CLIMATE VARIABILITY AND METEOROLOGICAL DROUGHT INCIDENCES IN SOKOTO, NIGERIA

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Abstract
The paper attempted to determine the direction of climate variability in Sokoto using rainfall parameter. It also undertook an in-depth analysis of meteorological droughts in the study area using different time scales. The study made use of 64 years unbroken rainfall data spanning the period 1915 to 1979, obtained from the office of Nigerian Meteorological Services Department, Oshodi, Lagos. A five year moving average was used to establishe climate swing direction, while the Standardized Precipitation Index (SPI) technique with time scale 3 (J,A,S), 6 (M,J,J,A,S,O) and 12 (Jan to Dec) were used for the drought analysis. Results obtained shows that rainfall is on the decrease in Sokoto. Analysis of the 3 months SPI shows that rainfall between the months of July to August is relatively constant and if crops were grown within this period, drought incidents would be unheard of in Sokoto. The 6 months SPI covers May to October and the result shows that precipitation deficiency varies from near normal to severe dry conditions. The 12 months SPI covers January to December and the result reveals a great inter annual variability. The research observes that drought is a time variant occurrence. For example, drought analysis shows that there was enough rainfall for crop growth within the growing season (May to October) in the years 1925, 1940, 1972 and 1975, yet, annual SPI values (January to December) shows that they were drought years with varying magnitude. The research concludes that drought analysis techniques should always be compared with yield figures for a proper understanding of drought measuring efficacy. Appropriate recommendations where proffered.
Keywords; climate, droughts, efficacy, rainfall, SPI technique and variability.
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Introduction
Since man started sedentary life and the art of cultivation, he had regularly contended with natural hazards. Prominent among them is "drought". The holy book states in part "Who is wise enough to count the clouds and tilt them over to pour out the rain...?" (Job 38:17). Adefolalu (2006) stated that weather has been of primary concern to mankind for all times. Biblical stories of Noah's flood, drought and famine in Pharaoh's Egypt and others during king Solomon's reign while the life and times of Elijah, Ezekiel and the rest prophets told vividly established the quasi regular famine episodes. All these events and several other later happenings are as a result of precipitation deficiency in space and time.

Drought is a slow-onset natural hazard that is often as a result of a cumulative departure from normal or expected precipitation. That is, a long-mean or average. This precipitation deficit generally appears initially as deficiency in soil water; therefore agriculture is often the first sector to be affected. When this cumulative deficit builds up quickly over a period of time, the difference begins to appear in other forms such as, reduced stream flows, reservoir levels or increases depth to the ground water table.

All forms of droughts are initiated by natural climate variability. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impact cascade from this deficiency. Meteorological droughts are first noticed because of its sensitivity to precipitation deviations, especially in terms of amount of precipitation, precipitation intensity and even deviation from timing of precipitation may reduce infiltration capacity and increase run off. A deviation in meteorological elements observed, especially tending towards higher values is capable of initiating meteorological drought thereby lowering deep percolation and ground water recharge capacity. For example, an increase in temperature and sunshine coupled with high wind velocity, lower relative humidity and less cloud cover will definitely lead to an increase in evaporation and transpiration processes. The overall effect of this is a loss of soil water moisture. This is overtly translated into plants that are water stressed manifesting reduced yield and biomass production. This is what encapsules agro climatic drought. When these observed conditions persist, the situation may degenerate to the level of hydrological drought. This is characterized by reduced stream flow, inflows to lakes, reservoirs and ponds may even cease. Finally it may be followed by reduced wetlands and wild life habitat. This processes lives in its wake severe impacts covering economic, social and environmental consequences.

Several authors have used various parameters to establish incidences of climate change and droughts on local, regional and global scales. Binbol (2009), Binbol and Wakayi (2010) and Binbol and Edicha (2011) used long term rainfall records spanning over 3 climatological periods for 3 stations in the savannah region of Nigeria to established climate change scenarios and drought occurrences. They introduced a 5 years moving average to smoothen out extreme values. Results obtained shows a downward sloping trend which is indicative of climate change characterized by increasing temperature, high evaporation and reduced rainfall.as observed by Ojo (2003). Ayodeji (2009) used water vapour data over West Africa for a period of 60 years obtained from National Centre for Environmental Protection and National Centre for Atmospheric Research (NDEP and NCAR) to investigate its inter annual variability. His results shows that the trend of water vapour over West Africa has decreased progressively at a rate of about 0.00005k/kg per year especially in the 1960s. Ojo and Oladusu (2009) also used temperature trends in northern and southern parts of Nigeria to establish a climate change possibility over a 30 year period. Their result shows that there is a significant rise in air temperature by about 1.20C in the northern part of the country, while the coastal area shows an increase of about 10C.

The effects of drought have been documented by many scholars (Appa, 1987; Binbol, 2009; Binbol and Wakayi, 2010 and Binbol and Edicha, 2011) just to mention a few. It therefore becomes necessary and imperative to analyze drought incidences in Sokoto for a better understanding of its frequency, magnitude, duration and other relevant characteristics. This forms the main thrust of this present paper.

Materials and Methods

Study area

Sokoto state lies to the northwest of northern Nigeria and it shares boundary with Niger republic to the north, Katsina state to the east, Niger State to the south-east, Kwara state to the south and Benin Republic to the west. The state is located between latitudes 13004'N to 13065'N and longitudes 5014'E to 5023E'. As of at 2006 it had a population of 427,760 inhabitants. The state is characterized by two distinct seasons, the wet and dry seasons. The wet season spans a period of 5 months (June to October), while the dry season last about 7 months (November to May). Rainfall generally commenced late and ceased early with a mean annual range of 500mm to 1,200mm. Temperatures are generally high throughout the year with an annual average of 28.30C. Day time maximum is in the region of 400C. There is a marked seasonal variation in the temperature; the warmest months are February to April with day time high exceeding 450C; this period represents the dry season. The cold season in Sokoto stretches from November to February and it is characterized by the predominance of the Harmattan wind, a cold dusty wind that originates over the Sahara desert. The dust dims the sunlight, thereby lowering the temperature in this period significantly. Agriculture is practiced intensively along the Sokoto Rima River valley. Crops grown include millet, maize, rice and other cereals. Sokoto falls within the Savannah region; therefore, animal husbandry is practiced greatly.

Data

This research made use of secondary data in the form of monthly rainfall data obtained from documented materials from the head office of Nigerian Meteorological Services Department, Lagos. Data was obtained for a period of 64 years (1915 – 1979), monthly rainfall value is particularly important for this study because of its flexibility in time scale drought analysis as provided by the Standardized Precipitation Index technique. Its annual value also gives a good measure of departure from annual mean.

Analysis

In order to make definite pronouncement concerning climate change possibility in Sokoto, the annual rainfall data was subjected to a 5 year moving average analysis. This is necessary to smoothen out extreme annual values that might distort annual flow pattern. Drought periods and characteristics were established using the Standardized Precipitation Index (SPI) technique. This technique has been adjudged a good indicator of moisture supply (Wu et al, 2004).

Results and Discussion

Climatic variability in Sokoto

Landsberg (1979) in Adebayo (2010) argues that for a definite pronouncement of climate change over any region, there should be an unbroken data observation for at least 150 years. This should equally be accompanied by a shift from mean values of observed elements to a new equilibrium. The present study used rainfall data spanning a period of 64 years. This covers about two climatic periods, therefore, climatic variability can be observed and not an outright climate change. Total annual rainfall for Sokoto was plotted on yearly basis as presented in figure 1, to enable an overt observation of annual variability. The total annual rainfall in figure 1 gave no definite direction as to the swing of rainfall pattern in Sokoto. This is because the rainfall pattern is characterized with extreme highs and lows. The annual rainfall values were then subjected to a 5 years moving average in order to smoothen the highs and lows. The result shows that from the 1950s rainfall have been on the decrease in Sokoto (see Fig. 1).

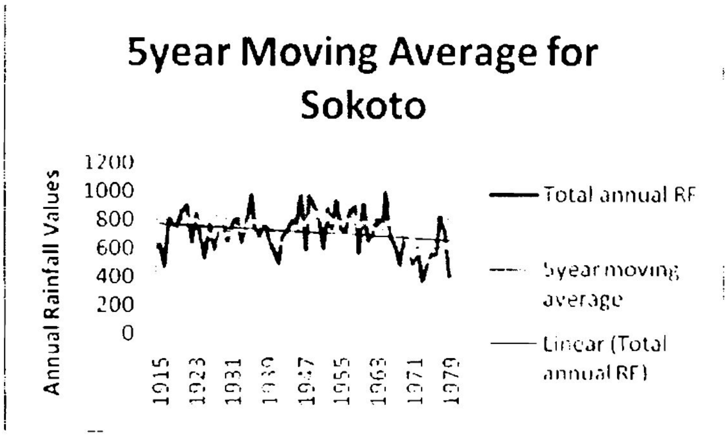


Figure 1; A 5year moving average with trend line for Sokoto

The study also employed the use of climatic mean for the two periods (1915 – 1947 and 1948 – 1979) to plot a linear trend line on both total rainfall and the 5years running average. The result in figure 1 clearly shows that on the average, annual rainfall in Sokoto is on the decrease.

Meteorological Droughts Issues

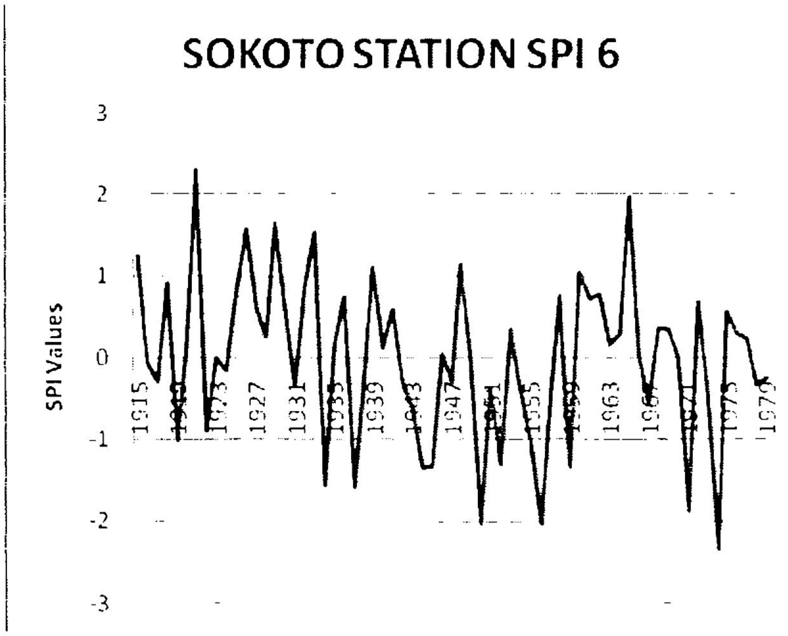
Having established in the previous section that rainfall is generally on the decrease in Sokoto, it therefore becomes imperative to examine how this decline affects drought characteristics in Sokoto. Droughts in this study were established using the Standardized Precipitation Index technique which recognizes drought occurrence on various time scales. This study made use of SPI 12 covering total annual rainfall and SPI 6 which covers rainfall from May to October (crop growth season). A drought frequency count analysis on decadal basis was undertaken and the result obtain is presented in table 1.

Table 1. Drought frequency/Temporal analysis in Decades.

	1925 – 34	*1935 – 44*	*1945 – 54*	*1955 – 64*	*1965 – 74*	*1975 – 79*	*SPI value*
5	*6*	*5*	*3*	*5*	*8*	*3*	*SPI 12*
5	*2*	*5*	*6*	*4*	*4*	*2*	*SPI 6*

Results from table 1 shows that on annual rainfall basis 35 drought episodes were recorded in Sokoto during the study period. SPI 12 accommodates rainfall from January to December and in view of the great annual variability in Sokoto, the tendency is for it to translate into high drought frequencies. SPI 6 on the other hand yielded 28 episodes of drought; this is because SPI

6 considers rainfall during the growing season (May to October). Further analysis of table 1 reveals that the 1965 – 1974 decade had the highest drought frequency of 8 episodes. This finding agrees with earlier works of Mortimore (1989), Apeldoorn (1981), Fasola and Omojola (2005) and Binbol and Wakayi (2010) who in various studies found out that the decade 1965 to 1974 had the lowest rainfall values. In fact Mortimore (1989) observed crop yield reduction of between 12, 4 and 7 percent for millet, sorghum and groundnut respectively in the 1973 drought.



For drought detection during the growing season, analysis of SPI 6 shows that the decade 1945 to 1954 recorded the highest frequency of 6 episodes. Ordinarily it would be expected that since the 1965 to 1974 decade had the highest frequency of 8 droughts, it should also reflect in the growing season drought analysis. However, what this simply means is that it is not the total annual precipitation in any location that determines crop yield, rather the time the precipitation is available for the crop use. This finding corroborated the earlier works of Adebayo and Adebayo (1997), Binbol and Zemba (2007), Adefolalu (1989) and Kowal and Andrew (1973).

Analysis was also carried out for drought duration in Sokoto and the result presented in table 2. The finding shows that Sokoto has a high rate of one year drought event, 10 for SPI 12 and 09 for SPI 6. This type of drought is considered mild not interms of magnitude but in terms of recovery. It simply means precipitation conditions was below long term mean for the location and the situation can be easily corrected the next year with improve precipitation. The 2 years to

Table 2: Drought Duration in Sokoto

Drought length	*Frequency SPI 12*	*Frequency SPI 6*
1 year	*10*	*09*
2 years	*08*	*04*
3 years	*00*	*01 (1950 – 1952)*
4 years	*01 (1966 – 1969)*	*02 (1942- 45, 1954 – 57)*
5 years	*01 (1971 – 1975)*	*00*

5 years droughts are referred to as stretched or back to back drought events. It means precipitation deficiency for the drought year could not be corrected with the next year's rainfall and so the dry conditions continue persistently for the number of years that constitute the drought length. Result in table 2 reveals that Sokoto had 08 and 04 2years back to back drought for SPI 12 and SPI 6 respectively. It was also observed that the longest drought stretch of 4 and 5 years occurred once each in the study period and particularly with SPI 12. This is possible because precipitation may fall below long term average and depending on it's timing, may be sufficient for agriculture.

Another drought characteristic analyzed for Sokoto was its severity/magnitude.

Table 3: Drought severity/Magnitude for Sokoto

SPI scale	*Frequency SPI 12*	*Frequency SPI 6*	*Severity*
0 to -.99	*26 (74.3%)*	*16 (57.1%)*	*Near normal*
-1.0 to -1.49	*05 (14.3%)*	*06 (21.4%)*	*Moderately dry*
-1.5 to -1.99	*01 (2.8%)*	*03 (10.7%)*	*Severely dry*
-2.0 to -3.0	*03 (8.6%)*	*03 (10.7%)*	*Extremely dry*

Analysis of results in table 3 shows that on the SPI 12 scale, 74% of the drought events in Sokoto were of magnitude less than -1.0 which is interpretated on the severity scale as near normal situation. Water deficiency associated with this type of drought is quite small so much so that it tend to have very little effect on agricultural activities. This explains why the growing season analysis using SPI 6 also shows that 57.1% of droughts affecting crops are the mild type. Droughts of severely dry and extremely dry conditions are quite few in Sokoto as shown in table 3.

Conclusion

The research recognized a high variability in precipitation in Sokoto and noted that with the imposition of a running average and the fitting of a trend line using the mean of two climatic periods, it became clear that rainfall is on a down ward trend in the study area. It is this high variability that account for the equally high number of observed drought episodes using the SPI 12 scale. The growing season drought analysis showed a reduction in drought episodes and further analysis revealed that more than half of such droughts were near normal situations. The research therefore concludes that given the SPI 6 findings, rainfed agriculture can conveniently be practiced in Sokoto with very little risk. The research noted that it is not the amount of water available to a plant per annum that determines its yield capability, rather the timing of the availability during the phenological growth stages of the plant is more important. It is therefore suggested that in order to attain food sufficiency, sustainability and stability in Sokoto, more researches should be geared towards trying to understand precipitation pattern via an indebt analysis of onset and cessation dates and most especially the incidents of dry spell occurrence in Sokoto.

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