Journal of Sustainable Development Studies
ISSN 2201-4268
Volume 2 (2013), Number 1, 69-90

Invisible Drought in Some Stations above Latitude 9^0N of Nigeria

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Abstract

This study is on invisible drought occurrence and reoccurrence in the Sudan-Sahel 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. This was with the intention of finding out the percentage of invisible drought occurrence over a 70 year period (1941-2010). There is statistical evidence of increasing invisible drought. Apart from these, other findings concerning the occurrences of invisible droughts in the decades and sub-periods used for the study were made and are in the study. Measures on how to ameliorate the effects of droughts, especially invisible drought on the populace and environment were suggested. These suggestions when implemented collectively will reduce the effects of invisible drought in the study area.

Keywords: Drought, Drought Intensity, Invisible, Percentages, Sub-period

INTRODUCTION

Drought is the deficiency or abnormal deficit of water in an area during a specific period (Okorie, 20003; Olatunde, 2011b). This means, its occurrence varies spatially and temporally. Apart from this variation, the degree of drought severity also varies temporally and spatially. This degree of water availability or non-availability has resulted in the classification of drought into; permanent, seasonal, contingent and invisible (Ayoade, 1988; Olatunde, 2011a). This study however is concerned with the occurrence and reoccurrence of invisible drought in

the study region. It has been defined as that drought that the "effects are not physically visible on plants, soil and the environment in general. That is the water deficit may not result in the wilting of plants or the cracking of the soil but with crops failing to grow at their optimum rates" (Ayoade, 1988). Rainfall amount also varies. The interannual variability of rainfall in the study area is very large. It can be as high as 20% of the average annual values. Reports of droughts in past decades may have been done on this region (James, 1973; Mortimore, 1973; Oguntoyinbo and Richards, 1977; Adefolalu, 1986; Shuaibu*et al*, 1993; Oladipo, 1993; Okorie, 2003; Abaje*et al*, 2011; Aremu, 2011) however few (Oladipo, 1993;Abaje *et al*, 2011) have looked in details on the various drought intensities especially invisible drought. This study therefore apart from looking into the occurrence and reoccurrence of invisible drought in the study region. It will also, look into the effects of invisible drought in the region and also proffer measures to ameliorate those effects. This study therefore will focus attention on this intensity of drought and its effects as attention have tended to be on other intensities like severe and extreme droughts.

THE STUDY AREA

The study area lies north of latitude 9^0 00^1 N and extend to latitude 14^0 00^1 N within the Savanna region of Nigeria (Fig 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 grouped into the Sudan Savanna and Sahel Savanna (Olaniran, 1987; Abaje*et al*, 2012). The study region produces a huge percentage of the grains consumed in the country. The outputs of these crops (millet, maize, sorghum and so on) are affected by drought. The grasses that cows also graze on in the region are also affected. 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.

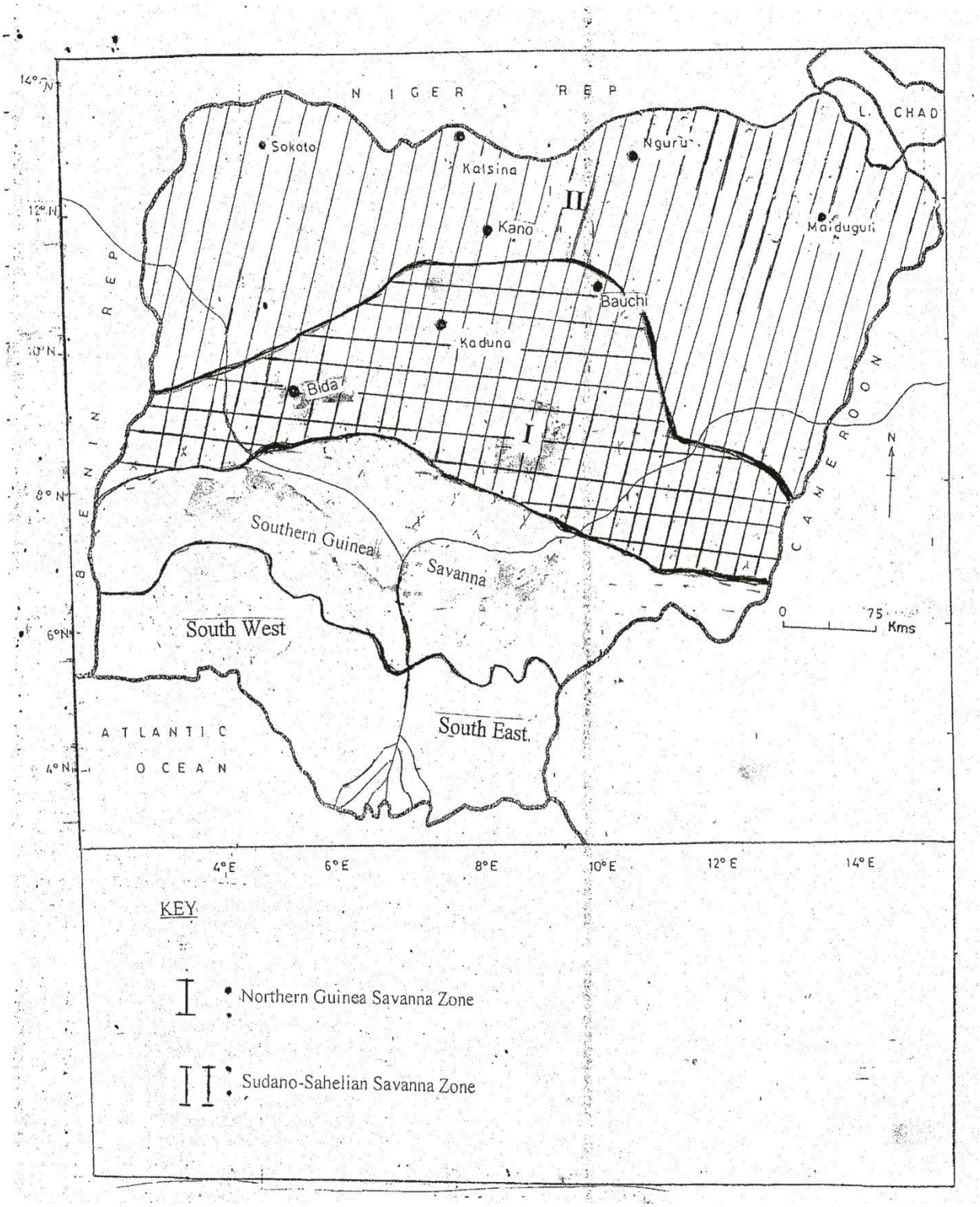

Fig 1.0: Map Showing the Study Region with the Stations Used.

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.

The method used for analysis in this study is by 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).

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 and 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 whenmore 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 $\mathbf{I_K} = (MK / d) + (1 + C) I_K$ .....(3)

Where;

C is a constant

d is a constant

$\mathbf{I_K}$ = drought intensity for the **Kth** month.

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

M, the moisture index is given by

$\mathbf{M} = 100 (X - \ddot{X}) / S$ .....(4)

In equation (4),

X = the monthly rainfall value,

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

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

. Equation (3) is then given as;

$\mathbf{I} = M /d$ .....(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 and 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 B.M.D.I classification chart (Shuaibu and Oladipo, 1993).

Table 2: BMDI Classification Chart.

BMDI	CHARACTEROF 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.

The negative parts of near normal were taken as invisible droughts according to the explanation of Ayoade (1988).

Analyses of Invisible Droughts Using Decades

Table 3 shows that it was only Bida that did not have invisible drought in the decade 1941 to 1950, other stations had invisible drought that ranged between six years for Sokoto and two years for Kano and Maiduguri. In the decade 1951 to 1960, all the eight stations had at least one year of invisible drought with Kano experiencing three years. The last decade of study showed Nguru with the highest years of invisible drought of five years, Bauchi four years, Maiduguri three years, Sokoto and Katsina two years while Bida and Kaduna had one year each with Kano not experiencing invisible drought. Other decades frequencies of occurrences of invisible drought are as shown in Table 3 below.

Table 3: Frequency of Invisible Drought during the Decades in Stations.

STATION	1941 -50	1951 -60	1961 -70	1971 -80	1981 -90	1991 -2000	2001 -2010	Total
Bauchi	3	1	1	4	2	2	5	18
Bida	-	1	-	3	5	1	1	11
Kaduna	2	1	2	2	4	3	3	17
Kano	2	3	4	-	-	1	-	10
Maiduguri	2	2	3	2	2	2	3	16
Sokoto	6	2	3	3	4	2	2	22
Nguru	1	1	3	1	2	4	7	19
Katsina	1	2	2	5	-	2	2	14
Total	17	13	18	20	19	17	23	127

Source: Fieldwork, 2012.

Viewing the region as a whole, the decade from 2001 to 2010 experienced the most years of invisible droughts (23 years), it represents about 18.11% of years with invisible droughts (Fig.2). It was followed by the decade 1971 to 1980 with 20 years (15.75%). The decade with the least invisible drought being 1951 to 1960 with 13 years of invisible drought representing about 10.66% of all years with invisible droughts. Other decades frequency of occurrences and corresponding percentages for invisible droughts are as shown in Fig. 2. On the whole, of the total number of drought years for all stations (282 years), 127years (45.04%) were of invisible droughts (Table 3). This means that out of every 10 drought years, four years were invisible drought years. Therefore, invisible droughts were the most dominant among the low intensity drought that affected the study area during the period of study.

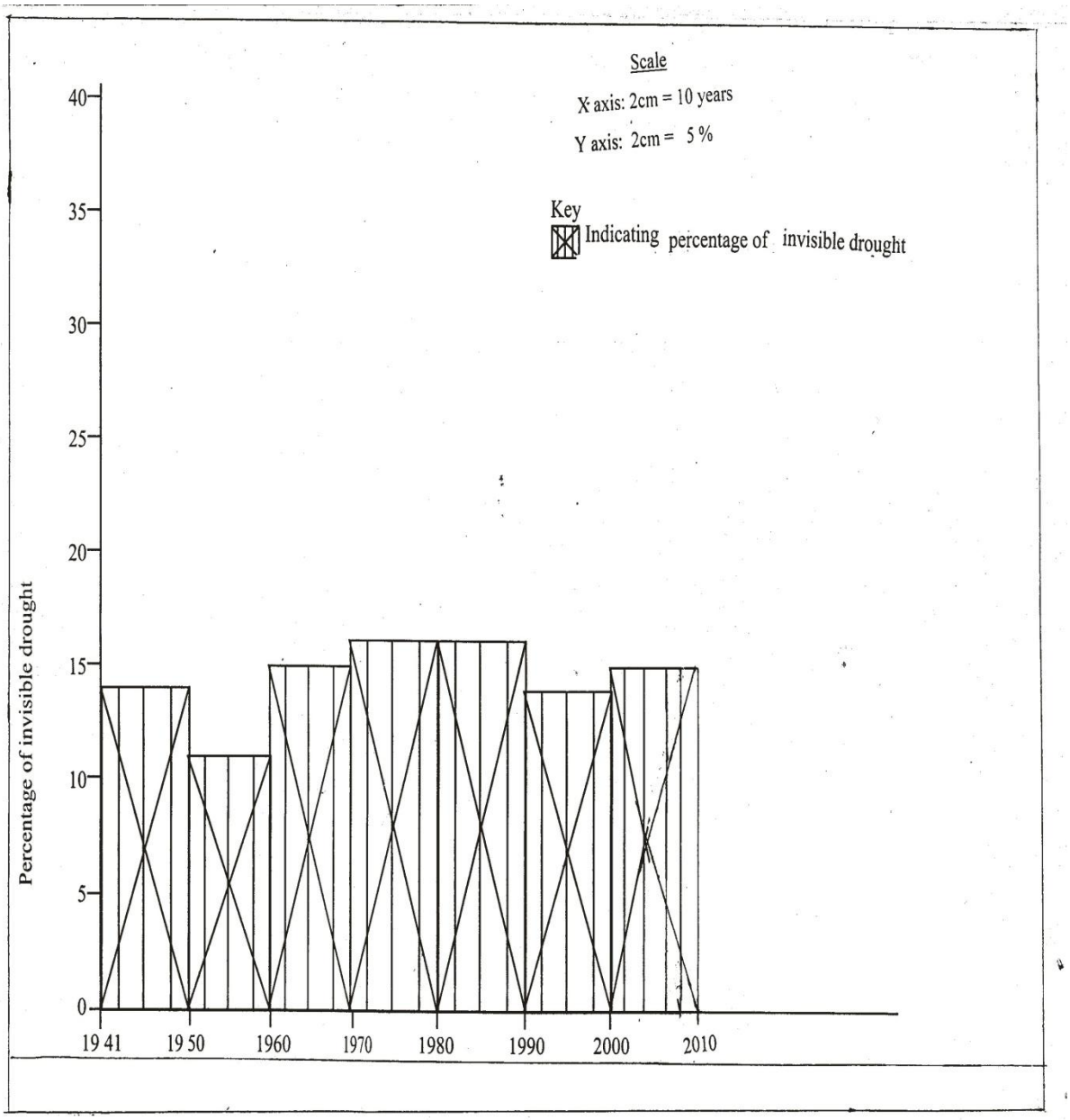

Fig. 2.0: Percentages of Invisible Drought in Study Area (Decades).

Analyses of Invisible Drought Occurrences Using Sub-Periods (Over Lapping) 1941 to 1970

The total number of years of invisible drought for the 30 years (1941-1970) overlapping sub-period was 48 years (Table 4). Sokoto had the highest invisible drought years of 11 (22.92%), followed by Kano with nine years (18.75%), Maiduguri with seven years (14.58%), Bauchi, Kaduna and Nguru each with five years (10.42%). Bida had the least with one year (2.08%)(Table 4).

Table 4: Invisible Drought Occurrences in Stations within the Sub-period 1941 to 1970

Station	Frequency of Occurrences	%age of Total Occurrence
Bauchi	5	10.42
Bida	1	2.08
Kaduna	5	10.42
Kano	9	18.75
Maiduguri	7	14.58
Sokoto	11	22.92
Nguru	5	10.42
Katsina	5	10.42
Total	48	100.00

Source: Fieldwork, 2012

1951 to 1980

In the sub-period 1951 to 1980 (overlapping), Katsina had the highest of invisible drought years with nine (17.65%), next was Sokoto with eight years(15.69%), Kano and Maiduguri with seven years(13.73%) each, Bauchi with six years(11.76%), Kaduna with five years(9.80%) and Bida with four years(7.84%) out of a total of 51 years(100%) of invisible drought for the overlapping sub-period (Table 5).

Table 5: Invisible Drought Occurrences in Stations within the Sub-period 1951 to 1980

Station	Frequency of Occurrences	As %age of Total Occurrence
Bauchi	6	11.76
Bida	4	7.84
Kaduna	5	9.80
Kano	7	13.73

Maiduguri	7	13.73
Sokoto	8	15.69
Nguru	5	9.80
Katsina	9	17.65
Total	51	100.00

Source: Fieldwork, 2012

1961 to 1990

The sub-period 1961 to 1990 (overlapping) had 57 years of invisible drought. Sokoto had the most invisible drought of 10 years(17.54%) followed by Bida and Kaduna with eight years (14.04%) each, next are Bauchi, Maiduguri and Katsina with seven years(12.28%) each. Nguru had six years (10.53%) and Kano had four years (7.02%)(Table 6).

Table 6: Invisible Drought Occurrences in Stations within the Sub-period 1961 to 1990

Station	**Frequency of Occurrences**	**As %age of Total Occurrence**
Bauchi	7	12.28
Bida	8	14.04
Kaduna	8	14.04
Kano	4	7.02
Maiduguri	7	12.28
Sokoto	10	17.54
Nguru	6	10.53
Katsina	7	12.28
Total	57	100.00

Source: Fieldwork, 2012

1971 to 2000

The sub-period 1971 to 2000 had 56 years of invisible drought. Bida, Kaduna and Sokoto jointly had the highest years of invisible drought at nine years

(16.07%),next to them being Bauchi with eight years (14.29%), while Katsina and Nguru had seven years (12.50%)each. Kano had the least year in this sub-period with one year (1.79%)(Table 7).

Table 7: Invisible Drought Occurrences in Stations within the Sub-period 1971 to 2000

Station	Frequency of Occurrences	As %age of Total Occurrence
Bauchi	8	14.29
Bida	9	16.07
Kaduna	9	16.07
Kano	1	1.79
Maiduguri	6	10.71
Sokoto	9	16.07
Nguru	7	12.50
Katsina	7	12.50
Total	56	100.00

Source: Fieldwork, 2012

1981 to 2010

The last sub-period of study 1981 to 2010 had 54 years (100%) of invisible drought with Nguru having the highest of 13 years (22.03%), followed by Kaduna with 10 years (16.95%), Bauchi with nine years (15.25%) and Sokoto with eight years (13.56%). Next were Bida and Maiduguri with seven years (11.86%) each, Katsina with four years (6.78%) and Kano with one (1) year (1.69%) (Table 8).

Table 8: Invisible Drought Occurrences in Stations within the Sub-period 1981 to 2010

Station	Frequency of Occurrences	As %age of Total Occurrence
Bauchi	9	15.25

Bida	7	11.86
Kaduna	10	16.95
Kano	1	1.69
Maiduguri	7	11.86
Sokoto	8	13.56
Nguru	13	22.03
Katsina	4	6.78
Total	59	100.00

Source: Fieldwork, 2011

Sudano-Sahel Region

Sub-periods analyses showed the sub-period 1981 to 2010 had the most years of invisible drought with 59 years (21.77%). The sub-period with the least years of invisible drought was 1941 to 1970 with 48 years (17.71%). Other sub-periods years of invisible drought occurrences and their corresponding percentages are as shown in Table 9 below.

Table 9: Invisible Drought Occurrences in Sub-periods at Regional level

Sub-period	**Frequency of Occurrences**	**As %age of Total occurrence**
1941-1970	48	17.71
1951-1980	51	18.82
1961-1990	57	21.03
1971-2000	56	20.66
1981-2010	59	21.77
Total	271	100.00

Source: Fieldwork, 2011

Bauchi: The sub-period with most years of invisible drought for Bauchi was 1981 to 2010 with nine years (25.71%) of invisible drought. Next were the sub-periods 1971 to 2000 with eight years (22.86%) and 1961 to 1990 with seven years (20.00%) respectively, they were followed by 1951 to 1980 with six years

(17.14%) and 1941 to 1970 with five years (14.29%)(Table 10).

Table 10: Invisible Drought Frequency and Percentages in the Sub-periods for Bauchi

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	5	14.29
1951-1980	6	17.14
1961-1990	7	20.00
1971-2000	8	22.86
1981-2010	9	25.71
Total	35	100.00

Source: Fieldwork, 2011

Bida: The sub-period with most invisible drought for Bida was 1971to 2000 with nine years (31.03%). It was followed 1961 to 1990 with eight years (27.59%), 1981 to 2010 with seven years (24.14%), 1951 to 1980 with four years (13.79%) and 1941 to 1970 with one year (3.45%) of invisible drought (Table 11).

Table 11: Invisible Drought Frequency and Percentages in the Sub-periods for Bida

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	1	3.45
1951-1980	4	13.79
1961-1990	8	27.59
1971-2000	9	31.03
1981-2010	7	24.14
Total	29	100.00

Source: Fieldwork, 2012

Kaduna: The sub-period 1981 to 2010 had the highest years of invisible drought in Kaduna with 10 years (27.03%). Next to it were the sub-periods 1971-2000

with nine years (24.32%) and 1961 to 1990 with eight years (21.62%). Following these were the sub-periods 1941 to 1970 and 1951 to 1980 with five years (13.51%) each (Table 12).

Table 12: Invisible Drought Frequency and Percentages in the Sub-periods for Kaduna

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	5	13.51
1951-1980	5	13.51
1961-1990	8	21.62
1971-2000	9	24.32
1981-2010	10	27.03
Total	37	100.00

Source: Fieldwork, 2011

Kano: The sub-period 1941 to 1970 had nine years (40.91%) of invisible drought for Kano making it the highest. It was followed by 1951 to 1980 with seven years (31.82%), 1961 to 1990 with four years (18.18%) and 1971 to 2000 and 1981 to 2010 one year (4.55%) each (Table 13).

Table 13: Invisible Drought Frequency and Percentages in the Sub-periods for Kano

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	9	40.91
1951-1980	7	31.82
1961-1990	4	18.18
1971-2000	1	4.55
1981-2010	1	4.55
Total	22	100.00

Source: Fieldwork, 2012

Maiduguri: Maiduguri had a unique case as all sub-periods had seven years (20.59%) of invisible drought except the sub-period 1971 to 2000 with six years (17.65%) of invisible drought (Table 14).

Table 14: Invisible Drought Frequency and Percentages in the Sub-periods for Maiduguri

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	7	20.59
1951-1980	7	20.59
1961-1990	7	20.59
1971-2000	6	17.65
1981-2010	7	20.59
Total	34	100.00

Source: Fieldwork, 2012

Sokoto: The sub-period with the highest number of years of invisible drought for Sokoto station was 1941 t0 1970 with 11 years (23.91%).The sub-period 1960 to 1990 was next with 10 years (21.74%), while the sub-period 1971 to 2000 had nine years (19.57%).Both 1951 to 1980 and 1981 to 2010 sub-periods had eight years (17.39) of invisible droughts (Table 15).

Table 15: Invisible Drought Frequency and Percentages in the Sub-periods for Sokoto

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	11	23.91
1951-1980	8	17.39
1961-1990	10	21.74
1971-2000	9	19.57
1981-2010	8	17.39
Total	46	100.00

Source: Fieldwork, 2012

Nguru: In Nguru, the most recent sub-period (1981 to 2010) (overlap) during the study period had the most invisible drought years of 13 (36.11%). It was followed by 1971 to 2000 with seven years (19.44%), 1961 to 1990 with six years (16.67%), 1941 to 1970 and 1951 to 1980 with five years (13.89%) each of invisible droughts. Therefore, in this station there was gradual decrease in the numbers of invisible drought from the recent sub-period (1981 to 2010) to the first sub-period of study (1941 to 1970) (Table 16).

Table 16: Invisible Drought Frequency and Percentages in the Sub-periods for Nguru

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	5	13.89
1951-1980	5	13.89
1961-1990	6	16.67
1971-2000	7	19.44
1981-2010	13	36.11
Total	36	100.00

Source: Fieldwork, 2012

Katsina: The sub-period 1951 to 1980 had nine years (28.13%) of drought in Katsina, making it the highest sub-period with invisible drought. Next were 1961 to 1990 and 1971 to 2000 with seven years (21.88%) each. They were followed by the sub-period 1941 to 1970 with five years (15.63%) and 1981 to 2010 with four (4) years (12.50%) of invisible drought (Table 17).

Table 17: Invisible Drought Frequency and Percentages in the Sub-periods for Katsina

Sub-period	Frequency of Occurrence	As %age of Total Occurrence
1941-1970	5	15.63
1951-1980	9	28.13
1961-1990	7	21.88
1971-2000	7	21.88
1981-2010	4	12.50
Total	32	100.00

Source: Fieldwork, 2012

Region (Sudano-Sahel): Out of the five sub-periods, the sub-period 1981 to 2010 had the highest of 59 years of drought followed by 1961 to 1990 with 57 years, 1971 to 2000 with 56 years, 1981 to 2008 with 54 years, 1951 to 1980 with 51 years and the sub-period with the least years being 1941 to 1970 with 48 years.

Invisible droughts were more in the first two sub-periods for Sokoto, Maiduguri, Kano and Katsina than the last two sub-periods (Table 19). However, in Bauchi, Bida, Kaduna and Nguru, the last two-sub periods had more years of invisible drought than those of the first two sub-periods. The ratio of invisible drought in the first two sub- periods to the last two sub- periods were as follows: Bauchi (11:17), Bida (5:16), Kaduna (10:19), Kano (16:2), Maiduguri (14:13), Sokoto (20:17), Katsina (14:11), Nguru (10:20 or 1:2). In Bauchi, Bida, Kaduna and Nguru, the drought years were more in the last two sub-periods than the first two sub-periods (Table 18). Therefore, invisible droughts in these stations have prevailed in the last 30 years or more. The reverses however were the cases in Kano, Maiduguri, Sokoto and Katsina with more invisible drought years in the first two sub-periods than the last two sub-periods. This may mean a reduction of invisible drought in the last thirty 30 years in these stations.

Table 18: 30 Year Overlapping Sub-Periods for Invisible Drought in the Region.

STATION	1941-1970	1951-1980	1961-1990	1971-2000	1981-2010	TOTAL
Bauchi	5	6	7	8	9	35
Bida	1	4	8	9	7	29
Kaduna	5	5	8	9	10	37
Kano	9	7	4	1	1	22
Maiduguri	7	7	7	6	7	34
Sokoto	11	8	10	9	8	46
Nguru	5	5	6	7	13	36
Katsina	5	9	7	7	4	32
Total	48	51	57	56	59	271

Source: Fieldwork, 2012

Sokoto had the most invisible drought in fact it had the highest or second highest years of invisible drought in each sub-period (Table 20). It also had 46 years (16.97%) across the sub-periods (overlap) as against other stations like Kaduna with 37 years (13.65%), Nguru with 36 years (13.28%) Bauchi had 35 years (12.92%), Maiduguri with 34 years (12.55%), Katsina with 32 years (11.81%), Bida with 29 years (10.70%) and Kano with 22 years (8.12%) of invisible droughts (Table 19).

Table 19: Invisible Drought Frequency Occurrence and Percentages for Stations in the Region.

Station	Frequency of Occurrence	As %age of Total Occurrence
Bauchi	35	12.92
Bida	29	10.70
Kaduna	37	13.65
Kano	22	8.12

Maiduguri	34	12.55
Sokoto	46	16.97
Nguru	36	13.28
Katsina	32	11.81
Total	271	100.00

Source: Fieldwork, 2011

Analyses of Invisible Drought Occurrences in Two Sub-periods (1941 to 1975 and 1976 to 2010) (Non Overlap).

The sub-period 1941 to 1975 had 59 years (46.46%) of invisible drought out of the 127 years of invisible drought recorded during the study period. The balance of 68 years (53.54%) of invisible drought occurred between 1976 and 2010, making this sub-period much more prone to invisible drought than the earlier sub-period (Table 22). The ratio of invisible drought years between the non-overlap two sub-periods varied from Kano (9:1), Bida (2:9) to as close as that of Maiduguri (8:8or1:1) (Table 20).

Table 20: Years And Percentages of Invisible Drought in the Two Sub-periods (1941 to 1975 and 1976 to 2010) (Non-Overlap)

Station	**1941 to 1975**	**1976 to 2010**	**Total**
Bauchi	7	11	18
Bida	2	9	11
Kaduna	7	10	17
Kano	9	1	10
Maiduguri	8	8	16
Sokoto	13	9	22
Nguru	5	14	19
Katsina	8	6	14
Total	**59 (46.46%)**	**68 (53.54%)**	**127 (100%)**

Source: Fieldwork, 2012

CONCLUSIONS

This study has been able to prove that there exists an increase in the number of years experiencing visible drought in most of the stations in the study area. This is especially so in recent years. Therefore the presence of invisible drought in the region is becoming the new normal, probably as a result of climate change. Unfortunately, this situation affects the growth of vegetative crops such as onions, tomatoes and cabbages. This is because it results in the stunt growth of those crops. This invariably affects the income of the farmers and the society. It also reduces the available grasses for grazing animals. This results in animals entering farmlands for food, thereby causing conflicts between farmers and animal herders.

Invisible droughts make the soils to be prone to wind erosion in the study area. This is as a result of the soil drying up. This dry condition encourages the growth of certain weeds in the study area, for example, *striga*. These problems enumerated above pose serious challenges to the small scale farmers in this region. As a result of this, the following recommendations are suggested;

- The dissemination of information to the farmers, animal herders and other stakeholders should be done regularly and as at when due. This is to inform them of an impending drought, its likely intensity and the measures to be adopted by the citizens to mitigate its effects.
- Installation of drip irrigation that directs water straight to the roots of plants.
- The extensive planting of crops and plants that do not require lots of water. These are normally indigenous plants which can survive with low amount of rainfall with out additional watering. In the study area such crops will include drought resistant and short season varieties of cereals like sorghum, maize, millet and rice.
- Animal herders need to adopt modern systems such rotational ranching.

- Farmers in the study area should be encouraged to use organic fertilizers to enhance soil composition and improve water retention thereby combating invisible drought.
- The use of Green Infrastructure (G.I) in cities, towns and villages in the study region will help to reduce the actual and potential impact of radiation especially in reducing evaporation of water from soils and water bodies.

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❖ This article is part of Ph.D thesis submitted to N.D.A