Nigerian Journal of Physics (NJP)
ISSN online: 3027-0936
ISSN print: 1595-0611
DOI: https://doi.org/10.62292/njp.v33i1.2024.194
Volume 33(1), March 2024

Evaluation and Impact Assessment of Meteorological Drought Characteristics over West Africa

[1]Ogolo, E. O., [1]Ojo, O. S. and *[2]Akinwande, D. D.

[1]Department of Physics, Federal University of Technology, Akure, Ondo State, Nigeria
[2]Department of Physics, Adeyemi University of Education, Ondo, Ondo State, Nigeria

*Corresponding author's email: akinwande_dolapo@yahoo.com

ABSTRACT

When a region receives little precipitation for an extended period of time, droughts occur. The environmental and socioeconomic effects it has make it one of the most devastating natural disasters that can happen to a location. For the purpose of enhancing early warning systems and lowering the risk of disasters caused by drought, research into the effects of meteorological drought characteristics on a location is crucial. Therefore, this study uses the Standard Precipitation Index (SPI) and Standard Precipitation Evapotranspiration Index (SPEI) to assess the effects of meteorological drought characteristics over West Africa. The study area includes West Africa's Saharan, Sahelian, and Sudanese climate zones, and Copernicus Service provided the meteorological information (temperature and precipitation). The data was based on four monthly time scales (3, 6, 12, and 24) and covered 42 years (1979-2021). The data were analyzed and the characteristics of the drought were assessed using SPI and SPEI. According to the results, there was extreme drought between the years 1982 to 1985 and year 2021. However, 1982 was the year with the highest incidence of drought, across nearly all the stations. Additionally, it was found that location 4 experiences drought continuously from 1982 to 2021, whereas all other locations experienced absence of drought for a short period of time. Comparing the SPI and SPEI results, SPI produced results for the drought analysis that were comparable to those of SPEI for each of the monthly time scales for all locations. Majority of the locations will likely experience drought every seven to ten years, with location 4 possibly experiencing at least a mild drought every year. Finally, this study suggests that, in light of the time-scales analysis and drought classification for each location, SPI and SPEI represent the most suitable measures for the region's drought monitoring.

Keywords:
Standard Precipitation Index,
Standard Precipitation Evapotranspiration Index,
Drought analysis,
Meteorological drought characteristics,
Temperature,
Precipitation.

INTRODUCTION

Drought is a natural phenomenon characterized by low rainfall or precipitation over a long period of time. A natural decrease in precipitation over an extended time, such as a season, year, or decade, results in drought, which is frequently accompanied by high temperatures, strong winds, and low humidity. (Yacoub and Tayfur, 2017). It is one of the major natural calamities that has a negative impact on people, river basins, water resource systems, and ecosystems (M. Wambua et al., 2014). Due to climate variability, droughts have increased in frequency and severity on a worldwide scale, with different regions experiencing them at varying periods and intensities (Shiru et al., 2020). Intensity and duration of rain, timing and characteristics of rainfall, including distribution of wet days during agricultural growth seasons, high winds, low relative humidity, and temperatures all significantly contribute to the occurrence of droughts (Mishra and Singh, 2010).

Drought is classified into four parts, which are meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. Meteorological drought is determined by the amount of dryness, the lack of rain, and the length of the dry period. Occurrence of meteorological drought leads to the occurrence of the other three types of drought. River basins can be affected by this drought either directly or indirectly, as a result, there is decrease in crop output, a rise in livestock and wildlife mortality rates, an increase in soil erosion and land degradation, as well as an increase in plant diseases and insect infestations (Wambua et al., 2014). The Sahel, a semiarid region of West Africa between the Sahara desert and the rainforest along the Guinea coast, had been suffering from a drought of exceptional severity since the late 1960s making it one of the poorest regions in the world (Mishra and Singh, 2010). According to the UN World Food Programme, which defined the situation as serious, Niger, Chad, eastern Mali, and northern Cameroon have all been severely impacted by the failing rains. Global warming is a major concern now because of how it influences the rate and timing of evapo-transpiration. Some areas of the world are likely to get wetter due to global warming, whereas those that are already dry are probably going to become drier. (Wambua et al., 2014).

For the planning and management of freshwater resources, drought assessment is of the utmost importance. Understanding the region's past droughts and their effects on the local environment is necessary for this (Mishra and Singh, 2010). As a result of increasing drought occurrence in West Africa, researchers have been working on highlighting the impact of drought using different drought indices. It is possible to utilize meteorological variables or parameters to monitor meteorological drought using drought indexes. Drought Indexes are numerical measurements that combine data from one or more variables (indicators), such as precipitation and evapotranspiration, into a single number to quantify the severity of drought. (Yacoub and Tayfur, 2017). These linked indexes are commonly based on temperature and precipitation data series. (Danandeh et al., 2020). Several drought indexes exist, they include normal Standardized Precipitation Index (normal-SPI), log normal Standardized Precipitation Index (log-SPI), Standardized Precipitation Index using Gamma distribution (Gamma-SPI), Percent of Normal (PN), the China-Z index (CZI), and Deciles (Yacoub and Tayfur, 2017), and the most recent standardized precipitation evapotranspiration index (SPEI). These DIs were used to launch drought relief initiatives and to calculate water resource shortages to gauge the severity of the drought (Yacoub and Tayfur, 2017).

The aim of this research is to evaluate the impact of meteorological drought characteristics over West Africa using SPI and SPEI indices. This is done by highlighting the characteristics of drought over a period of 42 years (1979-2021). The paper gave a brief description of the study area, followed by the methods, analysis of result and then the conclusion.

Study Area and Data

Study Area

West Africa as defined by the United Nation is the 16 countries of Benin, Burkina Faso, Cameroon, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. It is located on coordinate 13.5317°N, 2.4604°W and covers an area of 6.14 million km². It is bordered by the Atlantic Ocean on the west, the Gulf of Guinea on the south, and the Sahara and the Sahel, a semiarid belt-shaped transition region between the Sahara desert and the Sudanian Savanna, on the north. Due to the latitudinal oscillation of the Inter-tropical Discontinuity (ITD), West Africa exhibits a bi-modal rainfall pattern. The dry season begins in October and lasts until March of the following year, whereas the wet season begins in April and lasts until September (Eresanya et al., 2017). The dry Sahara to the north and east, which produces dry winds during the harmattan and the humid climate of the Atlantic to the south and west, which produces seasonal monsoons, have a significant impact on the climate and ecosystem (Figure 1).

West Africa can be split into five broad east-west bands that define the climate and vegetation from north to south or from the Sahara to the humid southern coast. The bioclimatic regions are known as the Saharan, Sahelian, Sudanese, Guinean, and Guinea-Congolian Regions. The Sahel and Sudan zones are the "harsh lands" of West Africa.' These arid and semi-arid lands include parts of present day Senegal, Mali, Northern Ghana, Mauritania, Niger, Northern Benin, Upper Volta, Chad, and Northern Nigeria. The term "harsh lands" describes an area of extreme environmental uncertainty, but it also describes as a place where man has learned to survive by taking advantage of its natural resources and its productive microenvironments, by cooperating with people who lead different but complementary lifestyles, and by creating biologically rich habitats where specific plants can grow (Scott, 1979). In West Africa, farmers and nomads frequently use these survival strategies; while they may not be particularly effective by western standards, they are very trustworthy (Scott, 1979). The study area covers the Sahara, Sahel and the Sudan zones.

The Sahara Desert to the north and the Sudanese Savannah to the south are divided by the West African Sahel region, which extends from the Atlantic Ocean eastward to Chad. The area is one of the poorest and most environmentally damaged in the world, and because temperature rises are expected to be 1.5 times higher than elsewhere in the world, it is also one of the locations that are most sensitive to climate change. Sahel is well known for the severe droughts that ravaged the region in the 1970s and 1980s (Nicholson, 2013). The Sahel region features a hot, semi-arid environment with high temperatures (average of 21.9°–36.4°C) all year long, a long, harsh dry season from October to May, and a short, erratic rainy season related to the West African monsoon.

The Sahara, also known as the Saharan Region, is the whole northern portion of West Africa and is made up of the Sahara Desert. It has several different desert environments, from sand sheets and dune fields to gravel plains, low plateaus, and rough mountains. Sahara records between 0 and 150 mm of rain fall on average each year. The Saharan region is the hottest big region on earth due to the high position of the Sun, the extremely low relative humidity, the lack of vegetation, and rainfall.

Sudan sits in the transitional zone between the humid, lush equatorial rainforest and the Sahelian arid desert environment. The range of the yearly average temperature is between 23 to 29 degrees. The coldest months have highs of 20 degrees Celsius, while the hottest months have highs of 30 degrees Celsius. Hay, forest cliffs, and gallery forests along the rivers are characteristics of Sudan. Desertification is a problem in the area due to the drought and livestock grazing.

Figure 1: West Africa bioclimatic regions

MATERIALS AND METHODS

Data collection

Many studies in climatology and related areas rely on long-term observations from precipitation stations. This data is necessary for analyzing climate variability and change (Trenberth, 2011). Monthly precipitation data are primarily used in drought analysis to specify the absence of precipitation at various time scales. These time ranges represent the consequences of drought on the ability to utilize various water supplies (Nosrati and Zareiee, 2011). The meteorological data (precipitation and temperature) used in this research were collected from Copernicus Service managed by The European Commission. Based on long-term recording data and a combined record period duration of 42 years (1979–2021), the monthly precipitation data of 12 stations across three climate zones in West Africa have been chosen. Four different time scales (3, 6, 12, and 24) were considered.

Standard Precipitation Index (SPI)

Standardized Precipitation Index (SPI) is a popular metric for describing meteorological drought on various timescales. The SPI is a multi-scalar probability indicator that determines the amount of precipitation lacking during periods of both wet and dry weather and permits drought monitoring at various timescales (McKee et al., 1993). It is the most widely used indicator for identifying and describing meteorological droughts worldwide. Due to its simplicity, monthly data requirement, and general acceptance on a larger scale, this index was recommended by the World Meteorological Organization as a starting point for meteorological drought monitoring and has been

utilized in numerous prior research (Danandeh et al., 2020).
SPI was developed by McKee et al., (1993), and described in detail by Edwards and McKee in 1997 (Edwards, 1997). The goal of SPI is to categorize precipitation into a single numerical number that may be compared across places with distinctly differing climates. Any location's SPI computation typically needs a long-term precipitation record for the relevant time period. After fitting the long-term data to a probability distribution, which is then transformed into a normal distribution, the mean SPI for the place and desired period is set to zero (Edward and McKee, 1997).
Using monthly input data, the SPI can be constructed for various time periods ranging from 1 to 36 months. The Index was designed to show that it is possible to simultaneously experience wet conditions on one or more time scales, and dry conditions at other time scales. Consequently, a separate SPI value is calculated for a selection of time scales. Strictly speaking, the SPI does not have a specific threshold, but a drought is regarded as drought when the SPI is −1.0 or lower (Kwak et al. 2016). Table 1 shows the drought category as classified by McKee et al. (1993) and Kwak et al. (2016).

Table 1: Drought intensity with SPI

SPI values	Drought category
0 to −0.99	Mild drought
−1.00 to −1.49	Moderate drought
−1.50 to −2.00	Severe drought
< −2.00	Extreme drought

SPI has been acknowledged as the standard index that should be used for quantifying and reporting meteorological drought on a global scale. However, given that it ignores changes in evapotranspiration, questions have been raised about the SPI's usefulness as a gauge of drought changes brought on by climate change. SPEI and other indexes that address evapotranspiration have been suggested.

Standard Precipitation Evapotranspiration Index (SPEI)

An expansion of the often used Standardized Precipitation Index (SPI) is the Standardized Precipitation Evapotranspiration Index (SPEI). When determining drought, the SPEI is intended to consider both precipitation and potential evapotranspiration (PET). Thus, in contrast to the SPI, the SPEI effectively measures the primary effect of rising temperatures on water demand.
Since its creation in 2010, a rising number of meteorological and hydrological researches have used the standardized precipitation evapotranspiration index (SPEI) (Beguería et al., 2014). Like the SPI, the SPEI can be calculated on a range of timescales from 1-48 months, it can determine the beginning and end of drought events as well as the severity of the drought based on its intensity and duration. Moreover, (Keyantash and Dracup, 2002) suggested that drought indices must be simply produced, statistically reliable, and have a transparent and understandable calculating process. Table 2 presents its classification according to the moisture state as stated by Quenum et al. (2019).

Table 2: Classification of moisture level with SPEI

SPEI values	Drought category
+2.0 and greater	Extremely wet
+1.5 to 1.99	Very wet
+1 to 1.49	Moderately wet
−0.99 to 0.99	Near normal
−1.49 to −1.0	Moderately dry
−1.99 to −1.5	Severely dry
Less to −2.0	Extremely dry

RESULTS AND DISCUSSION

The characteristics obtained in the SPI and SPEI method is mostly the same for each of the time-scales with extreme or severe drought occurrence in mostly all the years within 1979 to 2021. By both methods, 1982 was predicted to be the extreme drought year (Table 3). The frequency of occurrence as predicted by the two methods is the same for all time-scales. As seen in the table, the drought's magnitude ranges from 7.25 to 0.1, with 7.25 being the highest magnitude observed in timescale 3 of the SPI analysis. The smallest value across all timescales is 0.1 for both SPI and SPEI. It shows no discernible trend because the values increase and decrease year over year. However, there was an increase in the year 2021. It can be predicted that severe or moderate drought years might be experienced in location 1 every six to ten years.

Table 3: Characteristics of Droughts in West Africa as detected by SPI AND SPEI for location 1

Time-Scale	Characteristics	SPI	SPEI
3	Onset	1979	1979
	Duration	1979-2021	1979-2021
	Severity	Extremely dry in 1982 with magnitude of 7.25 Mild in 1979, 1985, 1998, 2005	Extremely dry in 1982 with magnitude of 4.0 Mild in 1979, 1985, 1998, 2005
	Frequency	Occurred throughout between 1979 and 2021	Occurred throughout between 1979 and 2021
	Cessation	No cessation	No cessation
6	Onset	1981	1981
	Duration	1981-2021	1981-2021
	Severity	Extremely dry in 1982 with magnitude of 5.9 Mild in 1981, 1985, 1988, 1989, 1995, 1998, 2014, 2015.	Extremely dry in 1982 with magnitude of 2.9 Mild in 1981, 1985, 1988, 1989, 1995, 1998, 2014, 2015.
	Frequency	Occurred frequently between 1981 and 2021	Occurred frequently between 1981 and 2021
	Cessation	Ceased in year 2019.	Ceased in year 2019.
12	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 4.8 and in 2021 with magnitude 2.4.	Extremely dry in 1982 and 2021 with magnitude of 2.3 in both years.
	Frequency	Mild in 1994, 1995, 1998, 2016. Occurred frequently between 1982 and 2021	Mild in 1994, 1995, 1998, 2016. Occurred frequently between 1982 and 2021
	Cessation	Ceased in 1989, 1999, and 2019.	Ceased in 1989, 1999, 2019
24	Onset	1983	1983
	Duration	1983-2021	1983-2021
	Severity	Extremely dry in 1985 and 2021 with magnitude of 2.2 and 2.4 respectively. Mild in 1990, 2011, and 2019.	Extremely dry in 1985 and 2021 with magnitude of 2.2 and 2.0 respectively. Mild in 1990, 2011, and 2019.
	Frequency	Occurred frequently between 1983 and 2021	Occurred frequently between 1983 and 2021
	Cessation	Ceased in 1995, 1996, 1999, 2000, 2004, 2005, 2006, 2016, and 2019.	Ceased in 1995, 1996, 1999, 2000, 2004, 2005, 2006, 2016, and 2019.

Table 4: Characteristics of Droughts in West Africa as detected by SPI and SPEI for location 2

Time-scale	Characteristics	SPI	SPEI
3	Onset	1981	1981
	Duration	1981-2021	1981-2021
	Severity	Extremely dry in 1982 with magnitude of 3.1 Mild in 1985, 1986, 1987, 1988, 1990, 1995, 1998, 2008, 2016.	Extremely dry in 1982 with magnitude of 2.9 Mild in 1985, 1986, 1987, 1988, 1990, 1995, 1998, 2008, 2016.
	Frequency	Occurred frequently between 1981 and 2021	Occurred frequently between 1981 and 2021
	Cessation	Ceased in 1979, 1980, 1989, 1994, 1999, 2002, 2003, 2004, 2005, 2014, and 2015.	Ceased in 1979, 1980, 1989, 1994, 1999, 2002, 2003, 2004, 2005, 2014, and 2015.
6	Onset	1981	1981
	Duration	1981-2021	1981-2021
	Severity	Extremely dry in 1982 with magnitude of 2.7 Mild in 1981, 1986, 1987, 1988, 2006, 2007, 2014, 2015, 2020, and 2021.	Extremely dry in 1982 with magnitude of 2.7 Mild in 1981, 1986, 1987, 1988, 2006, 2007, 2014, 2015, 2020, and 2021.
	Frequency	Occurred frequently between 1981 and 2021	Occurred frequently between 1981 and 2021
	Cessation	Ceased in 1974, 190, 1989, 1994, 1995, 1998, 1999, 2013, 2016, and 2019.	Ceased in 1974, 190, 1989, 1994, 1995, 1998, 1999, 2013, 2016, and 2019.
12	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 2.4 Mild in 1994, 2014, 2015, and 2016.	Extremely dry in 1982 with magnitude of 2.4 Mild in 1994, 2014, 2015, and 2016.
	Frequency	Occurred frequently between 1982 and 2021	Occurred frequently between 1982 and 2021
	Cessation	Ceased in 1979, 1980, 1989, 1995, 1998, 1999, and 2019.	Ceased in 1979, 1980, 1989, 1995, 1998, 1999, and 2019.
24	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Severely dry in 2002 with magnitude of 1.8 Mild in 1990, 1991, 2011, 2012.	Severely dry in 2002 with magnitude of 1.8 Mild in 1990, 1991, 2011, 2012.
	Frequency	Occurred frequently between 1982 and 2021	Occurred frequently between 1982 and 2021
	Cessation	Ceased in 1979, 1980, 1995, 1996, 1999, 2000, 2004, 2005, 2006, and 2016.	Ceased in 1979, 1980, 1995, 1996, 1999, 2000, 2004, 2005, 2006, and 2016.

The characteristics obtained in the SPI and SPEI method are mostly the same for each of the time-scales. Extreme/severe drought was recorded in mostly all the years within 1981 to 2021. However, this location has more years with absence of drought compared to location1. By both methods, 1982 was predicted to be year with the highest level of drought. The frequency of occurrence as predicted by the two methods is the same for all time-scales (Table 4). As seen in the table, the drought's magnitude ranges from 3.1 to 0.1, with 3.1 being the highest magnitude observed in timescale 3 of the SPI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1. This shows no describable trend because the values increase and decrease year over year. It can be predicted that extreme or severe drought years might be experienced in location 2 every five to eight years.

The characteristics obtained in the SPI and SPEI method is mostly the same for all the time-scales. Extreme drought was recorded in year 1982 under SPI and SPEI. From both methods, 1982 was predicted to be year with the highest level of drought. The frequency of occurrence as predicted by the two methods is the same for all timescales. As seen in the table, the drought's magnitude ranges from 7.5 to 0.1, with 7.5 being the highest magnitude observed in timescale 3 of the SPI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1. It shows no particular trend because the values increase and decrease year over year though the year 2021 experienced a slight increase in timescale 12 and 24. It can be predicted that drought might be experienced in location 3 every to seven to ten years (Table 5).

The characteristics obtained in the SPI and SPEI method is mostly the same for all the time-scales with extreme or severe condition of drought occurrence in 1982, 1984 and 2021. By both methods, 1982 was predicted to be the highest drought year in time-scale 3 and 6 while 1984 and 2021 was predicted to be the highest drought year in time-scale 12 and 24. The frequency of occurrence as predicted by the two methods is the same for all time-scales. The drought's magnitude for this location ranges from 4.5 to 0.1, with 4.5 being the highest magnitude observed in timescale 3 of the SPEI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1. It shows no describable trend because the values increase and decrease year over year, though the year 2021 experienced a slight increase in timescale 12 and 24. The magnitude of drought experienced in this location is lesser compared to the other three locations. Therefore, it can be predicted that the location is not likely to have extreme drought in 37 years. However, moderate or mild condition can be recorded every year (Table 6).

The characteristics obtained in the SPI and SPEI method is mostly the same for each of the time-scales with severe or moderate drought occurring in mostly all the years within 1971 to 2021. By both methods, 1982 was predicted to be year with extreme drought. The frequency of occurrence as predicted by the two methods is the same for all time-scales. The drought's magnitude for this location ranges from 7.5 to 0.1, with 7.5 being the highest magnitude observed in timescale 3 of the SPI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1 which shows no describable trend because the values increase and decrease year over year, though the year 2021 experienced a slight increase in timescale 24. It can be predicted that extreme/severe drought years might be experienced in station 1, HAR zone every eight to ten years.

In station 3 of SAH zone, the characteristics obtained in the SPI and SPEI method is mostly the same for each of the time-scales with severe/moderate drought occurrence in mostly all the years within 1982 to 2021. The years with highest level of drought as predicted by the two methods are 1982, 1983, 1984, and 1985. The frequency of occurrence as predicted by the two methods is the same for all time-scales. The drought's magnitude for this location ranges from 2.3 to 0.1, with 2.3 being the highest magnitude observed in timescale 24 of the SPI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1. Also this shows no describable trend because the values increase and decrease year over year. It can be predicted that moderate drought years might be experienced in this station every six to eight years.

In station 3 of SDN zone, the characteristics obtained in the SPI and SPEI method is mostly the same for each of the time-scales with extreme or severe drought occurrence in mostly all the years within 1982 to 2021. The years with highest level of drought as predicted by the two methods are 1982, and 1985. The frequency of occurrence as predicted by the two methods is the same for all time-scales. The drought's magnitude for this location ranges from 2.5 to 0.1, with 2.5 being the highest magnitude observed in timescale 3 of the SPI analysis. The smallest value across all timescales for both SPI and SPEI is 0.1. It shows no describable trend because the values increase and decrease year over year. It can be predicted that moderate drought years might be experienced in this station every six to eight years (Supplementary tables A-H).

Table 5: Characteristics of Droughts in West Africa as detected by SPI and SPEI for location 3

Time-scale	Characteristics	SPI	SPEI
3	Onset	1979	1979
	Duration	1979-2021	1979-2021
	Severity	Extremely dry in 1982 with magnitude of 7.5 Mild in 1979, 1998, 2005	Extremely dry in 1982 with magnitude of 4.1 Mild in 1979, 1998, 2005
	Frequency	Occurred frequently between 1979 and 2021	Occurred frequently between 1979 and 2021
	Cessation	Ceased in 1980	Ceased in 1980
6	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 6.0 Mild in 1981, 1988, 1989, 1995, 2014, 2015.	Extremely dry in 1982 with magnitude of 2.9 Mild in 1981, 1988, 1989, 1995, 2014, 2015, 2019.
	Frequency	Occurred frequently between 1979 and 2021	Occurred frequently between 1979 and 2021
	Cessation	Ceased in 1979, 1980, 2019.	Ceased in 1979, 1980.
12	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 5.4 Mild in 1990, 1998, 2014, 2015, and 2016.	Extremely dry in 1982 with magnitude of 2.3 Mild in 1990, 1995, 1998, 2014, 2015, and 2016.
	Frequency	Occurred frequently between 1982 and 2021	Occurred frequently between 1982 and 2021
	Cessation	Ceased in 1979, 1980, 1981, 1989, 1995, 1999, and 2019.	Ceased in 1979, 1980, 1981, 1989, 1999, and 2019.
24	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1985 and 2021 with magnitude of 2.2 and 2.4 respectively. Mild in 1990, 2007, 2012 and 2019.	Extremely dry in 1985 and 2021 with magnitude of 2.2 and 2.1 respectively. Mild in 1990, 2007, 2012 and 2019.
	Frequency	Occurred frequently between 1982 and 2021	Occurred frequently between 1982 and 2021
	Cessation	Ceased in 1980, 1981, 1989, 1992, 1995, 1996, 1999, 2004, 2005, 2006, 2016, and 2020	Ceased in 1980, 1981, 1989, 1992, 1995, 1996, 1999, 2004, 2005, 2006, 2016, and 2020

Table 6: Characteristics of Droughts in West Africa as detected by SPI and SPEI for location 4

Time-scale	Characteristics	SPI	SPEI
3	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 2.8 Mild in 1985, 1992, 1993, 2003, 2004, 2005, 2009, 2016, 2017, and 2018.	Extremely dry in 1982 with magnitude of 4.5 Mild in 1985, 1992, 1993, 2003, 2004, 2005, 2009, 2016, 2017, and 2018.
	Frequency	Occurred throughout between 1982 and 2021	Occurred throughout between 1982 and 2021
	Cessation	No cessation.	No cessation.
6	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Extremely dry in 1982 with magnitude of 2.4 Mild in 1985, 1991, 1992, 1996, 1997, 2011, 2015, 2016, and 2017.	Severely dry in 1982 with magnitude of 1.5 Mild in 1985, 1991, 1992, 1996, 1997, 2011, 2015, 2016, and 2017.
	Frequency	Occurred throughout between 1982 and 2021	Occurred throughout between 1982 and 2021
	Cessation	No cessation	No cessation
12	Onset	1982	1982
	Duration	1982-2021	1982-2021
	Severity	Severely dry in 1984 and 2021 with magnitude 1.6 and 1.5 respectively. Mild in 2014 and 2017.	Severely dry in 1984 and 2021 with magnitude 1.6 and 1.5 respectively. Mild in 2014 and 2017.
	Frequency	Occurred throughout between 1982 and 2021	Occurred throughout between 1982 and 2021
	Cessation	No cessation	No cessation
24	Onset	1984	1984
	Duration	1984-2021	1984-2021
	Severity	Severely dry in 1984 with magnitude 1.5 and moderately dry 2021 with magnitude 1.4. Mild in 2014, 2015, 2016 and 2017.	Severely dry in 1984 with magnitude 1.5 and moderately dry 2021 with magnitude 1.3. Mild in 2014, 2015, 2016 and 2017.
	Frequency	Occurred throughout between 1982 and 2021	Occurred throughout between 1982 and 2021
	Cessation	No cessation	No cessation

CONCLUSION

The work studied the impact of drought characteristics in some locations in West Africa using SPI and SPEI indices and the following conclusions were gotten from the result of the work:

1. SPI produced similar results of the drought analysis as SPEI for all locations
2. In the monthly period (time-scales) drought analysis; SPI and SPEI make similar predictions for all the stations.
3. Most of the locations experienced extreme drought in 1982, making 1982 the year with the highest drought occurrence.
4. Generally, more droughts were experienced in the eighties than in the nineties.
5. The drought did not follow any pattern. The values fluctuate over time, with a few locations showing a slight increase in 2021
6. Although the values are within the same ranges of drought intensity, SPI recorded higher values than SPEI.
7. Most locations experienced severe drought in 2021 as a result of the increase in the drought intensity in the year 2021 as recorded by SPI and SPEI.
8. Stations in the same location/zone experienced similar characteristics.
9. There was no cessation of drought in location 4 since its onset in 1982. Therefore, there is a possibility of drought occurring in location 4 every year while the other locations may experience drought every seven to ten years.

RECOMMENDATION

Due to their similar predictions in each category of drought occurrences, the indices SPI and SPEI represent the most appropriate measures for the region's drought monitoring, according to the time-scales analysis and drought categorization for each location. Climate change can be predicted to cause places that are currently experiencing mild or moderate drought to become more severe in the future, and the total impact of drought in West Africa will increase. It is therefore important that assessment of meteorological drought characteristics in West Africa using available data be done more frequently in order to explore its impact.

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