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Short Communication

Comparative study of meteorological drought indices for Adilabad district, Telangana, India

GUHAN VELUSAMY[1]*, SRAVANI A.[1], RAO L.V.[1], and HARSHANA[2]

[1]*Meteorological Centre, India Meteorological Department, Begumpet, Hyderabad, Telangana, India*
[2]*Meteorological Centre, India Meteorological Department, Bhopal, Madhya Pradesh, India*
Corresponding author email: guhanthiran@gmail.com*

Water, a resource that is necessary for both human survival and the survival of other living things, is the foundation of sustainability. While water is plentiful, there won't be any problems with utilization; nevertheless, when it's scarce, things will go really bad (Sikdar *et al.,* 2017). Droughts and floods are the result of extreme water occurrences that must be managed properly to help future generations and meet demand in the event of a shortage. Droughts are one sort of tragedy that starts later and affects people more because they affect ground water (Di Baldassarre *et al.,* 2017). It is possible to precisely mimic the effects that are felt during a drought using drought indices.

Using inputs from meteorology, hydrology, and climate, drought indices are often computed mathematical representations of the severity of a drought (Mukherjee *et al*., 2018). According to experts, utilizing RS and GIS technology makes it simpler to determine the many factors impacting the Earth's surface (Sundararajan *et al*., 2021). Standardized precipitation index (SPI), Decile indicator (DI), Rainfall anomaly index (RAI), and Z score index (ZSI) are some of the indices that rely solely on precipitation data for drought identification and monitoring. Sridhara *et al.,* (2021) analyzed SPI, DI, ZSI, percent normal (PN), China-Z index (CZI) to asses the drought conditions in Karnataka, India and reported that SPI could be best used for onset of drought conditions.

To monitor the drought situation in the selected research area, a number of factors are evaluated. The intensity of the region's previous drought epidemics varied from year to year. They gave rise to meteorological drought, which was followed progressively by hydrological dryness. In 2021, the region experienced a major flood, causing considerable damage to the community. Water is in low supply even after the land has flooded due to the region's inadequate water management systems and little rainfall. All of these elements can contribute to drought, but by monitoring the situation and taking measures, it is possible to change it and protect the land from future floods and droughts.

Study area

The town of Adilabad serves as the capital of the Adilabad district (Fig. 1), which is situated in the northern region of Telangana, India, and is considered the entrance to South and Central India. The district, which is 4,153 square kilometers in size, is bordered by the state line of Maharashtra, the districts of Asifabad and Nirmal. There are eighteen Mandalas in the district, and the primary industries are agricultural and forest products. The main crops farmed in the region include rice, maize, cotton, and other pulses. The district experiences tropical weather, with the majority of its rainfall coming from the monsoon season

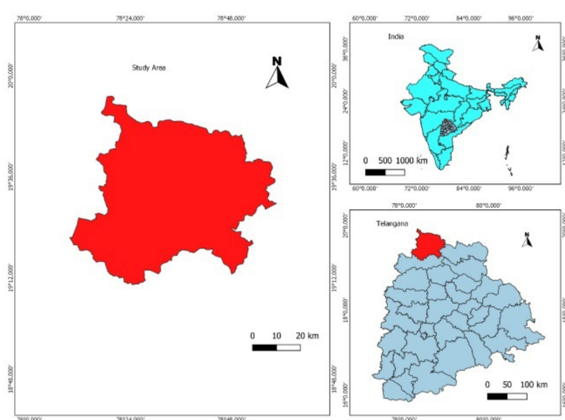

Fig. 1: Study area map of Adilabad district, Telangana

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Table 1: Categorization of different drought indices

Standardized precipitation index (SPI)		Deciles index (DI)		Rainfall anomaly index (RAI)		Z-score index (ZSI)	
Value	Intensity	Value	Intensity	Value	Intensity	Value	Intensity
≥ 2.00	Extremely wet	>5	No drought	>0.3	Extremely wet	>0.25	No Drought
1.99 to 1.50	Very Wet	4	Weak drought	0.3 to -0.3	Moderately wet	0.25 to -0.25	Weak Drought
1.49 to 1.00	Moderately Wet	3	Moderate drought	-0.3 to -1.2	Near Normal	-0.25 to -0.52	Slight Drought
-0.99 to 0.99	Near Normal	2	Severe drought	-1.2 to -2.1	Moderately dry	-0.52 to -0.84	Moderately Drought
-1 to -1.49	Moderate drought	1	Extreme drought	-2.1 to -3.0	Severely dry	-0.84 to -1.25	Severely Drought
-1.50 to -1.99	Severe drought			<-3.0	Extremely dry	<-1.25	Extremely Drought
≤ -2.00	Extreme drought						

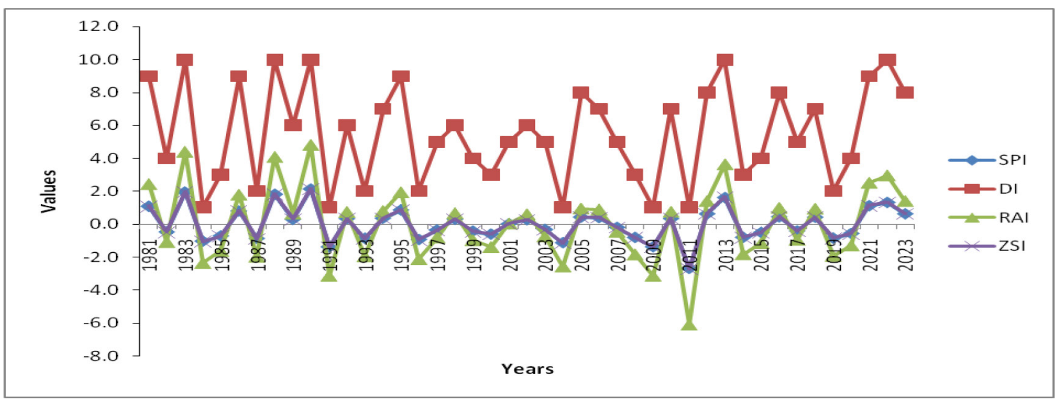

Fig. 2: Variation of different drought indices in Adilabad district during 1981 to 2023

Weather data

For the current study, daily rainfall data from the Adilabad district were obtained from 1981 to 2023 using IMD gridded data. The statistics were then analyzed and transformed.

Standardized precipitation index (SPI)

The SPI is widely recognized as an effective tool for defining meteorological droughts (Table 1). SPI across various time periods (1, 3, 6, 12, 24, and 48 months), with output values ranging from -2.0 to 2.0. The SPI is computed using the probability density function illustrated below, because precipitation data may be fitted by a gamma distribution:

$$g(x) = \frac{1}{\beta^{\alpha} T(\alpha)} x^{\alpha-1} e_{\beta}^{-x} \quad (x > 0)$$

where, the gamma function is defined as T(α), shape parameter (α>0), scale parameter (β), and precipitation (x) (mm).

Deciles index (DI)

The DI provides a precipitation rating for each time interval across the whole historic timeframe (Table 1). Monthly historical precipitation data is divided into ten equal segments, or deciles, ranging from greatest to lowest precipitation.

Rainfall anomaly index (RAI)

Positive and negative anomalies are both analyzed by the RAI (Table 1). First presented is the precipitation data in descending order. A threshold for the positive anomaly is created by averaging the 10 highest results, while a threshold for the negative anomaly is created by averaging the ten lowest values.

$$RAI = 3\,X\left[\frac{(p - \overline{p})}{(\overline{m} - \overline{p})}\right]$$

where, p is the actual precipitation for each year (mm), m is the mean of the ten highest and ten lowest p values for the positive and negative anomalies, respectively, and p is the long-term average precipitation (mm).

Table 2: Frequency of drought categories as per different indices

Standardized precipitation index (SPI)		Deciles index (DI)		Rainfall anomaly index (RAI)		Z-score index (ZSI)	
Categories	Frequency (%)	Categories	Frequency (%)	Categories	Frequency (%)	Categories	Frequency (%)
Extremely wet	2	Extreme drought	9	Extremely wet	49	No drought	49
Very wet	7	Severe drought	9	Moderately wet	2	Weak drought	5
Moderately wet	7	Moderate drought	9	Near normal	16	Slight drought	14
Near normal	72	Weak drought	9	Moderately dry	19	Moderately drought	12
Moderate drought	9	No drought	63	Severely dry	7	Severely drought	14
Severe drought	0			Extremely dry	7	Extremely drought	7
Extreme drought	2						

Z-score index (ZSI)

Fitting precipitation data to the gamma or Pearson type III distributions is not required, despite the occasional confusion between ZSI (Table 1) and SPI. ZSI can be calculated using the formula below:

$$ZSI = \frac{P_i - \overline{P}}{SD}$$

where, P is the average monthly precipitation (mm), SD is the standard deviation of any time period (mm), and Pi is the precipitation in a certain month (mm).

The year wise drought indices comparison from 1981 to 2023 is represented in the Fig. 2. To gain a comprehensive understanding of the drought patterns, it is crucial to compare these indices. Both SPI and DI identified the years 1984, 1991, 2004, 2009, and 2011 as dry years, indicating a strong correlation between these two indices. This suggests that both indices are consistent in identifying major drought years based on rainfall data. On the other hand, the RAI index identified several years as having abnormally rainy conditions, including 1981, 1983, 1986, 1988, 1989, 1990, 1992, 1994, 1995, 1998, 2002, 2005, 2006, 2010, 2012, 2013, 2016, 2018, 2021, 2022, and 2023. However, the SPI index did not identify these years as particularly wet, suggesting a discrepancy between these two indices in identifying wet years. Both SPI and ZSI identified 1984, 1991, 2004, 2009, and 2011 as years of severe to exceptional drought conditions. This consistency between SPI and ZSI further validates the reliability of these indices in identifying drought years (Maity *et al.,* 2024). The DI index identified 1984, 1991, 2004, 2009, and 2011 as years of extreme drought conditions. However, the RAI index did not identify these years as particularly dry, indicating a discrepancy between these two indices in identifying dry years. Both DI and ZSI identified 1984, 1991, 2004, 2009, and 2011 as years of severe to exceptional drought conditions. This consistency between DI and ZSI further validates the reliability of these indices in identifying drought years. The RAI index identified several years as having abnormally rainy conditions, while the ZSI identified the same years as having normal to severe drought conditions. This discrepancy suggests that these two indices may be capturing different aspects of the region's climate. Our comparative analysis reveals that while there is a high degree of consistency among some indices in identifying drought years, there are notable discrepancies in identifying wet years. This suggests that a multi-index approach is necessary for a comprehensive understanding of the drought conditions in the region.

The Table 2 compares the frequency of drought and wetness categories across four indices: SPI, DI, RAI, and Z-Score. SPI and DI show a balanced distribution, with most observations falling in the 'Near normal' and 'No drought' categories respectively. RAI and Z-Score indicate a higher frequency of 'Extremely wet' and 'No drought' conditions. The choice of index significantly influences the interpretation of drought and wetness conditions, highlighting the importance of careful selection in drought analysis studies.

Over the past 43 years, the region has experienced significant variability in rainfall, as indicated by the Standardized precipitation index (SPI), Drought index (DI), Rainfall anomaly index (RAI), and Z-score index (ZSI). Particularly dry years were 1984, 1991, 2004, 2009, and 2011, which were identified by multiple indices (SPI, DI, ZSI) and could have had substantial impacts on the ecosystem, water availability, and agricultural productivity. The RAI index identified certain years as abnormally rainy, but these did not always align with the wet years identified by other indices, suggesting that the RAI may be capturing different aspects of the region's climate. While there is a high degree of consistency among the SPI, DI, and ZSI indices in identifying drought years (Sridhara *et al.,* 2021), there are notable discrepancies in identifying wet years. This highlights the importance of using multiple indices for a comprehensive understanding of drought conditions. Despite occasional years of extreme drought, the overall drought condition has remained relatively stable over the past 40 years, which is crucial for maintaining sustainable growth and ensuring long-term water security in the region.

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Data availability: The IMD gridded rainfall data can be downloaded from its website (https://www.imdpune.gov.in/cmpg/Griddata/Rainfall_25_NetCDF.html).

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