DISCOVERY

58(320), August 2022

Characterization of drought and its impact on agriculture in two tropical stations in Nigeria

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To Cite:
Adaji JO, Ogolo EO. Characterization of drought and its impact on agriculture in two tropical stations in Nigeria. *Discovery*, 2022, 58(320), 907-913

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Peer-Review History
Received: 06 June 2022
Reviewed & Revised: 08/June/2022 to 14/July/2022
Accepted: 17 July 2022
Published: August 2022

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

Characterization of drought indices in two tropical climates located in the derived Savanna and southern Guinean Savannah region of Nigeria (Lokoja, Kogi State and Minna, Niger State) using Standardized Precipitation and Evapotranspiration Index (SPEI) for a period of 33 years, (1975- 2007), and the impact of drought on their agricultural activities was investigated. Climatic data such as temperature, rainfall, and potential evapotranspiration obtained from the Climatic Research Unit (CRU) were analyzed with Microsoft excel. The Standardized Potential Evapotranspiration Index (SPEI) was analyzed with R programming language. The non-parametric Mann-kendall test was used to observe the trends of the climatic variables on an annual scale using SPSS. The Mann-Kendall test revealed that the correlation of the trend parameter was not significant for Lokoja but significant for Minna. The SPEI showed that near-normal drought condition was ubiquitous in the study areas. This paper concluded that drought events have hazardous consequences on agricultural activities in Lokoja and Minna.

Keywords: Drought; SPEI; Trend Index; Anomaly Index; Characterization.

1. INTRODUCTION

Drought is an unpredictable and hazardous event that stems from the deterioration in precipitation over a protracted period resulting in colossal damage to the ecosystem (Polsky and Cash, 2005). Drought is a natural part of the climate and not a deviation from normal weather (Glantz, 2003, as cited (Polsky and Cash, 2005). (Gillette, 1950 as cited in Polsky and Cash 2005) described drought as a creeping phenomenon, therefore, accurate quantification of their characteristics in terms of intensity, frequency, length, and spatial scale is difficult to determine (Vicente-Serrano *et al*., 2010). Extensive severe drought occurring in Africa, India, North America, China, the USSR, Australia, and Western Europe has oftentimes revealed the susceptibility of both developed and developing countries of the world to drought (Wilhite and Glantz, 1985). The extent of drought can be compounded by certain climatic factors (such as high temperatures, strong winds, and low relative humidity) often correlated with its occurrence in many parts of the world (Polsky and Cash, 2005).

Thus, in the bid to effectively mitigate the fatal consequences of drought, we must possess a good knowledge of the various types of drought, the link between

the types of drought, and the practices of man that result in drought occurrence (Wang *et al*., 2016). According to Wilhite and Glantz (1985), there are four types of drought namely: meteorological drought, hydrological drought, agricultural drought, and socio-economic drought. The first three types explain how drought might be assessed as a physical phenomenon. The latter discusses drought in terms of supply and demand, monitoring the consequences of water shortages as they erupt through the socioeconomic system.

Drought indices are important aspects of surveillance and assessment of drought, as they clarify complicated interconnections between several climate parameters and climate (Tsakiris and Vangelis, 2005). Wilhite *et al*., (2000) stated that it is easier for scientists to convey climate anomaly knowledge to different consumer communities to quantitatively evaluate climate anomalies in terms of severity, period, frequency, and spatial extent.

A distinct drought indicator is not enough for describing intricate drought situations and influence, so, numerous drought-related variables and indices are needed to show diverse facets of alarming drought conditions. However, multivariate drought indices have been formulated lately to join numerous drought-related variables and indices for joint drought characterizations (Hao and Singh, 2015). Recent indices used for drought are the Reconnaissance Drought Index (RDI) (Tsakiris *et al*., 2008) and Standardized Evapotranspiration Index (SPEI) (Vicente-Serrano *et al*., 2010).

Many work have been done by individuals on drought characterization in the locations of study. However, none have used R program Package for SPEI drought characterization in the locations. This study aims to characterize drought in two tropical climates located in the derived Savanna and southern Guinean Savannah region of Nigeria (Lokoja, Kogi State and Minna, Niger State) using Standardized Precipitation and Evapotranspiration Index (SPEI) for a period of 33 years, (1975- 2007), and also to investigate drought impacts on their agricultural activities.

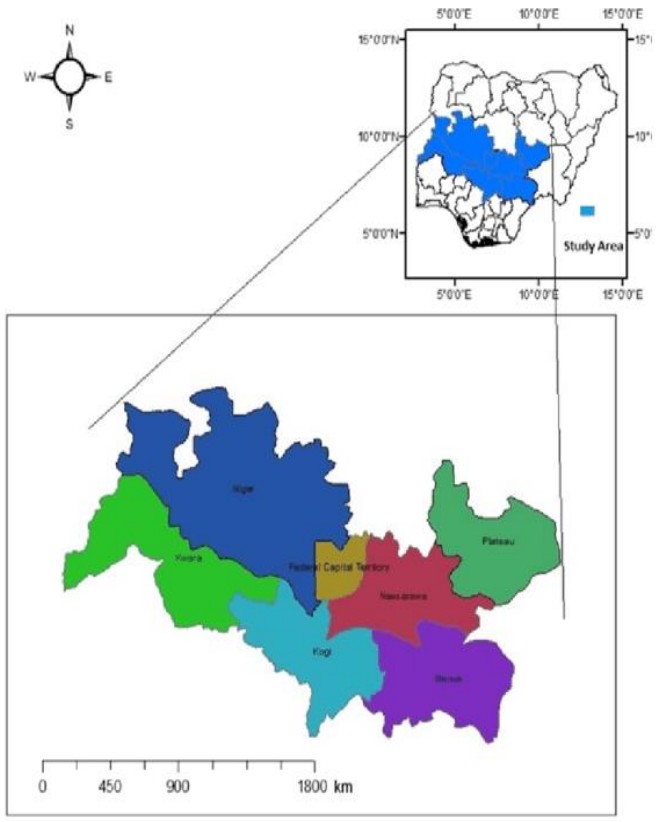

Figure 1: Map of North Central Nigeria. (Alhaji, 2017)

2. METHODOLOGY

The study was carried out in two cities located in the Derived Savanna and Southern Guinean Savannah region of Nigeria. The cities include Lokoja the state capital of Kogi State and Minna, the state capital of Niger state. Lokoja is situated at 7˚46'N - 7˚52' and longitudes 6˚38'E – 6˚48'E with a population of 196,643 in 2006 (Audu, 2012b). The tropical climate which is made up of wet and dry seasons and rainfall in the vegetation belt of the Guinean Savannah is prevalent in this area (Alabi, 2012). Alabi, (2012). The annual

precipitation record measures up to about 1150mm with 27.7°C mean annual temperature (Ukoje and Ibor, 2017). Lokoja has a relative humidity of 30% in the dry season and 70% during the rainy season. The rainy season commences in May and terminates in October (Alabi, 2012). The average daily wind speed is 89.9 km/hr and the average daily vapour pressure is 26 Hpa (Audu, 2012). Meanwhile, Minna is situated at latitude 09°36'45'' N and longitude 06°31'12''E. The population of Minna as of 2006 is 291,905 (Otaru and Abubakar, 2019). The annual mean temperature of Minna is 33.1°C with annual precipitation of 1209.7mm. Minna has an average annual relative humidity of 47.5%.

Data Collection

This study employed the use of Climatic Research Unit (CRU) data to obtain temperature, precipitation, and potential evapotranspiration data for the period of 33 years ranging between (1975 – 2007) for two tropical stations located in the derived savannah region of Nigeria. The two tropical stations are Lokoja the state capital of Kogi State and Minna, the state capital of Niger state. Lokoja is situated at 7°46'N - 7°52' and longitudes 6°38'E – 6°48'E with a population of 196,643 in 2006 (Audu, 2012b) while Minna is situated at latitude 09°36'45'' N and longitude 06°31'12''E. The population of Minna as of 2006 is 291,905 (Otaru and Abubakar, 2019).

Data Analysis

The Standardized Potential Evapotranspiration Index (SPEI) was obtained from the monthly precipitation and potential evapotranspiration data with the help of R programming language using the Thornthwaite equation and Microsoft excel.

Table 1: Defined Range Of Annual Scale Drought Level

Range	Condition
SPEI≤-2	**Extreme drought**
-2<SPEI≤-1.5	**Severe drought**
-1.5<SPEI≤-1	**Moderate drought**
-1<SPEI≤1	**Near Normal**
1<SPEI≤1.5	**Moderately wet**
1.5<SPEI≤2	**Severely wet**
SPEI≥2	**Extremely wet**

3. RESULTS AND DISCUSSION

Annual Drought Event and Rainfall Features in the Study Areas

The SPEI drought index value for 1, 6, and 12 months are shown in Figure 2 to Figure 4. For this study, the SPEI drought index value for the 6-month time scale which represent agricultural drought was discussed. The 6-month drought index value for Lokoja as shown in Figure 3a revealed that extreme drought occurred in 1982. Severe drought occurred in 1977, 1982-1984, 1989-1990, 1998, 2000, 2003, 2005, and 2007. Moderate drought events occurred in 1976-1977, 1981-1983, 1985, 1989-1990, 1993, 2000-2001, 2003 and 2005. Near Normal drought occurred in 1975-1982 and 1984- 2007. Moderately wet was seen in 1976-1979, 1989, 1990-1992, 1994, 1997-2000, 2002 and 2004-2007. Severely wet condition occurred in 1978-1979, 1987-1991, 1998-1999, 2004 and 2006-2007. The extremely wet condition was witnessed in 1999-2000, and 2004.

Meanwhile, as revealed in Figure 3b, Minna witnessed extreme drought condition in, 1983, 1987 and 2000 and 2005. Severe drought condition occurred in 1981, 1983-1985, 1987, 2002, 2004 and 2005. Moderate drought occurred in 1976-1977, 1980-1981, 1983-1986, 1988-1990, 1992, 2000, 2002 and 2004. Near normal condition occurred in all the years of the study period. Moderately wet condition occurred in 1975-1979, 1991-1992, 1994-1997, 1999-2001, 2003-2004 and2006-2007. Severely wet condition was witnessed in 1975-1978, 1991, 1994-1995, 2001, 2004 and 2006-2007. Extremely wet condition occurred in 1977-1978 and 2004.

Analysis from both locations of the study showed that throughout the study years, near-normal condition was prevalent for over 30 years with higher prevalence in Minna. Extreme drought and extremely wet conditions occurred more in Minna than in Lokoja. The above remark on drought events in Minna attests to the statement by Ideki and Weli, (2019) on the more proneness of Minna to drought incidence. However, severe drought occured more in Lokoja.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Drought Impact on Agricultural Activities

Agriculture which is an ancient occupation and one of the important sectors in the national economy is the major occupation in the study areas (Karimo and Major, 2017) and (Sule *et al*., 2020). There are various branches of agriculture, however, this study is focused on cropping and animal husbandry. Data of major crops grown throughout Niger State obtained for 10 years (1999-2008) from Niger State Agricultural Development Project (NSADP) are rice, maize, millet, sorghum, cassava, sweet potato, yam, sugar cane, Bambara groundnut, cowpea (beans), groundnut and soya beans (Sule *et al*., 2020), with similar crops grown in Lokoja (Olatunde, 2019). Olatunde (2019) however stated that millet and sorghum do not require much water for their germination.

As a well-known fact, drought poses a great threat to the growing of crops since there is a need for moderate and adequate moisture of the land for cultivation. Drought is most prevalent during the dry season and since the cultivation of crops takes place majorly during the wet season, the impact of dry season drought may be less alarming with the practice of irrigation systems. However, this study takes into cognizance the hazardous impact of drought during the planting season (rainy season). The study by Kangah (2004) noted that agricultural productivity is hinged on adequate and moderate rainfall. Therefore, drought events during the planting season is catastrophic as this will result in a low yield of the cereals and tuber crops (grown in the regions under study) that require moderate and adequate water for their growth. Prasad and Staggenborg (2008) mentioned that drought has a serious impact on the biochemical, physiological, and molecular constituents of photosynthesis.

Generally, the impact of drought on agricultural activities depends on the severity of the drought event. Extreme, severe and moderate drought events have more traceable impact on agriculture than the near normal drought event. Since the prevalence of near normal drought events in Lokoja and Minna according to the 6-month SPEI drought index value, drought impacts on agriculture in the study locations are minimal. The study by Eze *et al*., (2020) on assessment of drought and its implication on agriculture in Niger State, Nigeria revealed that crops yields were at their peak during near normal and mild wet events.

Animal husbandry also experiences the same harmful impact of drought as there is little or no water for rearing animals. The animals will die of thirst, grasses for grazing will not be readily available or will be less sufficient for the cattle and consequently, these may lead to the low production or death of these animals. Human labour which is one of the key components in agricultural productivity is affected as the environment becomes unconducive for optimal productivity of both human labour and animals due to this dilemma. More so, communal war could emerge due to the stress posed on limited streams and rivers by rural dwellers which in turn will affect agricultural activities.

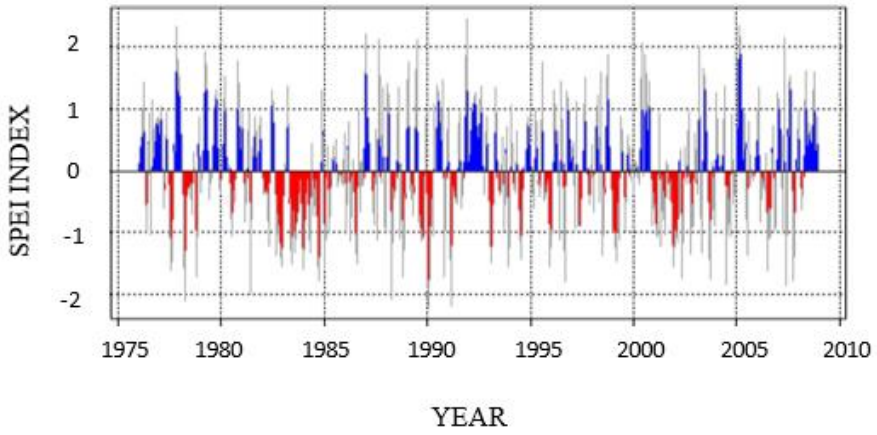

Figure 2a: 1-Month Time Scale SPEI Drought Index Value for Lokoja, Kogi State (1975-2007)

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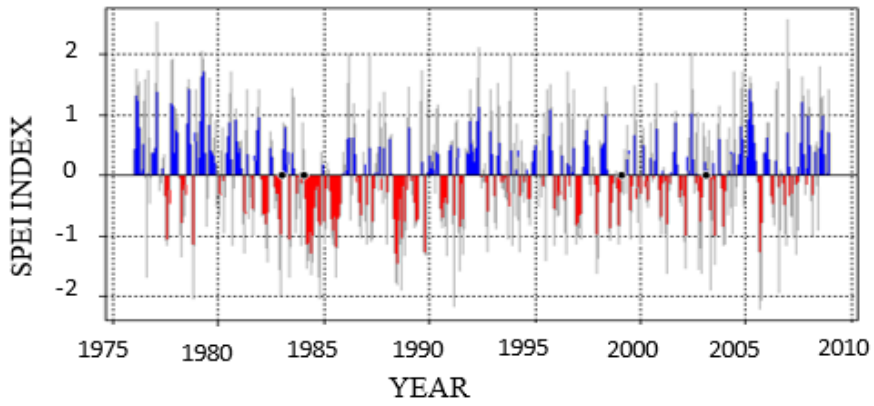

Figure 2b: 1-Month Time Scale SPEI Drought Index Value for Minna, Niger State (1975-2007)

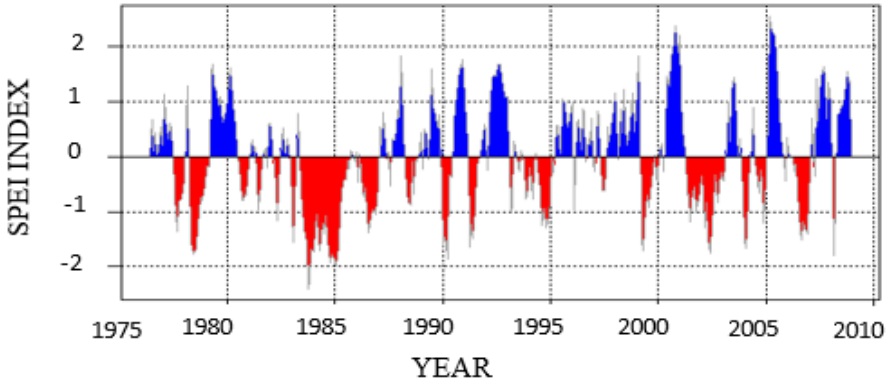

Figure 3a: 6-Month Time Scale SPEI Drought Index Value for Lokoja, Kogi State (1975-2007)

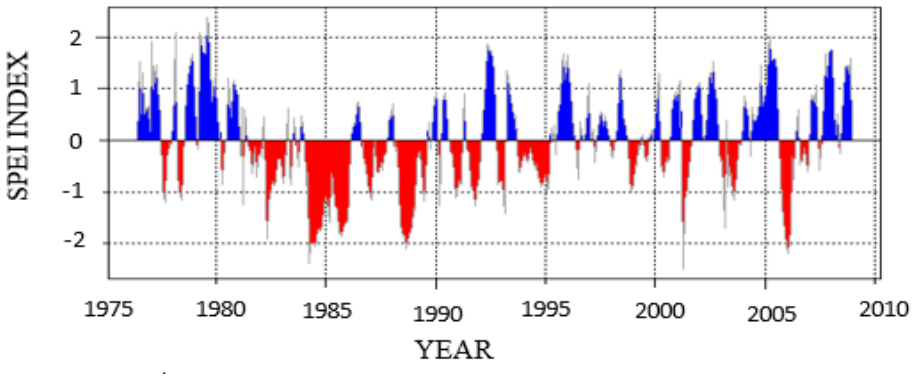

Figure 3b: 6-Month Time Scale SPEI Drought Index Value for Minna (1975-2007)

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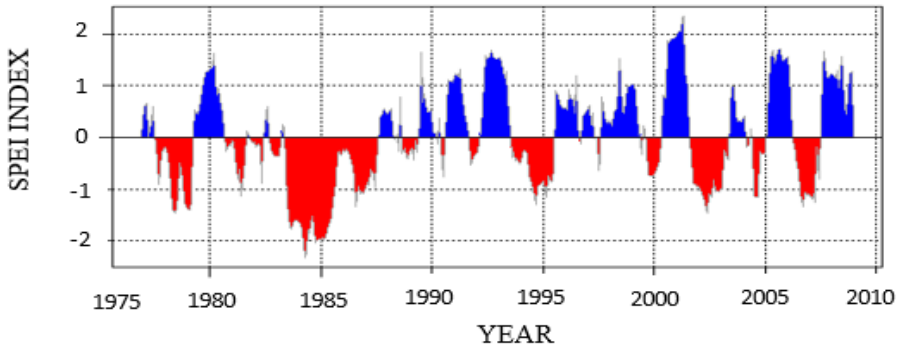

Figure 4a: 12-Month Time Scale SPEI Drought Index Value for Lokoja, Kogi State (1975-2007)

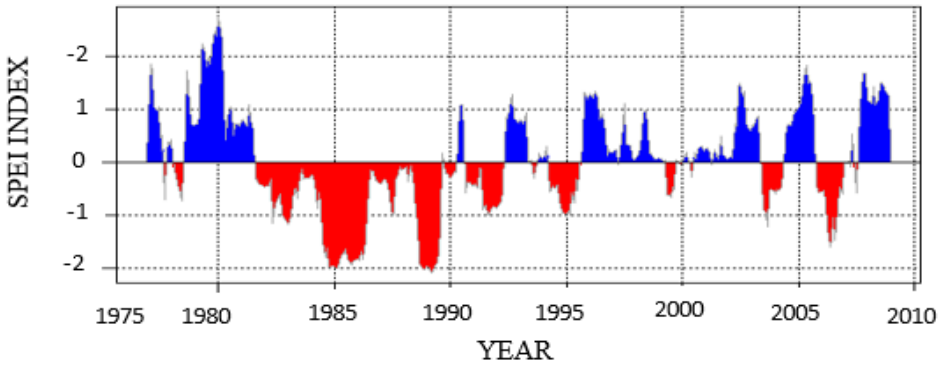

Figure 4b: 12-Month Time Scale SPEI Drought Index Value for Minna, Niger State (1975-2007)

4. CONCLUSION

In this study, drought indices were analyzed using the Standardized Precipitation Evapotranspiration Index in determining drought occurrence and its impact on the agricultural activities in two tropical locations in the Savannah region of Nigeria (1975-2007). 6-month SPEI time scale for the locations revealed near normal condition incidence was prevalent in the locations, during the period of study. The precipitation for both monthly and annual time scale for the locations witnessed a positive trend. The trend of monthly temperature for both locations understudy is negative while annual temperature trends are positive. Evapotranspiration trends for both locations are positive. The results of temperature and rainfall anomalies showed that both locations recorded positive trend in temperature and rainfall anomalies. It was also established that drought events have hazardous consequences on the agricultural activities in the study locations.

Funding

This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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