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Drought Intensities in the Sudano-Sahelian Region of Nigeria

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This study is on drought intensities occurrences in the Sudano-Sahelian region of Nigeria. The region is prone to drought occurrence. Data used were from 1941 to 2010 and for eight stations scattered over the region. The Bhalme and Mooley Drought Index (BMDI) was used to characterize drought occurrences into invisible, mild, moderate, severe and extreme. This was with the intention of finding out their percentages of occurrences over a 70 year period (1941-2010). Results show that low intensity drought prevailed in the study area during the study period. It also indicated that extreme droughts were confined to the Sahel zone of the region. These situations means that farmers and other stakeholders like governments in the study region needs to have a reorientation of not waiting for the occurrence and effects of high intensity drought, but put in place policies and measures that will consistently mitigate the occurrence and effects of low intensity drought. Apart from these, other findings were discussed in the study. Measures on how to ameliorate the effects of droughts, especially the dominant intensity on the populace and environment were suggested.

Keywords: drought, drought intensities, extreme, frequency, invisible, mild, moderate, percentages, severe

Introduction

Drought has many definitions. It can however be defined as "an extended period of months or years when a region notes a deficiency in its water supply" (Wikipedia, 2008). Drought also has many attributes. Some of these are; on-set, duration, persistency, intensities, return period and termination. However, out of these attributes, a very significant one is the intensity. This is because it determines the degree of severity or otherwise of the drought. The various intensities have effects on the environment, agriculture, water availability and human beings in the area of occurrence. However, the degree of impact of extreme drought on the environment for example will be greater than that of mild drought.

Droughts have been occurring in Nigeria especially the study region for decades. This mean it is a reoccurring phenomenon in the study area. Studies have also indicated that the Sudano-Sahelian region of Nigeria has suffered decrease in rainfall in the range of about 3-4% per decade since the beginning of the 19th century (FRN, 2003).

Other studies have given higher percentages (Oladipo, 1993a,b). This situation has resulted in several studies about drought in the region (James, 1973; Mortimore, 1973; Khalil, 1974; Oguntoyinbo and Richards, 1977; Adefolalu, 1986; Oladipo, 1993a,b; Aremu, 2011; Abaje et al, 2011).

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Most of these studies that have been carried out were mainly on the temporal and spatial occurrences of drought. Only very few reports discussed droughts intensities (Abaje et al, 2011; Aremu, 2011; Oladipo, 1993a; Adefolalu, 1986; James, 1973; Mortimore, 1973). These few studies only discussed intensities like moderate and extreme, others like invisible, mild and severe were not mentioned. Therefore only few studies concentrated on comprehensive analyses to determine the dominant type of drought intensity in the region. This however is very important because the intensity of a particular drought in an area as explained above will determine its effects. Therefore, there is the need to know the intensities of droughts that have occurred in this region as this will help the people and other stake holders like governments to be able to plan and implement comprehensive policies that will mitigate and ameliorate the usually negative effects of drought in this region. Thus the objective of this study is to determine the rate and percentages of occurrences of drought intensities in the study stations and to assess variations in drought intensities occurrences. This is with the view of recommending measures against the dominant and the most reoccurring drought intensity.

The study area lies north of latitude 8^0 10^1 N and extend to latitude 13^0 53^1 N within the Savanna region of Nigeria (Olaniran, 1987; Abaje et al, 2011) (Figure 1). The Tropical Hinterland climate dominates in the Sudan zone, while Tropical Continental climate prevail in the Sahel zone of the study area. The vegetation of the study area has been

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grouped into the Sudan Savanna and Sahel Savanna (Olaniran, 1987). The latitudinal location of the study area as well as other factors like local manifestations of anomalies in the large scale atmospheric circulation, wind and moisture anomaly patterns, the dynamical teleconnections between dominant drought time scales and those of global Sea Surface Temperature (SST) with other tropical phenomena like EL-Nino/ Southern Oscillations (ENSO) as well as anthropogenic changes in the atmosphere are individually and collectively responsible for drought occurrences in this region (Kidson,1977; Druyan, 1989; Oladipo,1993). The occurrences of these droughts have had devastating effects on the environment, people and agriculture of the study area. Other sectors of the economy of the area like banking, transportation are indirectly affected as money flow from agriculture to other sectors becomes reduced due to poor agricultural outputs caused by droughts. Occupations of the inhabitants of the study area apart from agricultural activities include fishing, mining, leather works, pottery works, brass and silver works. Other people work in offices, industries and in the informal sector of the economy like driving and trading. All these sectors are negatively affected directly or indirectly by the occurrence of drought.

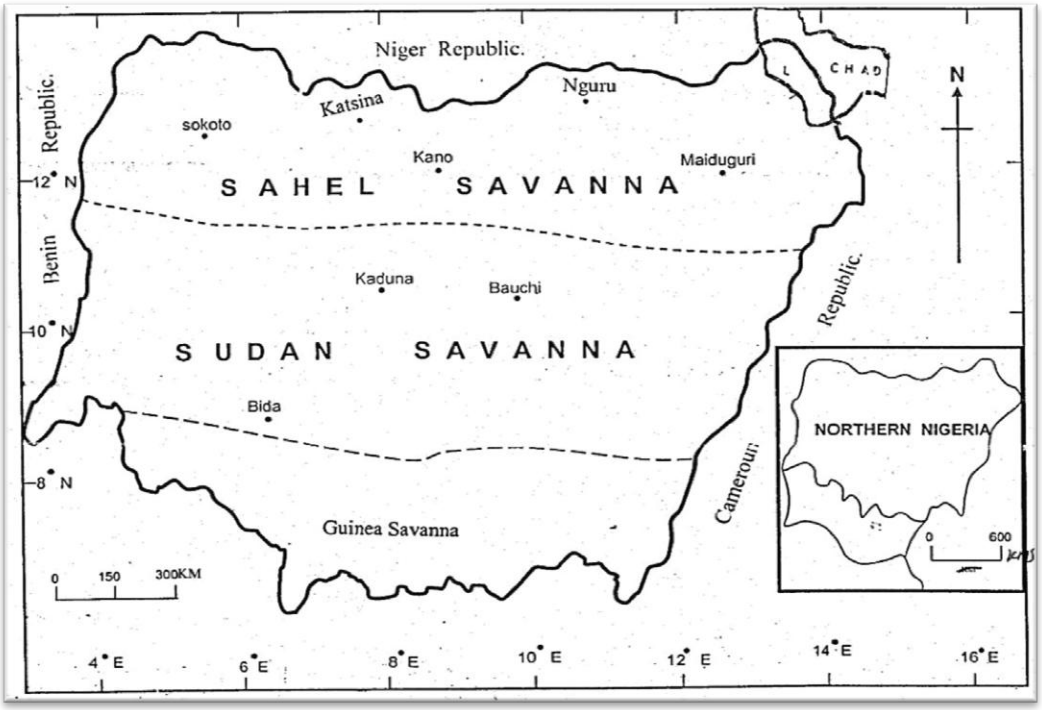

Figure 1. Stations and geographical regions used in the study, Adapted from Olaniran (1987).

Methodology

The basic research data used for this study was rainfall occurrence in the Sudan-Sahel region of Nigeria. The data were obtained from the Nigerian Meteorological Agency (NIMET) Oshodi, Lagos and covered a period of 70 years (1941-2010) for eight selected drought prone stations (Table 1).

These stations were also selected because they are in the drought prone areas of the region. Efforts were made to ensure that stations selected were from those with long and continuous period of daily, monthly and annual rainfall record data of at least 70 years.

Table 1. Stations used and their locations

NO	Stations	Latitudes	Longitudes
1.	Bauchi	10^0 17^1 N	9^0 49^1 E
2.	Bida	9^0 06^1 N	5^0 38^1 E
3.	Kaduna	10^0 35^1 N	7^0 26^1 E
4.	Kano	12^0 03^1 N	8^0 32^1 E
5.	Maiduguri	11^0 51^1 N	13^0 05^1 E
6.	Sokoto	12^0 55^1 N	5^0 16^1E
7.	Nguru	12^0 58^1 N	10^0 28^1 E
8.	Katsina	13^0 01^1 N	7^0 41^1E

Source: NIMET, Oshodi (2011).

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The method used for analysis in this study is the Bhalme and Mooley Drought Index (BMDI). It was used to assess the severity of drought over a period of 70 year. Details of this method are given in Bhalme and Mooley (1980) and below while its general applicability is given in Shuaibu and Oladipo (1993). The Bhalme and Mooley Drought Index (BMDI) is an empirical one that uses monthly rainfall as the sole climatological input. The index has been shown to perform comparatively well in depicting periods and intensities of drought (Oladipo, 1985). Apart from this, the index (BMDI) also has the following advantages over other methods when used in the study area; first, it is simpler and less intricate. It uses not terms like soil water capacity, evapo-transpiration for its calculation. These parameters are difficult to estimate. It is therefore an empirical index that uses monthly rainfall alone as the sole climatological input as said earlier. The method takes into account the importance of significant seasonal precipitation totals which other methods do not (Shuaibu & Oladipo 1993). In addition, it provides a good measure of the current status of drought. That is, the effects of short periods of dry weather are taken into consideration. This is not so with others which are designed to evaluate degree of severity and frequency of prolonged periods of abnormally dry conditions. Also, once the constant are determined, it is easy to adopt it for different climatic regions and lastly the BMDI index gave good correspondence between historically documented droughts and those depicted by BMDI (Shuaibu & Oladipo, 1993). Details of the BDMI are shown below. Monthly growing seasonal rainfall (April to October) values for the eight (8) selected stations were used to derive the Bhalme and Mooley Drought Index (BMDI) for the assessment of drought severity (Shuaibu & Oladipo, 1993).

For agricultural purposes, the months of April to October (the growing season) are considered to be the most important in drought study. This is because they are said to be the months when more than 95% of the annual rainfall total is received in the study area and also in the Savanna region of Nigeria (Anyadike, 1993). In its general form, the BMDI for a given month K is calculated using this formula $I_K = (MK / d) + (1 + C) I_K$ ……(3)

Where;

C is a constant

d is a constant

I_K = drought intensity for the Kth month.

I_{k-1}= drought intensity for the (K-1) month.

M, the moisture index is given by

$M=100(X–\ddot{X})/S$ ……(4)

In equation (4),

X = the monthly rainfall value,

$\ddot{X}$ = the long term mean monthly rainfall,

S = the standard deviation for the initial month under consideration (K-1).

Equation (3) is then given as; I=M/d ....……(5)

The values of C and d in equation (3) for northern Nigeria are 0.43 and 38.84 respectively. These are constant values (Shuaibu & Oladipo, 1993).These values were used in equations (3) and (5) to generate monthly values of BMDI for the stations under study. From these monthly values, the means or seasonal drought index (SDI) series were obtained for each year studied in the stations. The seasonal indices were then used to classify a year into any of the following wetness/ dryness categories using Shuaibu and Oladipo (1993) classification chart. The negative parts of near normal were taken as invisible droughts according to the explanation of Ayoade (1988) (Table 2**).**

Table 2. BMDI classification chart.

Bmdi	Character Of Anomalous Moisture Conditions (Camc).
4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.99 to – 0.99	Near normal
- 1. 00 to – 1. 99	Mild drought
- 2.00 to – 2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

Source: Shuaibu and Oladipo, 1993.

Results and Discussions

From the analyses, each zone's results were discussed below. Sudan Zone Bauchi: From Table 3, out of the 70 years in which study was done, Bauchi experienced drought for 36 years representing 51 .43% of study period. The dominant drought intensity was invisible drought at 50%.The least occurred intensity was severe at 2.8%. Extreme drought did not occur at all. Other intensities occurred for various years and percentages (Table 3).

Table 3. Drought intensities occurrence and percentages in Bauchi.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	18	50.00
Mild	14	38.90
Moderate	3	8.30
Severe	1	2.80
Extreme	0	0.00
Total	36	100.00

Bida: Invisible drought occurred 11 times to constitute 36.67% of total drought occurrence for the station. Mild drought occurred 12 times (40%).Other

intensities occurred for various years and percentages with extreme drought not occurring at all (Table 4). The 30 years of all drought intensities represents about 42.86% of study period (70 years) for this station.

Table 4. Drought intensities occurrence and percentages in Bida.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	11	36.67
Mild	12	40.00
Moderate	5	16.67
Severe	2	6.66
Extreme	0	0 .00
Total	30	100.00

Kaduna: Invisible drought occurred 17 times (47.22%), it was followed by mild drought with 12 occurrences (33.33%). Other intensities occurred for various years and percentages. Also, in this station extreme drought did not occur (Table 5). The 36 years of all drought intensities occurrence represents about 51.43% of study period (70 years) for this station.

Table 5. Drought intensities occurrence and percentages in Kaduna.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	17	47.22
Mild	12	33.33
Moderate	6	16.67
Severe	1	2.78
Extreme	0	0 .00
Total	36	100.00

Zone: From Tables 3 to 5 above, invisible drought occurrence (years) in the stations of the Sudan zone varied from 11 years in Bida to 18 years in Bauchi, mild drought occurrence varied from 12 to 14 years, moderate drought occurrence varied from three years in Bauchi to six years in Kaduna, severe drought from one year to two years with no station experiencing extreme drought in the zone during the period of study. Analyses further showed that invisible drought in the Sudan zone had 46 years (representing 45.10%) out of a total of 102 years of drought in the zone, making invisible drought the most common .It was followed by mild drought with 38 years (37.25%), moderate drought with 14 years (13.73%), severe drought with four years (3.92%) and extreme drought which did not occurred in the zone (0%)(Table 6). It is clear from this analysis that low intensity drought dominates this zone during the study period. This situation points to the likely hood of the low intensity drought (invisible, mild) occurring and dominating this zone in future years. This point to the need for farmers and other stakeholders like governments to put in place measures that will help plants to effectively withstand the low intensity drought. This is because it affects the amount of water available to the plants throughout their developmental stages especially more so during their reproduction stages.

Table 6. Drought intensities occurrence and percentages in Sudan Zone.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	46	45.10
Mild	38	37.25
Moderate	14	13.73
Severe	4	3.92
Extreme	0	0 .00
Total	102	100.00

Sahel Zone Kano: Invisible drought occurred 10 times to represent 27.03% of drought years. Other drought intensities occurred for various years and percentages (Table 7). Mild drought occurred most at 17 times (45.95%). The least occurred drought intensity was extreme drought at one occurrence (2.70%) (Table 7). The 37 years of all drought intensities occurrence represents about 52.86% of study period (70 years) for this station.

Table 7. Drought intensities occurrence and percentages in Kano.

Drought Intensity	Frequency of Occurrence	% of total occurrence
Invisible	10	27.03
Mild	17	45.95
Moderate	7	18.92
Severe	2	5.41
Extreme	1	2.70
Total	37	100.00

Maiduguri: Invisible drought dominates in this station, occurring 16 times (48.49%).Other drought intensities occurred for various years and percentages with severe and extreme droughts occurring once (3.03%)(Table 8). The 33 years of all drought intensities occurrence represents about 47.14% of study period (70 years) for this station.

Table 8. Drought intensities occurrence and percentages in Maiduguri.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	16	48.49
Mild	8	24.24
Moderate	7	21.22
Severe	1	3.03
Extreme	1	3.03
Total	33	100.00

Sokoto: Invisible drought was the most dominant drought intensity with 22 years of occurrences representing 59.46% of total drought occurrences for the station. Other intensities occurred for various years and percentages with severe drought occurring thrice (8.11%) and extreme drought not occurring at all (0%) (Table 9). The 37 years of all drought intensities occurrence represents about 52.86% of study period (70 years) for this station.

Table 9. Drought intensities occurrence and percentages in Sokoto.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	22	59.46
Mild	8	21.62
Moderate	4	10.81
Severe	3	8.11
Extreme	0	0.00
Total	37	100.00

Nguru: The dominant type of intensity was invisible, occurring 19 times (50%), while extreme drought did not occur at all (0%) during the study period. Other intensities occurred for various years and percentages (Table 10). The 38 years of all drought intensities occurrence represents about 54.29% of studied period (70 years) for this station.

Table 10. Drought intensities occurrence and percentages in Nguru.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	19	50.00
Mild	9	23.69
Moderate	8	21.05
Severe	2	5.26
Extreme	0	0.00
Total	38	100.00

Katsina: The most dominant drought intensity in this station was invisible drought with 14 years occurrences representing 40% of total drought occurrences during the period of study. The least occurred intensities were severe and extreme droughts with one year (2.86%) each. Other drought intensities occurred for various years and percentages (Table 11). The 35 years of all drought intensities occurrence represents about 50% of study period (70 years) for this station.

Table 11. Drought intensities occurrence and percentages in Katsina.

Drought intensity	Frequency of occurrence	%age of total occurrence
Invisible	14	40.00
Mild	12	34.29
Moderate	7	20.00
Severe	1	2.86
Extreme	1	2.86
Total	35	100.00

Zone: As shown in Tables 8 to 11 above, invisible drought occurrence ranged from 10 years in Kano to 22years in Sokoto, mild drought from eight years to 17 years, moderate drought from four years in Sokoto to eight years in Nguru, severe drought occurrence varied from one year in Maiduguri and Katsina to three years in Sokoto while extreme drought had no occurrences in Sokoto and Nguru, to one year occurrence each in Kano, Maiduguri, and Katsina during the period of study in the Sahel zone.

In the Sahel zone, invisible drought occurred in 81 years (45%) out of the 180 years of drought in the zone. It was followed by mild drought with 54 years representing 30% of drought years for the zone. Next to mild drought was moderate drought with 33 years (18.33%), severe drought with nine years (5%) and extreme drought with three years (1.67%) (Table 12). Also in this zone, like in the Sudan zone there is the need to put in place measures tailored towards tackling the effects of low intensity drought. However in this zone high intensity drought (extreme) occurred. This means the high intensity drought should not be discounted unlike the Sudan zone where it did not occurred throughout the study period.

Table 12. Drought intensities occurrence and percentages in Sahel Zone.

Drought Intensity	Frequency of Occurrence	%age of total occurrence
Invisible	81	45.00
Mild	54	30.00
Moderate	33	18.33
Severe	9	5.00
Extreme	3	1.67
Total	180	100.00

From analyses done above, in both the Sudan and Sahel zones, the low intensities drought of invisible, mild and moderate were dominant throughout the study period. High intense drought (severe and extreme) occurred for few years in both zones; in fact extreme drought did not occur in the Sudan zone during the period of study (Table 6).

Sudano-Sahel Region

Drought of various intensities occurred for 282 years representing 50.36% of the 560 years of study (100%) (Tables 13, 14 and Figure 2). Therefore, at the regional level, out 560 years (addition of study years for all stations) of study, invisible drought occurred for 127 years (22.68%), mild drought took 92 years (16.43%), moderate drought occurred for 47 years (8.39%), severe drought occurred for 13 years (2.32%) and extreme drought took three years

(0.54%) (Figure 2). As with the zonal situation it is clear from Tables 13 and 14 that low level drought (invisible, mild and moderate) dominate at the regional level. This situation at regional level is well illustrated in Figure.3 showing the drought intensities as percentages of the total drought years. It is also evident that except in Kano where the years of mild drought exceed those of invisible drought in all other stations there is a gradually decline of drought years from invisible to extreme. These low level droughts nevertheless constitute serious risk to food production. As Ayoade (1988) said invisible drought though may not be visible with crops wilting, it however does not allow plants to grow at their "optimum rate", inevitably affecting their output. This is more so in Nigeria where proper data is not kept, it is difficult quantifying the amount of crop output and money lost as a result of invisible and other low intensity drought. However it has been quantified that in 1987, about 5 million metric tonnes of grains valued at over ₦4billion [about $400million] were reportedly lost to drought (Oladipo, 1993). This huge loss of grains leads to increase in cost of grains especially for the poor people and reduces the income of the peasant farmers in the study region. This situation perpetuates the poverty circle of the farmers as they cannot easily break the poverty chain with drought intensity of various kinds being present every other year that inevitably affects their farm products and income. The low amount of grains available due to drought occurrence also affects the feeding pattern of the people with their health and immunity being compromised. This situation undermine the health facilities of the study region while other sectors of the economy like insurance, banking, trading are also affected since the income level of the people have been reduced. This study has shown that drought occurrence especially the low intensity one is a permanent phenomenon in the study area. As a result of this situation the farmers and other stakeholders like government need to put in place policies that can be implemented to tackle the effects of this low intensity drought.

Table 13. Drought intensities years for stations, zones and region.

Sudan zone	Invisible	Mild	Moderate	Severe	Extreme	Out of total for station(70yrs)
Bauchi	18	14	3	1	0	36
Bida	11	12	5	2	0	30
Kaduna	17	12	6	1	0	36
Zone total	46	38	14	4	0	102
Sahel zone						
Kano	10	17	7	2	1	37
Maiduguri	16	8	7	1	1	33
Sokoto	22	8	4	3	0	37
Nguru	19	9	8	2	0	38
Katsina	14	12	7	1	1	35
Zone total	81	54	33	9	3	180
Region total	127	92	47	13	3	282

Table 14. Drought intensities occurrence at regional level as percentages of the total study years.

Drought Intensities	No of Years of Occurrence	%age of Total Study Year (560) (100%)
Invisible	127	22.68%
Mild	92	16.43%
Moderate	47	8.39%
Severe	13	2.32%
Extreme	3	0.54%
Total	282	50.36% #

#: Drought Years, balance of 49.64% represents wet years.

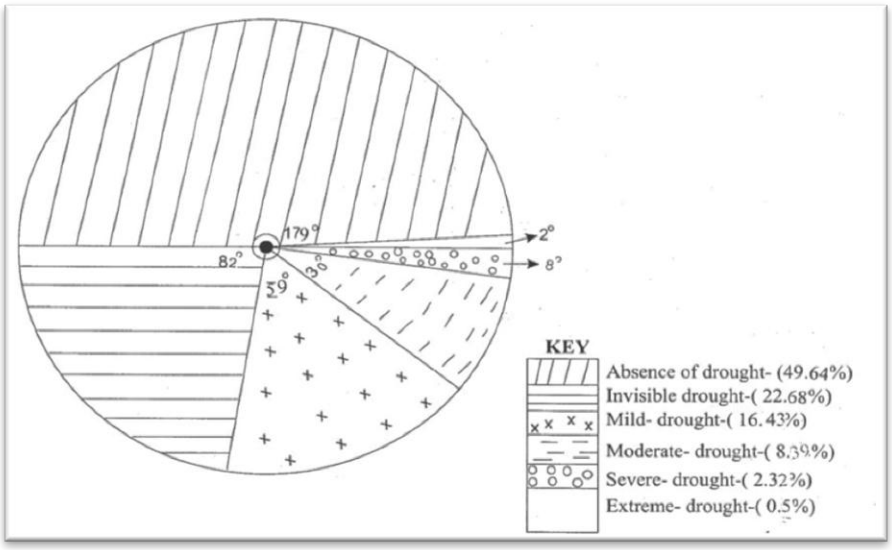

Figure 2. Drought intensities occurrences in relation/as percentages of the study period (560 years) for all stations used

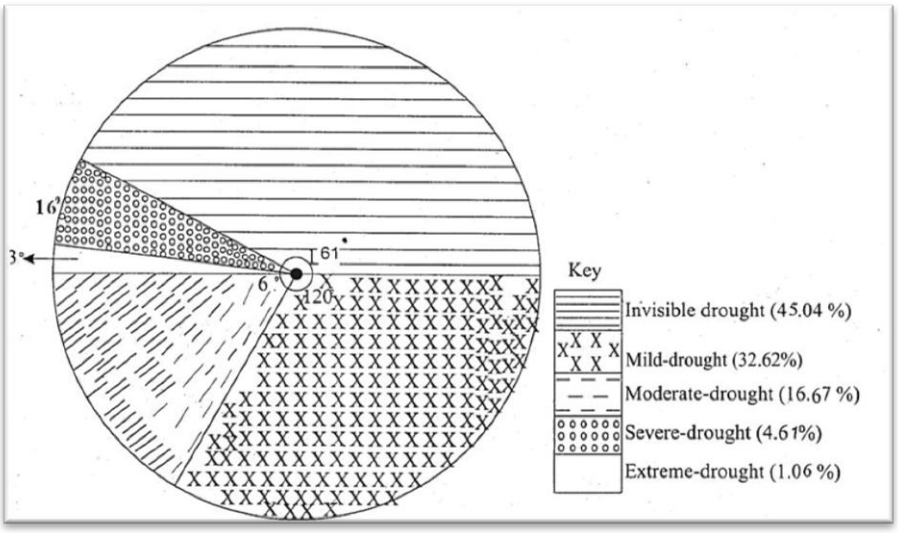

Figure 3. Drought intensities occurrences in relation/as percentages of the drought years (282 years for all stations used) during the study period.

Conclusion and Recommendations

This study has proven that low intensity droughts (invisible, mild and moderate) are much more dominant in the study region than the high intensity droughts (severe and extreme). What this means is that because the low intensity droughts are not evidenced with soil cracking and wilting of crops, the farmers and others might not be immediately aware of their occurrences. This means the low intensity droughts might have been in existence in the region for months or years before the farmers and others are aware. It also confirmed the extreme droughts of the 1980s and at the same time indicated that the extreme droughts were confined to the Sahel zone of the region and not at the Sudan zone.

This study therefore proves the need to put in place measures and strategies that can help in reducing the effects of drought especially the low intensity ones throughout the study region but more so in the Sudan Zone. That is there is the need to shift emphasis away from the old methods of tackling high

intensity drought effects to newer methods of combating the effects of low intensity drought. Some of these measures/methods that can be applied to tackle the low intensity droughts include, but are not limited to the followings; Installation of drip irrigation system that directs water to the roots of crops should be practiced in the study area. Irrigation of farmlands should be done in the morning to ensure that the water does not evaporate.

This method is very much recommended for tackling invisible drought as it will direct water that may be scare to the roots of the plant. Also crops and plants that do not require lots of water should be grown. That is drought resistant and short season varieties of crops like sorghum, maize, millet and rice. These plants are able to withstand the low volume of water and at the same time reproduce maximally.

The soil water in the region can be conserved and managed through the combination of the following practices; carefully planned crop rotation that can help to reduce the rate of erosion, terracing, minimum tillage of the soil, litter management, shelter belts construction, use of organic manure to improve soil composition and water retention. There is also the need to refurbish the old and shallow wells, boreholes and dams as well as the digging and construction of new ones to tap water from the ground and also preserve it in order to relieve the populace of the need for water during droughts. Green Infrastructure (G.I) in villages, towns and cities in the region can also be used to reduce the actual and potential impact of radiation especially in reducing evaporation of water from soils and water bodies.

This will also help to protect the soil against water and wind erosion and to combat anthropogenic causes of drought and desertification. Apart from the above suggested measures, rainwater harvesting techniques that involves the capture of rain water in depressions within fields and stream flood plains for use in agricultural should also be practiced more extensively. Also, this study is not exhaustive, more studies on drought vis-à-vis Northern Nigeria are still recommended. Through this, ways of ameliorating/ mitigating drought will be known so as to adequately tackle the menace for it keeps on re-occurring yearly.

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