PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 24 (4) 713-717 April 2020

Evaluation of Different Rainfall-based Drought Indices Detection of Meteorological Drought Events in Imo State, Nigeria

[1*]EKWEZUO, CS; [2]MADU, JC

[1]Department of Geography, University of Nigeria, Nsukka
[2]Department of Zoology and Environmental Biology, University of Nigeria, Nsukka
**Corresponding Author Email: chukwudi.ekwezuo@unn.edu.ng*

ABSTRACT: Drought Indices are extensively adopted as a drought detection and monitoring tool in all climatic regions. This study assesses and compares the performance of four rainfall based drought indices, Deciles index (DI), Percent of Normal Index (PNI), Standardized Precipitation Index (SPI) and Z-score Index (ZSI) in detection and classification of drought events in Imo state , a humid environment of Nigeria from (1982 to 2016). The result shows that droughts do occur in humid climatic region of Nigeria. The various indices differ in their detection and classification of drought events in the study area. However, they classified 2007 and 2008 as the year with the most severe drought event in the state. There is high correlation ($r > 0.70$) among the four indices, with ZSI and PNI showing the highest relationship to SPI ($r = 0.97$). The differences observed among the drought indices in detecting drought events in the study area can be reduced by using multiple drought indices in addition to the use of SPI in drought assessments especially in Nigeria since technological advancement in drought monitoring software's has made it easier. Also it is worthwhile to research on why drought detection varies with indices.

DOI: https://dx.doi.org/10.4314/jasem.v24i4.25

Dates: Received: 09 February 2020; Revised: 11 March 2020; Accepted: 22 March 2020

Keywords: Drought assessment, Rainfall-based drought indices, humid environment, Imo state, Nigeria.

Detection of extreme rainfall conditions is critical to the assessment and understanding of environmental changes in a given location. Extreme rainfall events occur around the tails of a given time series and excesses or deficit of its amount leads to wet and dry events. Prolong dry event leads to drought which is a period of below normal rainfall and water scarcity. Researches on drought tend to concentrate on rainfall marginal areas, whereas increasing rainfall vagaries with episode of dry spell and drought events in addition to episodes of flood events occurring in some years has been observed in Imo state. This study used PNI, SPI, ZSI and DI to detect the occurrence of drought in Imo state a tropical rainforest climate. Because of the humid nature of our study area, studies on drought occurrence seem lacking even though its impact is widely felt across the state unlike flood events. Drought events is characterised by a gradual beginning which makes its detection hard to perceive till its impact becomes noticeable on different sectors of the ecological and economic units. Below normal rainfall has been identified as the primary cause of drought with negative impact on health, livelihoods, agricultural productivity and the environment in its totality. It is seen as part of rainfall variability which occurs in any climate type ranging from deserts to tropical rainforests (World Meteorological Organization and Global Water Partnership (WMO and GWP, 2016)). Its definitions has always varied in respect to the purpose and discipline of its application, e.g. to the agriculturist his interest is in agricultural drought due to reduction in soil moisture, to the hydrologist, reduction in stream flow results in hydrological drought etc and socio-economic droughts Drought indices are used to detect and characterise drought events. These are representations of drought severity and magnitudes using numeric values of different time series inputs (WMO and GWP, 2016). Examples of these indices include: the Bhalme and Mooly Drought Index (BMDI), China-Z index (CZI), Decile Index (DSI), Modified China-Z index (MCZI), National Rainfall Index (RI), Palmer Drought Severity Index (PDSI), Percent of Normal Index (PNI), Rainfall Anomaly Index (RAI), Standardized Precipitation Index (SPI), Statistical Z-score and others (Salehnia *et al.,* 2017). These indices vary in the required input parameters and often give different result for a particular location and time. In addition drought research and mitigation groups adopt different indicators and indices as their assessment tool, thereby making comparison difficult. To bring consensus to this problem, SPI was recommended by WMO as the default drought monitoring tool to be used across all droughts monitoring and assessment studies (WMO and GWP, 2016). This has made it easier to evaluate the detection and degree of drought events across

**Corresponding Author Email: chukwudi.ekwezuo@unn.edu.ng*

different locations and time scales. Several authors have attempted to appraise different drought indices detection and representation of drought phenomena in different study area. For example Morid *et al*., (2006) show that the responsiveness and sensitivity to drought intensification tend to differ between DI and EDI in Iran,. CZI, SPI and ZSI have been reported to be effective for drought monitoring in four locations of China (Wu *et al,* 2001). Byakatonda *et al*., (2018) observed that SPI and SPEI can be used to detect droughts in Botswana, even though the severity of drought was overestimated by SPI in dry winter season. Oloruntade *et al*., (2017) observed a relatively high relationship between SPI and SPEI detection of meteorological droughts in the Niger-South Basin, Nigeria. Other studies such Javan *et al.,* (2016) and Bakheit (2017) observed varying results amongst the drought indices in their study. Thereby, suggesting the utilisation of the best fit indices in their respective study area. The differences and similarities in the performance of these drought indices in different locations raises serious problem on their applicability especially in Nigeria, where cases of drought occurrence have been reported (Oladipo, 1993; Okeke and Okeola, 2019). Despite the numerous studies on droughts in Nigeria, such studies are still lacking in Imo state and other tropical rainforest areas of Nigeria. Thus, this study used four rain-based indices (PNI, SPI, ZSI and DI) to detect the occurrence of drought in Imo state, Nigeria.

MATERIALS AND METHODS

Data: This study utilised daily precipitation amount from January 1982 to December 2016 for Owerri weather station from the archive of the Nigerian Meteorological Agency, Oshodi. It is the only weather station in Imo state.

The Study Area: Imo state, Nigeria is used as a case study. It is situated geographically between Latitude 4°45′ and 7°15′ North of the equator and Longitude 6°50′ E and 7°25′ E of the Greenwich meridian. The state occupies a total area of ~5,100 km^2 and is made up of 27 Local Government Councils with Owerri as the administrative capital. It is bounded to the east and north by Abia state, Anambra to the northwest and Rivers state on the southern part. The state falls within the Af (Tropical rainforest) climate of Koppen's classification, with two distinct seasons namely the rainy and dry seasons. It has an annual rainfall of ~2500 mm in the southern towns and ~2200 mm in the north. A greater percentage of its population depend on rainfall dependent activities for their livelihood. They cultivate plants and crops such as *Elaeis guineensis* (Oil palm), *Milicia excelsa* (Iroko), *Treculia africana* (African bread fruit), *Mangifera indica* (Mango tree), *Citrus spp* (Oranges of various types), *Bambussa spp* (Bamboo tree), yam, cassava, maize, potatoes, banana, plantain and coconut are grown in the area.

Fig 1. Imo State showing the Local Government Areas

Calculation of PNI, DI, SPI and ZSI: PNI (Willeke *et al.,* 1994) was calculated by dividing each year's rainfall by the mean rainfall for the time period. After which, the obtained quotient is multiplied by 100.

Decile Index (Gibbs and Maher, 1967) is calculated by simply sorting and ranking the rainfall values for each year into percentiles. Years with the lowest 40% of the ranked precipitation record are classified as drought years.

SPI (Mckee *et al.*, 1993) uses only rainfall to compute its value. It measures the standardized departure that the observed precipitation on a given time scale deviates from the long-term average rainfall. It is the standard drought index used in monitoring drought (WMO and GWP, 2016).

Z-Score index is calculated by subtracting individual (yearly) rainfall values from their climatology, divided by the series standard deviation. It is a relatively unknown as a drought index. Salehnia *et al.,* (2017), Wu *et al.,* (2001) and others have used it in their studies. The scale for interpreting the result from the above listed indices is shown in Table 1.

Table 1: *Scale for detecting and classifying drought in the Study*

Drought Category	PNI	DI	SPI	ZSI
Weak	70-80	4	*-0.5 to -0.99	< -0.52
Moderate	55-70	3	-1.0 to -1.49	-0.52 to -0.84
Severe	40-55	2	-1.5 to -1.99	-0.84 to -1.25
Extreme	<40	1	< 2	< -1.25

**SPI value - 0.5 to -0.99 are regarded as dry spell*

Meteorological Drought Monitoring software package (MDM) (https://www.agrimetsoft.com) was used to derive the drought classification for the different indices. The degree of association between the droughts indices were calculated using Pearson correlation analysis.

RESULTS AND DISCUSSION

Identification of Meteorological Drought Events in Owerri, Imo State, Nigeria: Figure 2 shows different drought events in Imo state as detected by the four drought indices. Years that fall below the no drought line are classified as drought years with their respective severity. Figure 2a-d shows the historical variability of the four drought index in detecting drought events in our study area. PNI depicts six drought events in 1983, 1998, 2004, 2007, 2008 and 2016, while SPI detects three droughts events in 2007, 2008 and 2016. Twelve years (1983, 1987, 1998, 2002, 2003, 2004, 2007, 2008, 2012, 2014, 2015 and 2016) were detected by ZSI and fourteen drought years (1983, 1986, 1987, 1993, 1998, 2002, 2003, 2004, 2007, 2008, 2012, 2014, 2015 and 2016.) were detected by DI.

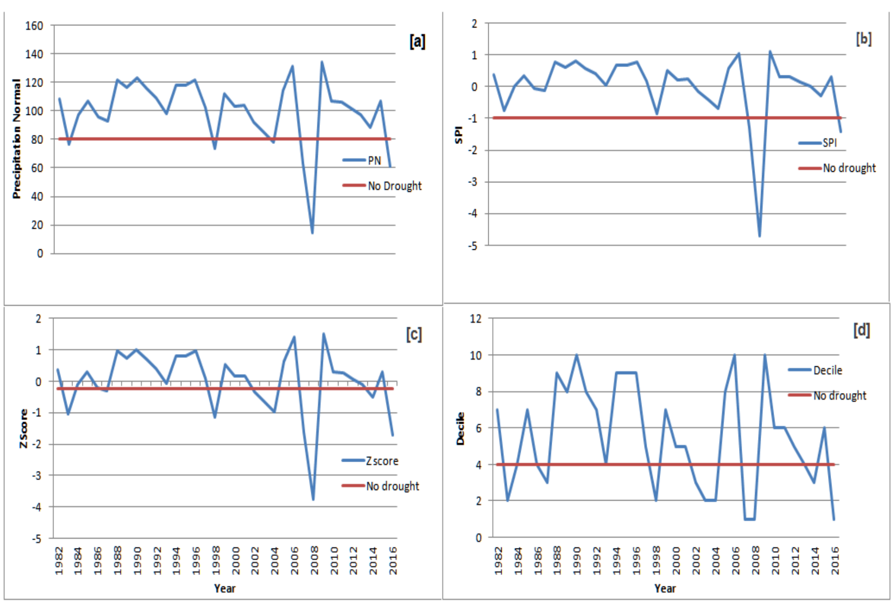

Fig 2 PNI, SPI, ZSI and DI detection of historical meteorological drought events in Owerri, Imo state

The occurrence of drought events in Imo state has been speculated by a related study (Ogunrinde *et al.,* 2019) on the occurrence of drought events across all climate zones in Nigeria. This implies that the possibility of drought and prolong dry spell together with their associated impacts should be adequately incorporated into the state emergency management strategy and water resource plan. The four indices classified 2008 as the year with the most severe drought events within the study period. Relative Occurrence of Meteorological Drought Events in Imo state, Nigeria: Detection and severity of drought incidences by the different rainfall based drought indices in Imo state is shown in Table 2. The number of years with drought events ranges from fourteen (DI) to three (SPI).

Table 2: *Detection and severity of drought incidences by the different rainfall based drought indices in Imo state*

	Number of Years and % of Occurrence					
Drought Index	Extreme	Severe	Moderate	Weak	Drought	No drought
PNI	1(17)	0	2 (33)	3 (50)	6 (17)	29 (83)
SPI	1 (33)	0	2 (57)	0	3(9)	32 (91)
ZSI	3 (25)	3 (25)	2(17)	4 (33)	12 (34)	23(66)
DI	3 (21)	4(29)	3(21)	4(29)	14 (40)	21 (60)

From Table 2 above, Imo state experiences relatively wet to near normal rainfall regime as all the indices detect relative drought years of 40% to 9% respectively. Out of the 14 years classified as drought years using the Decile Index, 21% of the years experienced extreme and moderate droughts respectively while 29% had severe and weak drought incidences respectively. SPI classified 3 years as drought years in the study period of which extreme and moderate droughts occurred in once and twice respectively.

The observed disparity in drought detection by different drought indices has been noted by Salehnia *et al.,* (2017)) in Iran. Also, some researcher recommends the use of a specific or group of indices for drought assessment e.g. Javan *et al.*, (2016) recommend the use of SPI and RAI in studying drought in Lake Urmia Basin in Iran instead of PNI in annual estimates of drought. Bakheit (2017) recommend PNI, DI and RAI against SPI in drought detection in South Darfur state, Sudan.

Relationship between the Different Drought Indices in the Study Area: The relationship among the drought indices is shown in Table 3. All the drought indices show a positive strong relationship with each other. When compared to SPI which is the standard drought monitoring index, ZSI and PNI show a very strong correlation (r = 0.971) respectively. All the relationship is statistically significant at 0.01 confidence level.

Table 3: Correlation Coefficients between SPI and other Drought index

	SPI	**ZSI**	**PNI**	**DI**
SPI	1	.971**	.971**	.757**
ZSI	.971**	1	1.000**	.882**
PNI	.971**	1.000**	1	.883**
DI	.757**	.882**	.883**	1

***. Correlation is significant at the 0.01 level (2-tailed)*

The high relationship between the indices is not surprising as it corroborates Byakatonda *et al.*, (2018) and Oloruntade *et al.*, (2017) studies in Bostwana and Nigeria respectively showing a relatively high correlation between the two indices used in their study. However, the obtained relationship varies considerably with time scale.

Conclusion: This study has shown that droughts do occur in Imo state, a tropical rain forest zone of Nigeria. The various rainfall based indices e.g. DI, PNI, SPI and Z-Score are good tools for drought assessment research. Differences in detection ability were observed among the drought indices, with DI and Z-Score performing better in detecting drought phenomena in the study area. Further researches should be conducted on why drought detection varies with rainfall indices.

REFERENCES

Bakheit, HIM (2017). Evaluation of selected meteorological drought indices for detecting climatic condition, South Darfur state, Sudan (1980-2040) (Master's Thesis, University of Gezira)

Byakatonda, J; Parida, BP; Moalafhi, DB; Kenabatho, PK (2018). Analysis of long term drought severity characteristics and trends across semiarid Botswana using two drought indices. *Atmos. Res.* 213: 492-508.

Gibbs, WJ; Maher, JV (1967). Rainfall deciles as drought indicators. Bureau of Meteorology bulletin No. 48; Commonwealth of Australia, Melbourne, VIC, Australia. https://www.agrimetsoft.com

Javan, K; Azizzadeh, MR; Yousefi, S (2016). An investigation and assessment of meteorological drought in Lake Urmia basin using drought indices and probabilistic methods. *Natural Environ. Chang.* 2(2): 153-164.

Mckee, TB; Doesken, NJ; Kleist, J (1993). The relationship of drought frequency and duration to time scale. In proceedings of the 8th conference on Applied Climatology, American Meteorological Society: Boston, 179-184.

Morid, S; Smakhtin, V; Moghaddasi, M (2006). Comparison of seven meteorological indices for drought monitoring in Iran. *Int. J. Climatol*. 26; 971– 985.

Okeke, TC; Okeola, OG (2019). Spatial and temporal drought analysis in the north central region of Nigeria. *J. Appl. Sci. Environ. Manage.* 23(4), 763-767.

Oladipo, EO (1993). Some aspects of the spatial characteristics of drought in northern Nigeria. *Nat. Hazards*. 8(2), 171-188.

Oloruntade, AJ; Mohammad, TA; Ghazali, AH; Wayayok, A (2017). Analysis of meteorological and hydrological droughts in the Niger-South Basin, Nigeria. *Glob. Planet. Chang*. 155: 225-233.

Salehnia, N; Alizadeh, A; Sanaeiejad, H; Bannayan, M; Zarrin, A; Hoogenboom, G (2017). Estimation of meteorological drought indices based on AgMERRA precipitation data and station-observed precipitation data. *J. Arid Land*. 9(6): 797–809.

Willeke, G; Hosking, JRM; Wallis, JR et al. (1994). The National Drought Atlas. In: Institute for Water Resources Report 94-NDS-4. U.S Army Corp of Engineers, CD-ROM. Norfolk, VA

World Meteorological Organization (WMO) and Global Water Partnership (GWP) (2016). *Handbook of Drought Indicators and Indices* (M. Svoboda and B.A. Fuchs). Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva.

Wu, H; Haye MJ; Weiss, A; Hu, Q (2001). An evaluation of te standardized precipitation index the China z- index and the statistical z-score. *Int. J. Climatol.* 21: 745-758.