the following:

- Reduction in Herd Numbers: When feed resources are getting short, one solution is to critically evaluate the members of the herd and eliminate those that are less useful. Sale or adjustment (relocating herd to non-affected pastures) are the two options available to reduce stock numbers.
- Strategic Weaning of Calves: During a drought, the production of milk rapidly depletes a cow's body reserves, while the calf derives little benefit. Weaning the calf gives the cow a better chance of survival. In drought years, early weaning is recommended. However, calves should not be weaned before 3 months of age unless absolutely necessary.
- Herd Segregation: Segregating animals into classes gives the herd a better chance of getting needed feed supplies. Segregation makes possible the preferential treatment of vulnerable classes. Pregnancy testing is a useful tool to identify heavily pregnant cows for special feeding, especially young cows that are pregnant for a second time.
- Parasite Control: Cattle under nutritional and other stresses are less resistant to parasites than in normal conditions. During drought conditions, all cattle under 18 months of age should be treated for worms.

The establishment and improvement of early warning systems for monitoring the occurrence of meteorological drought in these areas would help in planning of relief measures and will also provide input to determine agricultural drought.

The analysis of existing series of observed climatic data is of paramount important in order to develop the probability distribution of rainfall amount and timing. These distributions will provide information on the beginning, the end and the length of the rainy season and on the amount of available water during the season. Such knowledge is pertinent to the introduction of new, more productive and more drought resistant varieties of different crops and for introduction of improved farming systems. Where water retention and supplemental irrigation are possible, agricultural production can be boosted in a significant way through the use of high yielding varieties together with organic and inorganic sources of fertilization.

Construction of new wells, boreholes, and water harvesting are all mitigating measures that could be taken after the onset of drought.

Considering the importance of ground water as the major water resource for rural, urban, industry and agricultural applications in this zone, opportunities should be provided by the government for professionals to study and develop realistic methods for utilization of ground water without socio-political concerns. In such a case, it would be possible to counter drought crises by using static and dynamic storage capacities of ground water resources.

Drought and Flood Research Centers should be established in all the universities of the zone, and there should be regular organization of educational-/professional short courses on drought management for professional staff and managers and public educational programs to deal with drought problems.

References Références Referencias

1. Abaje, I.B. (2007). *Introduction to Soils and Vegetation*. Kafanchan: Personal Touch Productions.
2. Abaje, I.B., Ati, O.F. and Iguisi, E.O. (2012a). Changing Climatic Scenarios and Strategies for Drought Adaptation and Mitigation in the Sudano-Sahelian Ecological Zone of Nigeria. In: M.A. Iliya and I.M. Dankani, eds. *Climate Change and Sustainable Development in Nigeria.* Ibadan: Crown F. Publishers. Ch.5.
3. Abaje, I.B., Ati, O.F. and Iguisi, E.O. (2012b). Recent Trends and Fluctuations of Annual Rainfall in the Sudano-Sahelian Ecological Zone of Nigeria: Risks and Opportunities. *Journal of Sustainable Society,* 1(2), 44-51.
4. Alatise, M.O. and Ikumawoyi, O.B. (2007). Evaluation of Drought from Rainfall Data for Lokoja. A confluence of Two Major Rivers. *Electronic Journal of Polish Agricultural Universities (EJPAU).* 10 (1). Available from: http://www.ejpau.media.pl/volume10/issue1/art-05.html (accessed: 29 March 2008).
5. American Meteorological Society [AMS]. (1997). AMS Policy Statement on Meteorological Drought. Available from :http://www.ametsoc.org/policy/drought2.html (accessed: 5 February 2009).
6. American Meteorological Society [AMS]. (2004). Meteorological drought. *Bull. Amer. Met. Soc.,* 85. Available from http://www.ametsoc.org/POLICY/droughstatementfinal0304.html (accessed: 13 January 2009).
7. Areola, O., Irueghe, O., Ahmed, K., Adeleke, B. & Leong, G.C. (2002). *Certificate Physical and Human Geography for Senior Secondary Schools*. 2nd ed. Ibadan: University Press Plc.
8. Ati, O.F., Iguisi, E.O. and Afolayan, J.O. (2007). Are We Experiencing Drier Conditions in the Sudano-Sahelian Zone of Nigeria? *J. of Appl. Sci. Res.*, 3 (12), 1746-1751.
9. Ayoade, J.O. (1988). On Drought and Desertification in Nigeria. In: P.O. Sada and F.O. Odemerho, eds. *Environmental Issues and Management in Nigerian Development.* Ibadan: Evans Brothers (Nigerian Publishers) Limited. 271-290.
10. Ayoade, J.O. (2004). *Introduction to Climatology for the Tropics*. 2nd ed. Ibadan: Spectrum Books Limited.
11. Ayuba, H.K., Maryah, U.M. and Gwary, D.M. (2007). Climate Change Impact on Plant Species Composition in Six Semi-Arid Rangelands of Northeastern Nigeria. *The Nigerian Geographical Journal,* 5 (1), 35-42.
12. Bacanli, U.G., Dikbas, F., and Baran, T. (2008). Drought Analysis and a Sample Study of Aegean Region. *Ethics and Climate Change. Scenarios for Justice and Sustainability*. Sixth International Conference on Ethics and Environmental Policies, Padova, 23-25 October 2008. Available from http://www.webethics.net/padova2008/papers/3.pdf (accessed: 7 August 2009).
13. Barry, R.G. and Chorley, R.J. (2003). *Atmosphere, Weather and Climate*. 8th ed. London: Routlege Taylor and Francis Group.
14. Bates, B.C., Kundzewicz, Z.W., Wu, S.and Palutikof, J.P. (Eds). (2008). *Climate Change and Water.* Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva. Available from http://www.ipcc.ch/meetings/session-28/doc13.pdf (accessed: 7 August 2009).
15. Chappell, A. and Agnew, C.T. (2004). Modelling Climate Change in West African Sahel Rainfall (1931–90) as an Artifact of Changing Station Locations. *Int. J. Clim.*, 24 (5), 547–554.
16. Dai, A., Lamb, P.J., Trenberth, K.E., Hulme, P., Jones, D. and Xie, P. (2004). The Recent Sahel Drought is Real. *Int. J. Climatol.* 24, 1323-–1331.
17. Federal Republic of Nigeria, FRN. (2000). National Action Program (NAP) to Combat Desertification and Mitigate the Effect of Drought. Towards the Implementation of the United Nations Convention to Combat Desertification and Mitigate the Effect of Drought in the Country.
18. Federal Republic of Nigeria, FRN. (2003). Nigeria's First National Communication under the United Nations Framework Convention on Climate Change. The Ministry of Environment of the Federal Republic of Nigeria.
19. Federal Republic of Nigeria, FRN. (2005). Combating Desertification and Mitigating the Effects of Drought in Nigeria. The Revised National Report on the Implementation of the United Nations Convention to Combat Desertification (UNCCD) in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa.
20. Iloeje, N.P. (1982). *A New Geography of Nigeria.* Fifth Edition. Ikeja: Longman Nigeria Plc.
21. Loukas, A. and Vasiliades, L. (2004). Probabilistic analysis of drought spatiotemporal characteristics in Thessaly region, Greece. *Natural Hazards and Earth System Sciences*. European Geosciences Union. Available from http://hal.archives-ouvertes.fr/docs-/00/29/92/22/PDF/nhess-4-719-2004.pdf (accessed: 5 February 2009).
22. National Drought Mitigation Center, NDMC. (2006). What is Drought? Understanding and Defining Drought Available from http://drought.unl.edu/whatis/concept.\htm (accessed : 12 December 2007).
23. Nicholson, S.E., Some, B. and Kone, B. (2000). An Analysis of Recent Rainfall Conditions in West Africa, Including the Rainy Seasons of the 1997 El Niño and the 1998 La Niña Years. *J. Clim.*, 13, 2628–2640.

24. Odekunle, T.O., Andrew, O. and Aremu, S.O. (2008). Towards a Wetter Sudano-Sahelian Ecological Zone in Twenty First Century Nigeria. *Weather,* 63(3).
25. Okorie, F.C. (2003). Studies on Drought in the Sub-Saharan Region of Nigeria Using Satellite Remote Sensing and Precipitation Data. Available from http://www.mathaba.net/gci/docs/research/nigeria-drought.html (accessed: 21 September 2009)
26. Oladipo, E.O. (1993). Some Aspects of the Spatial Characteristics of Drought in Northern Nigeria. *Natural Hazards.* 8, 171-188.
27. Trenberth, K.E., Jones, P.D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A., …Zhai, P. (2007). Observations: Surface and atmospheric climate change. In Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor M., & Miller, H.L. (Eds), Climate *Change 2007: The Physical Science Basis*, 235-336. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. United Kingdom and New York, NY: Cambridge University Press. Available from http://www.ipcc.-ch/-pdf/assessmentreport/ar4/wg1/ar4-wg1-chapt-er 2.pdf (accessed: 5 February 2009).
28. Türkes, M. (1996). Meteorological Drought in Turkey: A Historical Perspective, 1930.93. *Drought Network News,* 8 (3), 17-21.