A GEO-LOCATIONAL ANALYSIS OF DROUGHT SEVERITY/MAGNITUDE IN THE SAVANNAH REGION OF NIGERIA

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Abstract

The study investigated the relationship between drought severity/magnitude and geographical parameters of Latitude, Longitude and Mean Annual Rainfall (MAR) of 50 locations in the Savannah region of Nigeria. Secondary data on rainfall for all stations was obtained from the headquarters of Nigeria Meteorological Agency (NiMets), Abuja. The research made used of the Standardized Precipitation Index (SPI) technique to established drought severity/magnitude for all locations. It further employed the use of Pearson Product Moment Correlation Analysis to test relationship between the SPI values generated with geographical parameters of Longitude, Latitude and Mean Annual Rainfall (MAR). Results obtained shows that latitude exerts a strong but negative relationship on MAR and SPI values. That is, an increase in latitude will lead to a decrease in MAR and SPI values with a correlation coefficient of (r = -0.787 and -0.805) respectively. Findings further revealed that a strong positive relationship existed between MAR and SPI values with r = 0.964. All relationships were significant at the 99% confidence level. The research therefore concludes that on the overall, drought magnitude generally increases with increasing latitude.

Keywords: Drought, SPI, Mean annual rainfall, latitude, longitude and relationship.

INTRODUCTION

Drought is generally considered by many to be the most complex but least understood of all natural hazards and it affects more people than other hazards (Wilhite, 1996; Chopra, 2006; Murad and Saiful Islam, 2011). It is a normal recurrent feature of climate for virtually all climatic regions. It is a temporary aberration that occurs in high as well as low rainfall areas. Drought is a question of water demand and supply. Inadequate supply of water to meet the demand creates drought. Drought is a complex phenomenon that is difficult to accurately describe because its definition is both spatially variance and context dependent (Quiring and Papakryiakou, 2003).

Drought seldom results in structural damaged. Therefore, the quantification of impacts and the provision of disaster relief is a far more difficult task for drought than it is for other natural hazards. Drought incidences are sometimes under reported because unless an affected country request for assistance from international aid or donor organizations, the incident is not noted. It is mostly the international community or donor governments that keep records. However, Blackie *et al.* (1994) has reported an increase in the reported cases of drought from 62 to 237 during the 1980's. There are evidences to show that this figure has also sky rocketed since that period (WMO, 2006; Andreadis *et al*., 2005 and Dai *et al*., 2004). The tendency towards more droughts occurrences could be associated to global warming. Furthermore, the drying of soils as a result of increased in temperature which is normally associated with this warming enhances the risk of long duration droughts.

Drought impacts in various ways. The effect of drought may be direct or indirect, singular or cumulative, immediate or delayed. Droughts lead directly to poor crop yield, famine, deterioration of pasture, dead of live stock etc. The direct losses caused by drought are more complex and many. Some of them lead to changes of land use practices, abandonment of fertile lands, migration of rural population, heavy pressure on urban areas and so on. These put severe strain on the economic development of a nation, either immediately or with a time lag (Appa, 1987; Redsteer *et al*., 2010).

The savannah region of Nigeria constitutes about 78% of the total landmass of the country. It produces a large proportion of the grains (maize, millet, sorghum and wheat) that provide the staple diet of Nigerians. Yet the region is frequently under drought attack and this effect food production and the region's economy negatively. The choice of Savannah region in Nigeria is predicated by the fact that the area is characterized by marked rainfall variability both seasonally and annually. The forested south has double rainfall maxima which gives room for double cropping per annum, while in the Savannah, agriculture is mostly dependent on the single maximum regime with high drought risk tendency. Previous works on droughts in the Savannah region of Nigeria have examined drought from various perspectives using different techniques including the Standardized Precipitation Index. However, its application has not gone beyond detecting drought years and magnitude (Akeh *et al*., 2005; Binbol, 2009; Binbol and Edicha, 2012). It therefore becomes imperative to undertake the present research in order to fine tune as well as update knowledge on drought frequency in selected locations in the savannah region of Nigeria. The study is also geared towards establishing the relationship between drought frequency and mean annual rainfall of the selected stations.

Methodology

Study area

The Savannah region of Nigeria lies within the geo-coordinates of Latitude $6^0$27'N to 14^0 N and Longitude 2^0 44'E to 14^0 42'E (Fig. 1). It constitute a bulk segment of the northern part of Nigeria covering about 730,000 km^2 or about 78% of the total landmass of the country (Oladipo, 1995). The region consists of nineteen states that form the northern part of Nigeria. It is bounded in the North by Niger republic in the east by the Cameroon republic and Benin republic in the west.

The climate in the Savannah region of Nigeria is characterized by two distinct seasons, wet and dry. The duration of each season varies from the south to the extreme north of the Savannah. There, however, seems to be a general increase in the dry season period of 5 months in the southern part of the savannah to about 8 months in the extreme north. Precipitation also decreases northwards; this is because some southern part of the Savannah region enjoys double maxima rainfall, while the Northern part experiences a single maximum regime. Mean annual rainfall in the region ranges between 630.3 mm in the Sahel Savannah region, 720.8 mm in the Sudan Savannah region and 1,430.1mm in the guinea Savannah region (Oladipo, 1995). Temperature is generally high in the Savannah region; this is partly due to the fact that the region lies within the topics where the apparent movement of the sun is limited.

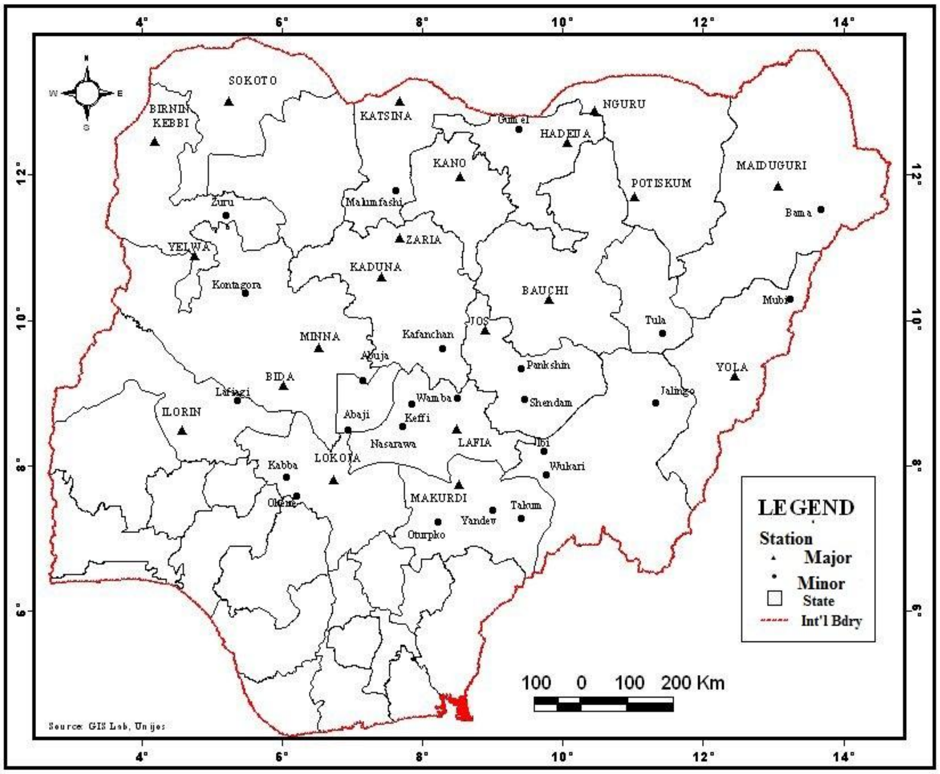

Fig 1. Map of Nigeria showing data collection points (Major and minor stations)

Secondly, the long period of dry season associated with the region means a clear sky without the moderating influence of cloud. There is however a noticeable spatial variation in temperature within the Savannah region. The highlands and plateaux e.g. Jos plateau records mean annual temperature of about 21^0C to 25^0C, while the plain, basin and lowlands generally have mean annual temperature of about 27^0C. There is also a seasonal or temporal variation component to temperature within the Savannah region.

Sunshine pattern for the Savannah region shows a general increase in sunshine hours from the south-northwards. Sunshine hour also varies with seasons in the Savannah region. Sun hours are high in January, averaging 6.2 hours. It decreases gradually from then to a minimum of 3.9 hours in August when the Savannah region records its highest rainfall and cloud. Relative humidity also varies with time in the study area. In January the value increases from north to south, with the north western part of the region having the lowest value of less than 20%. This low value is also replicated in parts of Bauchi/Gombe. Most parts of the Sahel and Sudan Savannah do record relative humidity value of up to 20-40% within the same period. The guinea savannah however reaches relative humidity values of between 40-60% in the same period. By July the entire savannah region comes under the influence of the tropical maritime(Tm) a warm moist wind that boost relative humidity values for the whole region. By this time, relative humidity values for the entire region ranges between 60-80%. The study area generally falls under the savannah vegetation; however, the zone is sub-divided into guinea, Sudan and Sahel savannah belts. There also exists montane vegetation on some prominent highlands within the savannah region, such as are found on the Jos plateau, the Biu plateau and the Mambilla plateaus.

Sampling

Secondary data in the form of monthly rainfall recordings for selected stations in the study area were transcript. Monthly rainfall total was used. It is most appropriate for generating Standardized Precipitation Index (SPI). All data were collected for as long a period as consistent records allow. The stations were then divided into two: those with long rainfall record spanning over 60 years (Major stations) and those with rainfall record below 35 years (Minor stations). The Savannah region is broadly divided into three ecological zones that vary in sizes and climatic conditions. Therefore a purposive sampling technique was adopted in selecting data collection points. This technique is necessary so that only stations with relatively long and consistent records were considered. Secondly, selection was done to ensured maximum spatial coverage of the entire region. In all 50 rainfall stations were used for the study. This is made up of 15 major and 35 minor stations as shown in table 1. All data required for this study was obtained from documented records by Akintola (1983) and the headquarters of the Nigerian meteorological services department, Abuja.

In order to properly analyze meteorological drought, the Standardized Precipitation Index (SPI) based on the probability of precipitation for any time scale, subject to usage by many drought planners was used. This study adopted a 12 months SPI for an annual drought index for the savanna region of Nigeria. The 12 months SPI accommodates the entire rainfall for the year. The equation is simply sum up as:

$$SPI = (X_{ik} - \bar{X}_i) / \sigma_i$$

Where σ = standardized deviation for the ith station

X_{ik} = rainfall for the ith station and kth observation

$\bar{X}_i$ = mean rainfall for the ith station.

All negative SPI values were taken to indicate the occurrence of drought, while all positive values show no drought. A table of SPI values presented in table 2 was used to determine drought intensity/magnitude.

Table 1: List of Stations and Rainfall Duration

S/no	Minor stations (<35 years data)	Major stations (>60 years rainfall)	Period	Duration
1.	Abaji	Bauchi	1908 – 2011	104yrs
2.	Abuja	Bida	1928 – 2011	84yrs
3.	Bama	Ilorin	1927 – 2011	85yrs
4.	Biu	Jos	1927 – 2011	85yrs
5.	Gumel	Kaduna	1931 – 2011	81yrs
6.	Ibi	Kano	1925 – 2011	87yrs
7.	Jalingo	Katsina	1925 – 2011	87yrs
8.	Kabba	Lokoja	1931 – 2011	81yrs
9.	Kafanchan	Maiduguri	1915 – 2011	97yrs
10.	Kaiama	Makurdi	1927 – 2011	85yrs
11.	Kamba	Minna	1916 – 2011	96yrs
12.	Keffi	Nguru	1916 – 2011	96yrs
13.	Kontagora	Potiskum	1936 – 2011	76yrs
14.	Lafiagi	Sokoto	1915 – 2011	97yrs
15.	Malumfashi	Yola	1931 – 2011	81yrs
16.	Mubi			
17.	Nasarawa			
18.	Okene			
19.	Oturpko			
20.	Pankshin			
21.	Shendam			
22.	Takum			
23.	Tula			
24.	Vom			
25.	Wamba			
26.	Wukari			
27.	Yandev			
28.	Zonkwa			
29.	Zungeru			
30.	Zuru			
31.	Birnin Kebbi			
32.	Hadeija			
33.	Lafia			
34.	Yelwa			
35.	Zaria.			

Table 2: SPI Values and Interpretation

SPI Value	*Interpretation*
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and above	Extremely dry

Source: After McKee *et al*. (1995).

Product moment correlation analysis and regression techniques were used to test the relationships between SPI values, Mean Annual Rainfall (MAR) and geographical parameters used in the study. In order to achieve the former, all latitudinal coordinates in degrees were converted to decimal.

In order to determine the relationship between drought magnitude (SPI values) and selected geographical parameters of rainfall, latitude and longitude, the mean monthly rainfall for each station was calculated. Each station was then allocated a year's value. The SPI value for each station was then calculated and presented in table 3. The study adopted the use of SPI 12 value because it accommodates the total rainfall in the year, thereby giving a clear picture of the drought situation.

Results and Discussion

Table 3; Major and minor stations with SPI values.

S/no	station	Geo-coordinates	Mean Annual RF (mm)	SPI 12 values
1.	Okene	7^0 33′N, 6^0 11′E	1,359	0.67
2.	Lokoja	7^0 48′N, 6^0 44′E	1,171	0.14
3.	Kabba	7^0 50′N, 6^0 4′E	1,516	1.08
4.	Oturpko	7^0 13′N, 8^0 14′E	1,864	1.90
5.	Makurdi	7^0 44′N, 8^0 32′E	1,341	0.63
6.	Takum	7^0 16′N, 9^0 59′E	1,717	1.57
7.	Yandev	7^0 23′N, 9^0 1′E	1,308	0.53
8.	Wukari	7^0 52′N, 9^0 47′E	1,260	0.40
9.	Ilorin	8^0 29′N, 4^0 35′E	1,298	0.51
10.	Abaji	8^0 29′N, 6^0 57′E	1,219	0.19
11.	Nasarawa	8^0 32′N, 7^0 44′E	1,300	0.28
12.	Keffi	8^0 50′N, 7^0 52′E	1,595	0.51
13.	Lafia	8^0 30′N, 8^0 30′E	1,285	1.28
14.	Lafiagi	8^0 53′N, 5^0 22′E	1,189	0.47
15.	Wamba	8^0 55′N, 8^0 31′E	1,651	1.41
16.	Ibi	8^0 11′N, 9^0 45′E	1,148	0.07
17.	Shendam	8^0 54′N, 9^0 28′E	1,222	0.29
18.	Jalingo	8^0 51′N, 11^0 20′E	1,267	0.42
19.	Bida	9^0 6′N, 6^0 1′E	1,146	0.32
20.	Minna	9^0 37′N, 6^0 32′E	1,336	0.61
21.	Zungeru	9^0 49′N, 6^0 1′E	1,234	0.32
22.	Abuja	9^0 10′N, 7^0 10′E	1,707	1.56
23.	Kafanchan	9^0 36′N, 8^0 18′E	1,664	1.46
24.	Kaiama	9^0 45′N, 3^0 56′E	1,349	0.65
25.	Zonkwa	9^0 44 , 8^0 23′E	1,483	1.00
26.	Vom	9^0 44′N, 8^0 47′E	1,374	0.75
27.	Jos	9^0 52′N, 8^0 54′E	1,412	0.82
28.	Pankshin	9^0 20′N, 9^0 25′E	1,006	-0.38
29.	Tula	9^0 49′N, 11^0 46′E	866	-0.86
30.	Yola	9^0 14′N, 12^0 28′E	968	-0.51
31.	Yelwa	10^0 53′N, 4^0 45′E	1,016	-0.35
32.	Kontagora	10^0 21′N, 5^0 28′E	1,074	-1.12
33.	Kaduna	10^0 36′N, 7^0 27′E	1,280	0.46
34.	Bauchi	10^0 17′N, 9^0 49′E	1,095	-0.09
35.	Biu	10^0 36′N, 12^0 12′E	1,013	-0.37
36.	Mubi	10^0 17′N, 13^0 15′E	1,054	0.29
37.	Zuru	11^0 26′N, 5^0 13′E	1,026	-0.31
38.	Zaria	11^0 8′N, 7^0 41′E	1,148	-0.06
39.	Malumfashi	11^0 47′N, 7^0 38′E	988	-0.43
40.	Kamba	11^0 58′N, 3^0 42′E	866	-0.87
41.	Potiskum	11^0 42′N, 11^0 2′E	808	-1.07
42.	Bama	11^0 31′N, 13^0 42′E	739	-1.36

43.	Maiduguri	11^{0} 51′N, 13^{0} 5′E	655	-1.71
44.	Birnin kebbi	12^{0} 28′N, 4^{0} 11′E	785	-1.18
45.	Kano	12^{0} 3′N, 8^{0} 32′E	869	-0.86
46.	Gumel	12^{0} 38′N, 9^{0} 23′E	617	-1.91
47.	Hadeija	12^{0} 27′N, 10^{0} 4′E	632	-1.81
48.	Nguru	12^{0} 53′N, 10^{0} 28′E	572	-2.10
49.	Sokoto	13^{0} 1′N, 5^{0} 15′E	734	-1.38
50.	Katsina	13^{0} 1′N, 7^{0} 41′E	742	-1.38

The relationship between SPI values generated for the fifty stations under study was tested with geographical parameters of longitude, latitude and mean annual rainfall (MAR) using correlation and regression analytical techniques. The result obtain is presented in table 4. Results from table 4 shows that longitude has a negative and insignificant relationship with SPI. The same was observed for longitude and MAR. This is so because the longitude of locations only denotes their position east or west of the Greenwich meridian and except other geographical parameters like altitude and continentality plays mediating roles, its effect is insignificant. The correlation results further reveals that latitude has strong but negative relationship with mean annual rainfall and SPI. The negative sign implies that the higher the latitudinal values, the lower the mean annual rainfall received. The same relationship was observed for latitude and SPI value. Meaning that as latitudinal values increases, SPI values decreases towards higher negative values. Both relationships are significant at the 99% confidence level on the one tail test. It was however observed that MAR has a strong positive relationship with SPI, with a correlation coefficient (r) of 0.964. This simply means that rainfall greatly influenced the value of SPI obtain in any location. Increase in MAR will equally raised SPI value on the positive side and vice versa.

This findings corroborated the earlier works of Akeh et al, (2005), Fasona and Omojola (2005) and Oladipo (1995) who in separate studies found out that rainfall exhibit very strong relationship with latitudinal coordinates of locations. Oladipo (1995) went a step further to examine some spatial characteristics of droughts in the savannah region. He found out that drought severity and magnitude terns to increase in relation to water deficiency.

Regression technique was further used to confirm the established relationship. The result as presented in Table 5 shows that MAR and latitude exhibit major influence on SPI. MAR with a coefficient of determination (r^2) of 0.929 simply means that 92% of drought class is determined by the mean annual rainfall occurring at a particular location. The same finding was observed for latitudinal effects on SPI values. Again, the coefficient of determination (r^2) shows that 93% of SPI values are determine by the latitude of the location. This finding confirms the earlier establish relationship in the correlation between latitude and MAR where it was noted that as latitude increases, MAR decreases.

Table 4 correlation for SPI and Geographical parameters

	Longitude	Latitude		
Longitude	1	.033		
Latitude	.033	1		
MAR	-.212	-.787**		
SPI	.094	-.805**	.964**	1

Table 5; Regression for SPI and Geographical Parameters

Model	R	r^2	r^2 adjusted	Std. Error of the Estimate
MAR	.964[a]	.929	.928	.26656
Latitude	.967[b]	.935	.932	.25817

a. Predictors: (Constant), MAR

b. Predictors: (Constant), MAR, Latitude

Conclusion

The study tried to establish if the degree of severity or magnitude of drought is a function of the geographical location of the place where the drought occurred. The study made use of the Standardized Precipitation Index (SPI) to established drought conditions in 50 locations with historic rainfall data in the Savannah region of Nigeria. It was observed that drought severity and magnitude increases generally northwards. The validity of this observation was tested using the Pearson Product Moment Correlation analysis and findings reveals that while a strong positive relationship existed between Mean Annual Rainfall (MAR) and SPI values, a strong but negative relationship existed between latitude and MAR and latitude and SPI.

Based on findings above, the research therefore concludes that as latitudinal values increases upwards, annual rainfall total will decrease. In the same vein, as latitudinal values increases northwards, the SPI values generally decreases to the extent of taking negative values which in turn denotes the severity/magnitude of drought. The research therefore suggests the need for further study on relationship between drought frequency and latitudinal location as a way of buttressing the current findings.

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