A MEASURE OF DROUGHT – CROP RELATIONSHIP IN NORTHERN NIGERIA

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Abstract
The relationship between drought magnitude and crop yield was examined on 5 crops in 5 states of northern Nigeria. The states covered include Sokoto, Kaduna, Kano, Borno and Bauchi, while the crops investigated were Maize, Millet, Sorghum, Groundnuts and Cowpea. Secondary data on rainfall and crop yield in the selected locations were obtained for a period of 13 to 30 years from Agricultural Development Programme Offices (ADPs) of the states and Office of the Federal Bureau for Statistics. The rainfall data was subjected to the Standardized Precipitation Index (SPI) analytical technique to established drought occurrences and magnitude. The inferential statistical techniques of correlation and regression test were carried out on the crop yield and 12 months SPI values generated covering the same period. Results obtained shows that for Sokoto, Maize, Sorghum and Cowpea are affected positively by SPI values. This simply means that SPI values with high values of negative sign will affect the yield of Maize, Sorghum and Cowpea negatively in the location. Another major finding reveals that drought magnitude exhibit very little effect on the yield of Groundnuts in Sokoto and Kaduna states. Both findings were significant at the 0.05% confidence level. The implication of findings for crop cultivation in northern Nigeria was thoroughly discussed and appropriate recommendations proffered. The research concludes that drought occurrences in the studied states were mostly "Near Normal" droughts of very low magnitude (0.00 to -0.99) and they hardly occurred back to back thus its effect on crop – water need is quite minimal.
Keywords: Drought, Crop, Relationship, Measure, Correlation, yield, and Magnitude.
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INTRODUCTION

Drought has mostly been defined from a precipitation deficiency angle (Wilhite, 1996; Chopra, 2006; Murad and Saiful Islam, 2011). In classifying droughts according to types, the scientific literature recognized four main types. These are meteorological drought, agricultural drought, hydrological drought and socio-economic drought (see figure 1). Another classification method of drought based on duration identified four types. These are permanent, seasonal, contingent and invisible droughts. Ayoade (2004) explained permanent drought as that which exists in arid areas where in no season is precipitation enough to satisfy the water needs of plants. Crop cultivation in these regions can only be possible with irrigation. Seasonal drought occurs in areas with well defined wet and dry seasons, as in most parts of the tropics. The drought can be expected every year owing to seasonal changes in atmospheric circulation pattern. Rain fed agriculture is possible during the wet season, but irrigation must be introduced during the dry season. Contingent and invisible droughts result from the fact that rainfall is irregular and variable. Contingent drought occurs when rain fails to fall over a period of time. This type of drought is highly unpredictable; therefore it constitutes a serious threat to agriculture. Invisible drought as the name implies is less easily recognized unlike the other types that show on crop via wilting and reduced vegetative growth. Invisible drought occurs anytime the daily supply of moisture from the soil or falling precipitation fails to equal the daily water needs of plants. A slow drying of the soils result and crops fail to grow at their optimum rate. Crop yield is therefore less than the optimum. Seasonal drought occurs every year in areas characterized by well defined wet and dry seasons. Therefore, the term drought is usually used to describe the shortage in rainfall amount arising from rainfall variability over time (Ayoade, 2004).

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, Blaikie*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, death 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).

During, the 1970s and 1980s, West Africa experienced an extended period of drought which resulted in a 4 percent decline in the GDP of Nigeria and 6 percent for Niger in 1984. Also, about 250 million people are directly affected by land degradation and desertification. In addition, some one billion people in over 100 countries are at risk especially, those in very poor and often marginalized countries (Narasimhan and Srinivasan, 2005).

The savanna 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 leaving in its wake devastating effect on food production and the region's economy. The choice of Savanna region in Nigeria is predicated on 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 Savanna, agriculture is mostly dependent on the single maximum regime with high drought risk tendency. Previous works on droughts in the Savanna region of Nigeria have examined drought from various perspectives using different techniques including the Standardized Precipitation Index (SPI). However, its application has not gone beyond detecting drought years and magnitude (Akeh*et al.*, 2005; Binbol and Wakayi, 2010 and Binbol and Edicha, 2012). It is for these reasons that the current study is aimed at assessing the effect of drought class on crop yield in selected locations of the savannah region of Nigeria.

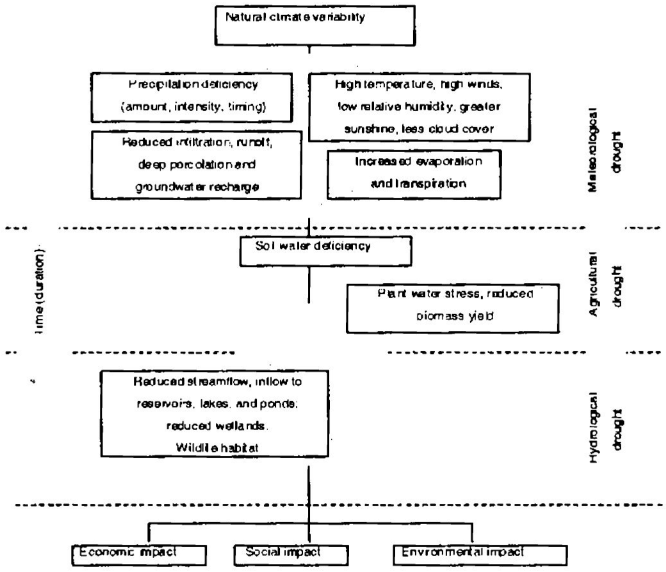


Figure 1 Sequence of drought occurrence and impacts for commonly accepted Drought types (Source National drought mitigation center. University of Nebraska, In WMO – No 1006, 2006)

MATERIALS AND METHODS

The study area

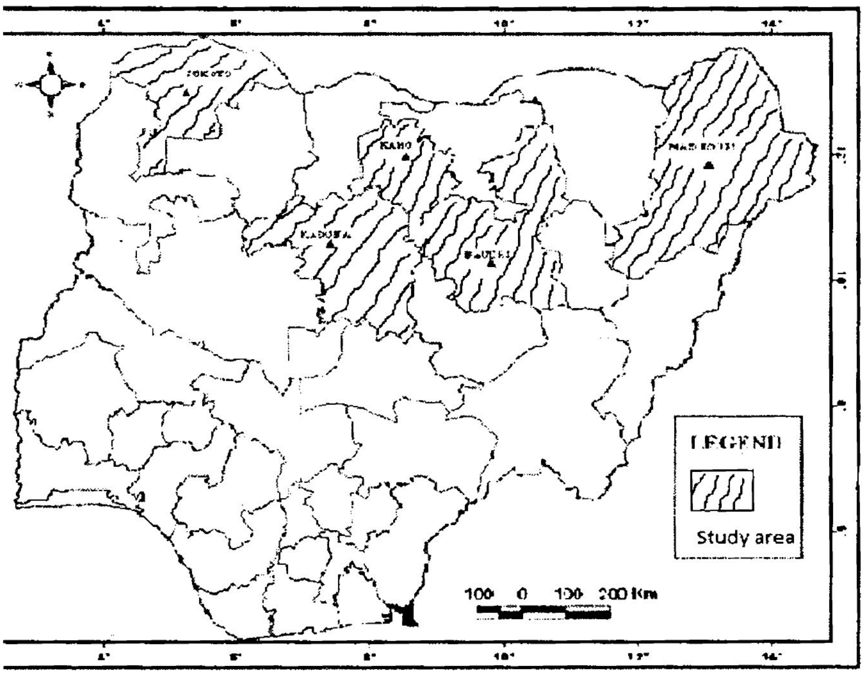
The Savanna region of Nigeria lies within the geo-coordinates of Latitude 6^0 27'N to 14^0 N and Longitude 2^0 44'E to 14^0 42'E (Figure. 2). It constitutes about 78% of the total landmass of the country covering about 730,000 km^2 (Oladipo, 1995). The region consists of nineteen states that form the 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 Savanna 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 Savanna. There, however, seems to be a general increase in the dry season period from 5 months in the southern part of the savanna to about 8 months in the extreme north.

›n also decreases northwards; this is ›me southern part of the Savanna region ıble maxima rainfall, while the Northern .ences a single maximum regime. Mean fall in the region ranges from 630.3mm in Savanna region, 720.8mm in the Sudan 'egion and 1,430.1mm in the Guinea gion (Oladipo, 1995).

re is generally high in the Savanna region; y due to the fact that the region lies within vhere the apparent movement of the sun is ;condly, the long period of dry season with the region means a clear sky without r. Sunshine pattern for the Savanna region ·neral increase in sunshine hours from the ıwards. Sunshine hour also varies with the Savanna region. Sun hours are high in /eraging 6.2 hours. It decreases gradually from then to a minimum of 3.9 hours in August when the Savanna region records its highest rainfall and cloud formation are more regular. From September the sunshine hours begin to increase again up to December.

A simplified soil zonation in the savanna region reveals 3 major classes of soils namely the northern zone of sandy soils, interior zone of laterite soils and zones of alluvial soils. The sandy soils cover the entire Sahel savanna and northern part of the Sudan savanna up to the southern parts of Kaduna. The soils having been formed under arid conditions are fine, sandy loam, friable, relatively easy to cultivate, little leached and therefore good for groundnuts and cotton. The zone of laterite soils covered the remaining part of the Sudan and Guinea savanna where pronounced wet and dry season encourage its formation (Iloeje, 2010).



: and Sources

ch project made use of secondary data. data in the form of monthly rainfall for selected stations in the study area were l from the archive of the Nigerian ;ical Services (Nimets) . Daily rainfall is ·iate in this situation because daily rainfall is most effective in determining soil potential and its ability to support or not. All data were collected for as long s consistent records allow. Annual crop ates on five crops (maize, millet, sorghum, groundnuts and cowpea) were obtained from Federal Bureau for Statistics, Abuja and the Agricultural Development Programme offices of concerned states. The states chosen are Sokoto, Kaduna, Kano, Borno and Bauchi. The data was used to test the efficacy of the SPI generated.

Methods of Data Analysis

The Standardized Precipitation Index (SPI) based on the probability of precipitation for any time scale, subject to usage by many drought planners was use to establish drought occurrence for this study. The understanding that a deficit of precipitation has different impact on ground water, reservoir storage, soil moisture, snowpack and stream flow led McKee *et al* (1993) to develop the SPI. The study considers rainfed crop yield as indicator of drought episodes, which captures easily period of rainfall below the mean. This study adopted a 12 months SPI for a seasonal drought index for the savanna region of Nigeria. This is because the 12 months accommodates the annual rainfall in the study area.

The equation is simply summed up as: SPI = (Xik – Xi) / σ i
Where σ = standardized deviation for the ith station
Xik = rainfall for the ith station and kth observation
Xi = 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 magnitude as presented in Tables 1 was used to determine drought intensity.

Table 1: 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)

The validity of SPI values generated for the study was also tested against crop yield in selected locations. Stations with unbroken records of yield for 5 major crops commonly grown in the savanna region were obtained from the Agricultural Development Programmeoffices of the selected states and the Federal Bureau for Statistic, Abuja. The crops for which data were available are Maize, Millet, Sorghum, Groundnuts and Cowpea and the stations for which crop yield data were available are Sokoto, Kaduna, Kano, Bornoand Bauchi. Table 2 provides a summary of stations and crop yield duration.

Inferential statistical technique of correlation analysis was carried out on the crop yield and the 12 month SPI values covering the same period. This is to enable the possible determination of relationships between calculated SPI values and crop yield in the various locations. This is necessary so as to enable a definite pronouncement on the efficacy and reliability of the 12 months SPI value as a drought assessment technique.

Table 2: Selected Stations and Crop Yield Duration

Station	Data collection point	Duration
Sokoto	Wurno	1993 to 2005
Kaduna	Samaru	1985 to 1999
Kano	Gezawa	1993 to 2005
Borno	Biu	1992 to 2005
Bauchi	Bauchi	1982 to 2010

RESULTS AND DISCUSSION

In order to establish the efficacy of the SPI 12 drought class calculated for each station, some selected stations with authentic and consistent records on crop yield were used to test the relationship between SPI values generated and crop yield (see Binbol, 2015 for details on SPI of stations under study). The stations with available records for the calculation are Sokoto, Kaduna ,Kano, Borno and Bauchi, while the crops considered are Maize, Millet, Sorghum, Groundnuts and Cowpea. The result of the correlation analysis is presented in Table 3.

The appriori expectation in this investigation is that low SPI values (high negative value) will result in low yield. Result in Table 3 Shows that for Sokoto station, maize, sorghum and cowpea are affected positively by SPI value. This simply means that low SPI values will affect the yield of maize, sorghum and cowpea in the location. The same was observed for all five crops under investigation in Kaduna SPI

Table 3: Correlation results for SPI 12 values and selected crops in the study area.

	Sokoto	Kaduna	Kano	Borno	Bauchi
Maize	.427	.384	.176	-.030	.333
Millet	-.292	.275	.182	.325	------
Sorghum	.403	.309	.268	.371	------
Groundnuts	-.583*	.599*	-.124	.398	.336
Cowpea	.273	.094	.272	.330	------

*Significant at 0.05% confidence limit
** significant at 0.01% confidence limit

effect on Groundnuts in Kaduna however exhibited a significant relationship which is significant at the 0.05% confidence level. Result for Sokoto further reveal that SPI class has little or no effects on Millet and Groundnuts production. Infact it was observed that Groundnut exhibited a significant degree of freedom from drought which is significant at the 0.05% level. The positive correlation recorded between SPI values and yield of maize, sorghum and cowpea are also weak and not significant. This goes to show that drought events and magnitude in Sokoto are mostly classified under the "near normal" group and they hardly occur in a back to back sequence. Water shortage for rain fed agriculture in one year is quickly addressed by normal rainfall in the next year. The highest drought magnitude for the period under study is –1.27 (occurring in the year 1995). Further observation shows that of the 13 years data used for this analysis, only 5 years were recorded as drought years of "near normal" situation.

Analysis of crop yield – drought relationship in Kaduna shows that drought events do not exert much negative influence on crop yield in the location except for groundnuts. Out of the 15 years analyzed (1985 to 1999), 7 years were "near normal" drought years with magnitude less than -1.00 on the SPI scale. Among the 5 crop examined, groundnuts seems to be the worst affected by drought incidence with a correlation coefficient of .599, which is significant at the 95% confidence limit. Out of the 13 years analyzed in Kano (1993 to 2005), only two years 1994 and 1995 were drought years. Therefore, it is not surprising that all crops studied exhibited positive relationship with SPI values except for groundnuts which showed a weak negative correlation with a correlation coefficient of -.124.

Analysis of the relationship between crop yield and SPI values in Borno shows that except for groundnuts which displayed a very weak negative relationship, all other crops examined exhibited a positive but very weak relationship with SPI values. Again, this could be explained based on the fact that for the period under examination 1992 to 2005 (14 years), only 5 years had negative SPI values classified as near normal condition. Analysis for Bauchi span a longer period 1982 to 2010 (30 years) and crop yield data was obtained on only maize and groundnuts. Result of analysis shows that both crops exhibited positive but weak relationship with SPI values generated. Again it was observed that of the 17 years with negative SPI values, most of them were near normal situations with magnitude less than -1.00 and only four were classify as "mild drought"

The observed different effects of SPI value on crop yield in different locations can thus be attributed to the fact that SPI values in most locations are of the near normal and mild drought class. These classes of drought are not associated with high water deficit. Mc Williams (2005) has shown that the effect of water deficiency depends on growth stages, deficiency level and environmental changes during drought conditions. He also opined that during later productive stages, yield losses from drought decreases as corn nears physiological maturity. In the same vein, he observed that to produce optimum grain sorghum yield, 23 to 25inches of water are required during the growing season. This water demand falls within the mean annual rainfall amount for stations under observation.

CONCLUSION

Longer rainfall periods were used to established drought occurrences for selected stations. This is necessary because the longer the rainfall record, the more accurate the findings. Thereafter, the period for which yield was available was then correlated with SPI 12 values generated for same duration. It was observed that drought occurrences within period analyzed were the "Near normal" type and does not occur on a back to back basis. Implication here is that even if a drought occurred mildly this year, enough rainfall the next year will correct it.

Out of the five crops studied, finding shows that Groundnut does not respond to negative SPI 12 value which denotes drought occurrences. Though the other crops Maize Millet, Sorghum and Cowpea showed a mild response to drought, its effect is statistically insignificant in locations studied. The research therefore concludes that low rainfall itself, which is evidence of drought occurrence may not necessarily affect crop yield. Instead as observed by Binbol, *et al* (2006) and Mc Williams (2005) the effect of water deficiency on the final yield of crops is determine by the phenelogical growth stage of the crop. This observation is aggravated by the deficiency level and environmental conditions.

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