Implementation of Rainfall-Based Drought Indices for Regional Drought Assessment

Shradhanjalee Pradhan and Bibhuti Bhusan Sahoo

Abstract Regional drought monitoring is a vital constituent of drought risk management. The effects of drought on the environment and ecosystem may cause disasters and result in socio-economic problems. Drought indices are an extremely useful tool for regional drought assessment. In this study, various rainfall-based drought indices are used for drought assessment of its four districts of the state of Odisha India. The six indices Standardized Precipitation" Index (SPI), Percent of Normal Index (PN), China-Z index (CZI), modified CZI (MCZI), Z- Score Index (ZSI), and deciles index (DI)"differ in their exposure and classification of drought procedures in the study area. Further, a comparative analysis has been done among all the rainfall-based indices. The differences mention among the drought indices in noticing drought in the events in the study area can be reduced by using numerous drought indices in computation to the use of SPI, in drought taxations. It is observed that SPI captured the historical extreme and severe drought periods successfully, and can be suggested to be applied to this district as drought assessment tools.

Keywords Drought · SPI · EDI · DI

1 Introduction

Droughts are usually periods that rainfall is below typical, leading to extended stages of water storage. It is every so often generally defined as a brief meteorological event that branches from the lack of rush over an extended historical compared with some continuing average condition of precipitation. However, drought develops slowly, is difficult to determine, and has many facets in any single area. The victory of drought

S. Pradhan (✉)
Department of Civil Engineering, Veer Surendra Sai University and Technology, Burla, Odisha, India
e-mail: shradha4972@gmail.com

B. B. Sahoo
Department of Agricultural Engineering, Centurion University of Technology and Management, Paralakhemundi, Odisha, India

preparedness and reduction depends, largely, based on current information on the commencement, progress, and region affected by the drought. Drought monitoring can provide you with this piece of communication. Drought indices are commonly used for monitoring. Drought indices provide information on the severity of drought to decision-makers and, if accessible, can be used to trigger drought eventuality measures. To date, many drought indexes have been established.

The Palmer Drought Severity Index (PDSI) [13] is a frequently used drought severity index in the U. S.. The decile index [4], that is, used in Australia, the Surface Water Supply Index (SWSI), Shafer and Dezman [16], which was adopted by many states in the U.S., as well as the standardized precipitation index (SPI) [9], which has achieved worldwide acclaim, the China-Z index (CZI), which is castoff by the National Meteorological Center of China (Wu The majority of these indicators are dependent on weather information (temperature and rainfall). There is no such thing as an ideal or all-encompassing index. The index's ability to consistently discern regional and temporal variations during a drought, as well as the volume of weather data available in the event should ultimately guide the selection of indices for drought nursing in a specific area.

Drought is one of the devastating expected disaster in India affecting various dimensions of society. It has major impacts on the environment, agriculture, the economy, and society as a whole. In recent decades, the severity and the frequency of droughts have increased due to erratic rainfall [10, 18]. To know the spatiotemporal behavior of drought over India, multiple drought indices have been used in the past" [1, 6, 8, 19]. SPI is one of the most commonly used drought index for assessment of drought [3, 12, 14, 15]. Some of the other studies on drought assessment in India context include the use of various drought indices for example PDSI, Integrated Drought Index (IDI), Standard Precipitation Evapotranspiration (SPEI), Effective Drought Index ('EDI), and many more [7, 17, 22]. Nevertheless, a drought index is appropriate for one region may not be applicable for other region or basin [20, 22]. Therefore, numerous researchers across the globe have compared different drought indices with an aim of discovery suitable drought index for a certain region or basin [2, 11, 21]. Morid et al. [11] used EDI, SPI, Percent Departure from Normal, Deciles Index, Z-index, modified CZI (MCZI), and China Z index (CZI) for six locations in Iran. They found that the EDI outperformed other indices. Barua et al. [2] compared Percent Departure from Normal, Deciles Index. Used for the Yarra River Catchment in Australia, Aggregated Drought Index (ADI), SPI, and the SWSI were used. They accomplish that the ADI performed better in sensing fraud based on decision criteria of historic droughts.

This drought assessment in the four selected districts of Odisha has never been the subject of a serious scientific study. In addition, nothing is known about the features of drought in the observed area. Therefore, the objective of this observed is to evaluate the drought situation in the four selected district as shown in Fig. 1. As there is no universal index for drought assessment it's more preferred to do a regional assessment and check which index fits the best for that area.
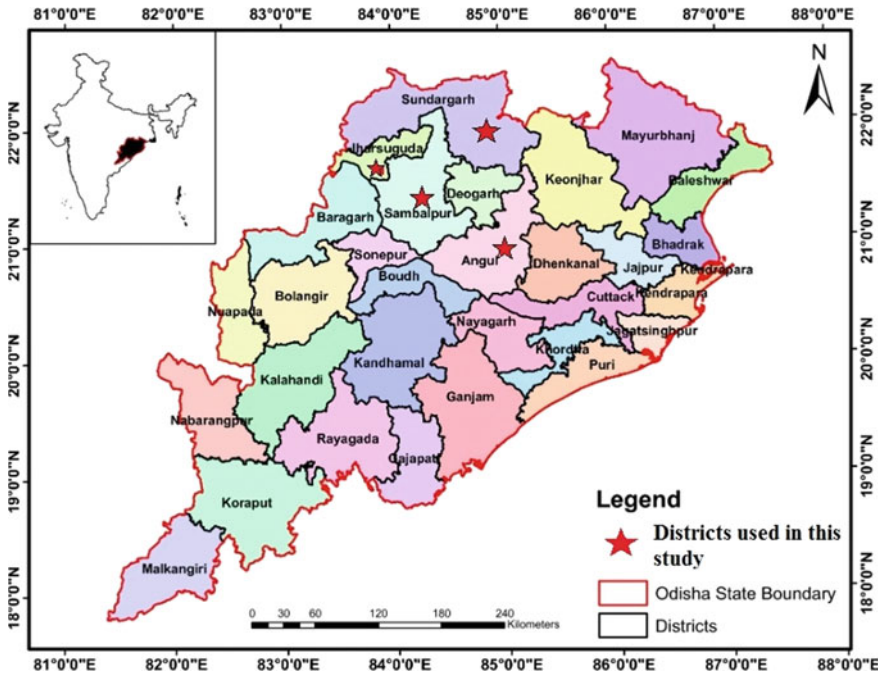
Fig. 1 Study area map

2   Study Area and Data Collection

An attempt was finished to perform drought susceptibility analysis in four districts of Odisha as shown in Fig. 1. The study area Long monsoon breaks (dry spells) in the course of the crop increasing in rich, as well as huge variations in rainfall quantity from year to year, outcome in crop failure on a regular basis, making the entire area drought prone. However, there is a need to analyze the spatial and secular distinction of drought in this area so that water users can frame drought alleviation plans and make decisions based on the future skyline to decrease the harmful footprint of drought. The rainfall data were collected from the Indian meteorological department.

3   Drought Indices

The goal of this study was to evaluate whether six indices "Standardized Precipitation Index (SPI), deciles index (DI), Percent of Normal Index (PN), China-Z index (CZI), "modified CZI (MCZI), Z-Score Index (ZSI)" detect and arrange droughts occurrences. One aspect that all of the carefully chosen indices have in mind is that they really rely only on precipitation data. Every one of the indexes examined have

indeed been applied to the study's different measurement variables. Each monthly has a separate time scale. The drought's point-by-point and spatial scope were determined correspondingly. The resulting text includes a summary of a indices of these values.

3.1   The Percent of Normal (PN)

The percent of normal index is one of the most simple ways to determine how far rainfall has deviated from its long-term average rainfall. 'Normal' is commonly set to a location's long-term mean rush value. The value of 'normal' is 100% and can be determined for a month, a season, or a period. Because the same PN might have various specific implications in different places, it's a bit of a crude metric of precipitation shortfall. In addition, what is normal may be perceived differently in divergent regions.

3.2   The Decile Index (DI)

Gibbs and Maher [4] proposed the Decile Index approach, which is widely used in Australia. Seasonal rainfall totals from a long track record are first ranked from highest to lowest to construct a cumulative probability dispensation. After then, the dispensation is divided into eleven pieces (tenths of distribution or deciles). The first decile is the quantity of precipitation that is not exceeded by the lowest 10% of all precipitation readings in a period. The second decile, which varies from 10% in terms to 20%, is situated between both the lowest and highest deciles. When evaluating the amount of precipitation in a month (or over several months) with the long-term cumulative dispersal of precipitation quantities in that period, the severity of drought can be determined.

There are five classes of deciles, each with two deciles. If precipitation falls into the lowest 20 percentage points of year, it is considered significantly below normal (deciles 1 and 2). Below-normal rainfall is noted by deciles three to four (20–40%), close precipitation is noted by deciles 5–6 (40–60 percent), above-normal precipitation is indicated by deciles 7 and 8 (60–80 percent), and substantially above-normal rush is indicated by deciles 9 and 10 (80–100%).

3.3   The Standard Precipitation Index (SPI)

A long-term rush record at the selected station is first fitted to a probability distribution, which will then be transformed into a normal distribution with mean zero SPI [9]. A variety of time periods could be used to determine the SPI (e.g., 1 month,

3 months, and 24 months). Also with long-term sets of data, Guttman [5] showed that employing SPI at extra duration increments is not recommended so because sample size diminishes. Different timeframes can be used to examine the effects of a precipitation shortage on different water resource elements (groundwater, soil moisture, reservoir storage, and streamflow). The dryness section of the SPI scale is classified at random into 'very dry' (SPI2.0), 'severely dry' (1.5 > SPI > 1.99), 'moderately dry' (1.0 > SPI > 1.49), and 'near normal' (0.99 > SPI > 0.99) conditions.

Positive SPI values show more precipitation than average, while negative results suggest less precipitation.

3.4 China-Z Index (CZI), Modified CZI (MCZI) and Z-Score

The CZI is constructed on the Wilson-Hilferty cube-root transformation. Undertake that haste data follow the Pearson Type III dissemination, the index is calculated as:

$$\text{CZI}_i = \frac{6}{S_c}\left(\frac{S_c}{2}\Phi i + 1\right)^{1/3} - \frac{6}{S_c} + \frac{S_c}{6} \tag{1}$$

$$S_c = \frac{\sum\limits_{i=1}^{n}(xi - \overline{x})^3}{n \times \sigma^3} \tag{2}$$

$$\Phi i = \frac{xi - \overline{x}}{\sigma} \tag{3}$$

where i is the present month, S_c" is coefficient of unevenness, n is the total number of months in the data, Φ_i is standard variate, also called the Z-Score and x_i is precipitation of i month." Instead of using the mean of precipitation in the CZI calculation, the median of precipitation is used to calculate the MCZI (i.e., Med is substituted for x in Eqs. 2 and 3). Wu et al. [23] attempted to lessen the discrepancies between the SPI and the MCZI by doing so. They determined, however, that the gaps between these two indexes did not narrow as much as the discrepancies between the CZI and the SPI.

4 Result and Discussion

The values obtained of the MCZI, CZI, Z-Score, and SPI all are almost identical (Table 1). As a consequence, they are all on the same page in this respect. The DI and PN, on the other side, have broad variations than the SPI, as previously established. To make the DI and PN values comparable to the SPI classes, they have indeed been organized into similar classes (Table 1). DI classes of 60–70% (slightly

Table 1 Different classes of various drought indices based on the index value

SPI	CZI	MCZI	Z score	DI (%)	PN (%)	Classes
≥ 2	≥ 2	≥ 2	≥ 2	≥ 90		Extremely wet
1.5–1.99	1.5–1.99	1.5–1.99	1.5–1.99	80–90		Severely wet
1–1.49	1–1.49	1–1.49	1–1.49	70–80	≥ 110[a]	Moderately wet
− 0.99–0.99	− 0.99–0.99	− 0.99–0.99	− 0.99–0.99	30–70	80–110	Normal
− 1–1.49	− 1–1.49	− 1–1.49	− 1–1.49	20–30	55–80	Moderately dry
− 1.5–1.99	− 1.5–1.99	− 1.5–1.99	− 1.5–1.99	10–20	40–55	Very dry
≤ -2	≤ -2	≤ -2	≤ -2	≤ 10	≤ 40	Extremely dry

[a] ≥ 110 considered as WET

above normal), 50–60% (normal), and 30–40% (slightly below normal) have been combined to form a broader 'normal' DI class of 30–70% (which correlates to the 'normal' SPI range). High PN values were not classified for this investigation, and all value higher than 110% were considered 'wet' circumstances (Table 1).

In all of the four districts SPI out performed in the year 1995, 2000, 2005, 2010, 2015 among all indices considered in this study. The SPI shows close resemblance with the actual percentage of drought affected in all the four districts. In most of the districts the CZI, MCZI and Z score overestimated than the actual area affected by drought. For example, in case of Sundargarh district the actual drought affected is 35% in the year 1995, while the SPI estimation shows 38% of the drought-affected area. Meanwhile CZI, MCZI and Z shows 41, 44 and 47%, that is, quite higher than the actual data. Which can be easily interpreted from the Fig. 2 and for other districts and for other years. Figure 2 shows a comparison between the actual drought percentage and various drought indices used in this study. All four districts rainfall-based drought indices (SPI, DI, PN, MCZI, CZI, and Z SCORE) are shown in Fig. 3.

5   Conclusions

- In this study, six drought indice" Standardized Precipitation Index (SPI), deciles index (DI), Percent" of Normal Index (PN), China-Z index (CZI), modified CZI (MCZI), and Z-Score Index (ZSI) were evaluated for monitoring and detecting drought periods, four districts of Odisha. The SPI method gives the superior result as compared to other rainfall-based results.
- Results derived by the SPI method are more similar to actual drought in the study districts. Therefore, SPI can be a suitable drought index for the four districts.
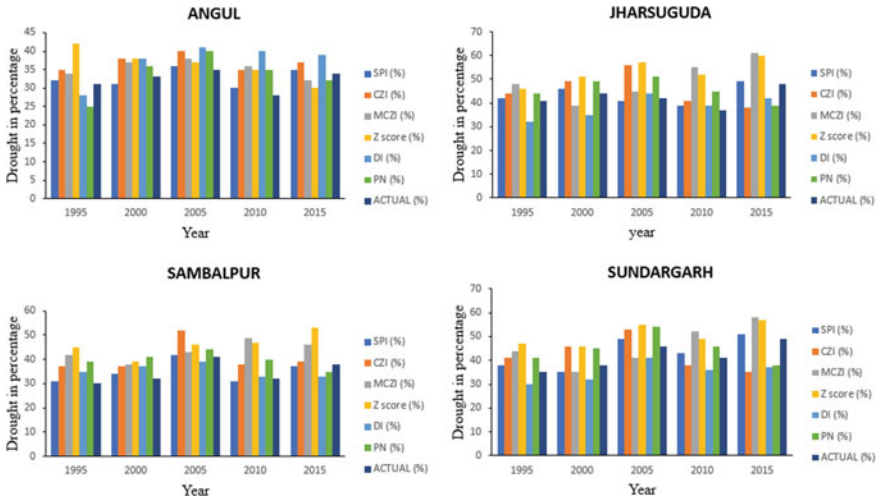
Fig. 2 Comparison between actual drought and rainfall-based drought indices for all the fore districts
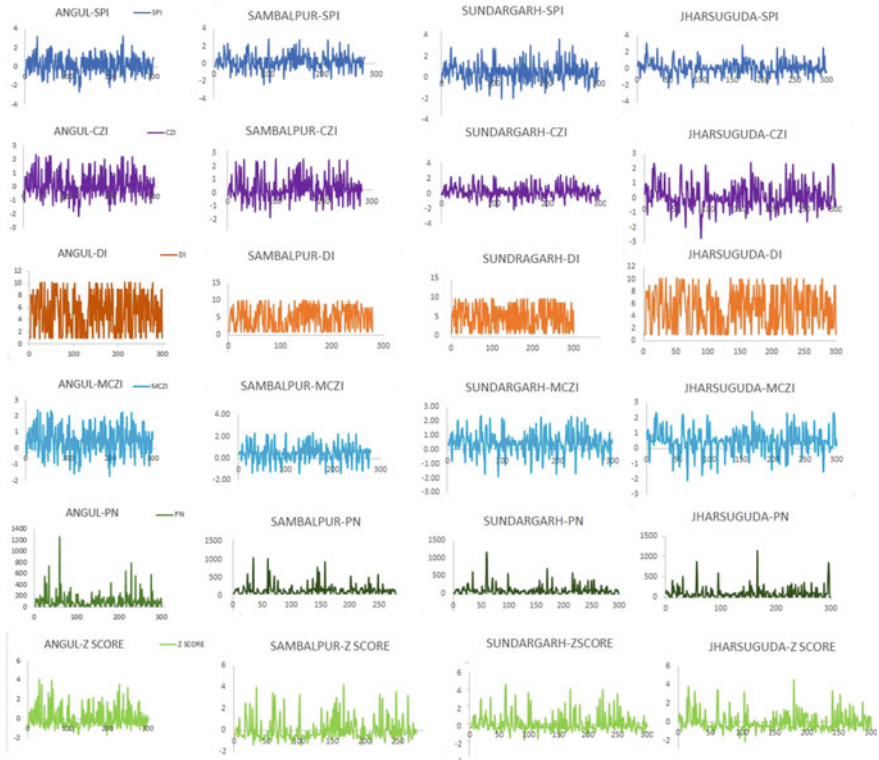

Fig. 3 All four districts rainfall-based drought indices (SPI, DI, PN, MCZI, CZI, Z SCORE)

The SPI index is capable drought nursing and describing attribute of drought circumstances.

- Having concerns to the effects of weather change, deficiency of comforting about various drought condition or span in various parts of the world is connected with climate change of climatical factors and requires estimation in a longer period. Totally, the occurrence of droughts is unavoidable, but observe and forecast of drought can be give rise to improve adversarial impressions of drought.

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