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Evaluation of Temporal Variation of Meteorological Drought in Marathwada Region

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Abstract

Drought is a devastating natural occurrence. It differs from other natural hazards in that it takes a long time to build up and has an infinite start and end. It is vital to assess the severity of a drought. Drought has various faces in any given place, and it always begins with a lack of precipitation, which can influence soil moisture, streams, groundwater, ecosystems, and humans (or not, depending on how long and severe the drought is). As a result, four types of droughts (meteorological, hydrological, agricultural, and socioeconomic) are identified, reflecting the perspectives of various sectors on water scarcity. Drought indices are used to categorise drought situations, with the Standardized Precipitation Indicator (SPI) being the most extensively used and approved by the World Meteorological Organization (WMO) as the standard drought index. The SPI with several years is computed for two-time steps 6,12 and compared with each other. Annual data with seasons is presented using tables, graphs. The R software was used to calculate all statistical processes. SPI12 and SPI6 has recognized 1973, 1985, 1986, 1992, 2016 as drought years. At last, temporal variation is seen in different districts of Marathwada region. Firstly, 60 years were divided into two groups each 30 years. Then drought years has been identified which were 1973, 1985, 1986, 1992, 2016. In these drought years, severity has been discussed according to SPI12 and SPI6.

Keywords: Drought, Precipitation, The Standardized Precipitation Index, Marathwada Region, Drought years

Highlights

- This study is about evaluating the variation year wise of meteorological drought (variable taken is precipitation) in Marathwada Region, Maharashtra.
- SPI6 and SPI12 are the two-time series taken for comparison long term drought.
- R-programming software is used in this paper.
- Drought years have been considered in 60 years of data and compared in two time series mentioned above.

Introduction

Climate change is a natural process, but human-caused increases in GHGs, which modify the climatic system, have triggered more sudden changes and influenced the recurrence of extreme (Drought, Flood etc.) climatic events. Extreme weather events, such as drought, are becoming more common as a result of climate change. Drought intensity is expected to worsen in several places of the world. Drought is notoriously difficult to identify and explain due to its insidious nature. Droughts are widely acknowledged as a natural environmental disaster that has drawn multidisciplinary attention from many sectors of science. Water shortage and demand have increased globally as a result of population growth and industrial expansion. Climate change, for example, has exacerbated the water scarcity (Vogt, 2017). The four-type drought classification method is based on the nature of water scarcity. According to this classification, meteorological, hydrological, and agricultural droughts are all environmental droughts, and are characterised as periods of inadequate rainfall, groundwater and river flow, and soil moisture. Socioeconomic drought is the fourth type of drought, and it is caused by water resource systems failing to fulfil demand. Droughts are long-term events that affect huge areas and result in significant human deaths and economic losses. Droughts are natural occurrences that are certain to occur again. The gravity of their socioeconomic consequences has prompted extensive research. Drought is caused by the persistence of atmospheric circulation patterns that fail to deliver needed precipitation, whether they are continuous or intermittent. These are the most common and dangerous in semi-arid environments. Their economic effects can be concentrated locally, but as they spread across the economy, they become diffused. Historically, drought buffering has been achieved through industry diversification, risk spreading, crop insurance, aid, and other methods. Sectors that aren't as well-known, such as cattle farming and farm implement manufacture, might be severely impacted. Existing economic systems are capable of coping with common dry spells. The biggest havoc is caused by extreme events. The chronic deterioration and loss of topsoil in semi-arid areas is unabated and less evident [1].

SPI expresses actual rainfall as a standardized deviation from the rainfall probability distribution function, and as a result, the index has gained popularity in recent years as a potential drought indicator that allows for comparisons across area and time [2]. Long-term precipitation data is needed to estimate the probability distribution function (gamma distribution), which is then transformed to a normal distribution with a mean of zero and a standard deviation of one. The longer the reference period used to determine the distribution parameters, the more accurate the results will be. SPI values are reported in standard deviations, with positive values indicating more precipitation than the median and negative values indicating less precipitation. A station's SPI should preferably be determined using at least 30 years of historical

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data. Only the monthly time scale should be used to calculate SPI. For an accurate SPI calculation and explanation with expertise, fitting relevant statistical distributions to time series rainfall data is crucial [2]. However, in many States, the lack of long-term Block level quality data is a restraint in computing SPI (Table 1).

Study area and data used

The goal of this study was to look into the varying drought conditions across the sub-divisions of Marathwada, Maharashtra, India. Jalna, Aurangabad, Parbhani, Hingoli, Nanded, Latur, Osmanabad, and Beed are the eight Maharashtra districts that make up the Marathwada region. This region is found in the upper Godavari basin, spanning 17° 35' North latitude to 20° 41' North latitude and 74° 40' East longitude to 78° 16' East longitude. Maharashtra's central region is known as Marathwada.

The Marathwada region is located in the semi-arid tropics, with the highest maximum temperature of 43°C in May and the lowest minimum temperature of 11°C in December. The south-west monsoon is the region's primary source of precipitation, with an average annual rainfall of 890 mm and 48 wet days in Parbhani. The majority of the state is located in the Western Ghat rain shadow area, with annual average precipitation ranging between 600 and 700mm (Figure 1).

Materials and methods

Standardized Precipitation Index

The SPI is a precipitation-based drought measure created by McKee et al [3]. The adaptability and ease of use of SPI are its strengths. It can be calculated on a variety of time scales and intervals [4]. SPI is a probabilistic index calculated by fitting a gamma distribution to a long-term precipitation time record [5,6]. Using the equal probability transformation, this distribution is transformed into a normal distribution.

Table 1: SPI values.

Values	Range
< -2	Extremely Dry
-0.49	Severely Dry
-0.49	Moderately Dry
-0.99	Mildly Dry
0 - 0.99	Mildly Wet
1.0 - 1.49	Moderately Wet
1.5 - 1.99	Severely Wet
>2.0	Extremely Wet

Positive SPI numbers indicate humid circumstances with more precipitation than the median, whilst negative SPI values indicate dry conditions with less precipitation. Using different periods, the SPI can also be used to represent several drought types [7]. Since drought conditions were analysed using the SPI with time periods up to six months, the SPI-1, SPI-3, and SPI-6 imply meteorological, agricultural, and hydrological droughts, respectively Abdulah [8]. Table 2 shows drought severity levels in terms of SPI values. For any of the time scales, the values define the occurrence of a drought event at various severity levels. Drought happens when the SPI number remains negative for an extended period of time. Its positive value indicates that there is no drought [9].

Results and discussion

According to study results, there are six droughts i.e., 1973, 1985, 1986, 1992, 2016 which taken into consideration (Table 3-7). Two groups were divided of 60years i.e., 1961-1990 and 1991- 2020 called as group 1and group 2 respectively.

In SPI 12, group 1 has more numbers of drought months than group 2 which can be clearly seen in table 5, 10 and Table 7. Group 1 has extremely dry months almost equal to moderately dry months whereas in group 2 moderately dry months are exponentially high than extremely dry months. That is why, drought years are more from group 1.

Now in SPI 6, group 1 has more effect like in SPI12 but Extremely dry months are less than moderately dry months. Here severely dry months and extremely dry months are equivalent to each other. We can see gradual severity in SPI6 where in SPI 12 exponentially less and Dmore severity can be seen.

In SPI12, Drought year 1973, Jalna, Hingoli and Parbhani are most affected districts due to the drought whereas aurangabad is less affected drought district. In 1985, Osmanabad has most severity as aurangabad and beed follows. From all drought years 1986 has most horrible drought

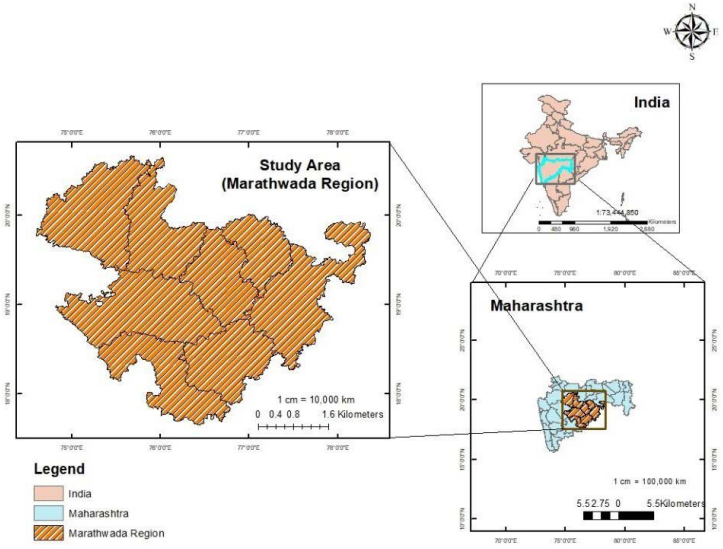

Figure 1: Index map of Marathwada Region.

Table 2: Number of drought months for SPI 12.

	1961-1990			1991-2020		
	Severity			Severity		
	Moderately	Severely	Extremely	Moderately	Severely	Extremely
Aurangabad	15	10	13	20	3	1
Beed	17	8	10	21	1	0
Jalna	5	5	20	30	1	1
Parbhani	3	4	19	14	3	0
Hingoli	12	5	20	27	4	1
Nanded	7	9	11	29	5	0
Latur	4	10	9	14	0	0
Osmanabad	11	10	13	22	2	0

Table 3: Severity in 1973 for four seasons in Marathwada region (Drought Year 1973).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Moderately Dry	Moderately Dry	Moderately Dry	Mildly Dry
Beed	Severely Dry	Moderately Dry	Moderately Dry	Mildly Dry
Jalna	Extremely Dry	Extremely Dry	Severely Dry	Moderately Dry
Hingoli	Extremely Dry	Extremely Dry	Moderately Dry	Mildly Dry
Parbhani	Extremely Dry	Extremely Dry	Moderately Dry	Mildly Dry
Nanded	Severely Dry	Severely Dry	Mildly Dry	Mildly Dry
Latur	Severely Dry	Severely Dry	Moderately Dry	Mildly Dry
Osmanabad	Severely Dry	Severely Dry	Moderately Dry	Mildly Dry

Table 4: Severity in 1985 for four seasons in Marathwada region (Drought Year 1985).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Moderately Dry	Mildly Dry	Severely Dry	Extremely Dry
Beed	Moderately Dry	Moderately Dry	Severely Dry	Extremely Dry
Jalna	Moderately Dry	Mildly Dry	Severely Dry	Extremely Dry
Hingoli	Mildly Dry	Mildly Dry	Moderately Dry	Extremely Dry
Parbhani	Mildly Dry	Mildly Dry	Moderately Dry	Extremely Dry
Nanded	Mildly Dry	Mildly Dry	Severely Dry	Extremely Dry
Latur	Mildly Dry	Mildly Dry	Moderately Dry	Extremely Dry
Osmanabad	Moderately Dry	Moderately Dry	Extremely Dry	Extremely Dry

Table 5: Severity in 1986 for four seasons in Marathwada region (Drought Year 1986).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Beed	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Jalna	Extremely Dry	Extremely Dry	Extremely Dry	Moderately Dry
Hingoli	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Parbhani	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Nanded	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Latur	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry
Osmanabad	Extremely Dry	Extremely Dry	Severely Dry	Mildly Dry

Table 6: Severity in 1992 for four seasons in Marathwada region (Drought Year 1992).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Moderately Dry	Moderately Dry	Moderately Dry	Mildly Dry
Beed	Mildly Dry	Moderately Dry	Moderately Dry	Mildly Dry
Jalna	Moderately Dry	Moderately Dry	Severely Dry	Mildly Dry
Hingoli	Moderately Dry	Moderately Dry	Severely Dry	Mildly Dry
Parbhani	Moderately Dry	Moderately Dry	Mildly Dry	Mildly Dry
Nanded	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry
Latur	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry
Osmanabad	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry

Table 7: Severity in 2016 for four seasons in Marathwada region (Drought Year 2016).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Mildly Dry	Moderately Dry	Moderately Dry	Mildly Dry
Beed	Moderately Dry	Moderately Dry	Moderately Dry	Mildly Dry
Jalna	Moderately Dry	Moderately Dry	Severely Dry	Mildly Dry
Hingoli	Moderately Dry	Moderately Dry	Severely Dry	Mildly Dry
Parbhani	Moderately Dry	Moderately Dry	Mildly Dry	Mildly Dry
Nanded	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry
Latur	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry
Osmanabad	Mildly Dry	Mildly Dry	Mildly Dry	Mildly Dry

Table 8: Number of drought months for SPI 6.

	1961-1990			1991-2020		
	Severity			Severity		
	Moderately	Severely	Extremely	Moderately	Severely	Extremely
Aurangabad	19	8	8	20	9	2
Beed	24	6	7	20	5	5
Jalna	12	10	10	26	4	3
Parbhani	16	4	11	23	4	2
Hingoli	15	8	14	28	10	5
Nanded	16	7	7	27	8	5
Latur	20	4	6	18	8	0
Osmanabad	19	6	9	28	7	1

Table 9: Severity in 1973 for four seasons in Marathwada region (Drought Year 1973).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Beed	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Jalna	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Hingoli	Severely Dry	Mildly Dry	Mildly Dry	Mildly Dry
Parbhani	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Nanded	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Latur	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry
Osmanabad	Moderately Dry	Mildly Dry	Mildly Dry	Mildly Dry

Table 10: Severity in 1985 for four seasons in Marathwada region (Drought Year 1985).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Beed	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Jalna	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Hingoli	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Parbhani	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Nanded	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Latur	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry
Osmanabad	Moderately Dry	Mildly Dry	Moderately Dry	Extremely Dry

Table 11: Severity in 1986 for four seasons in Marathwada region (Drought Year 1986).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Extremely Dry	Moderately Dry	Moderately Dry	Moderately Dry
Beed	Extremely Dry	Mildly Dry	Mildly Dry	Mildly Dry
Jalna	Extremely Dry	Moderately Dry	Mildly Dry	Mildly Dry
Hingoli	Extremely Dry	Mildly Dry	Mildly Dry	Moderately Dry
Parbhani	Extremely Dry	Moderately Dry	Mildly Dry	Mildly Dry
Nanded	Extremely Dry	Moderately Dry	Mildly Dry	Mildly Dry
Latur	Extremely Dry	Moderately Dry	Mildly Dry	Mildly Dry
Osmanabad	Extremely Dry	Moderately Dry	Mildly Dry	Mildly Dry

Table 12: Severity in 1992 for four seasons in Marathwada region (Drought Year 1992).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Beed	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Jalna	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Hingoli	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Parbhani	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Nanded	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Latur	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Osmanabad	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry

Table 13: Severity in 2016 for four seasons in Marathwada region (Drought Year 2016).

	Winter	Pre-Monsoon	South West monsoon	Post monsoon
Aurangabad	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Beed	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Jalna	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Hingoli	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Parbhani	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Nanded	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Latur	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry
Osmanabad	Mildly Dry	Moderately Dry	Mildly Dry	Mildly Dry

till now. All the districts were affected where Jalna tops it following all the remaining districts. 1992 is also considered as drought year but the severity was not at its peak but consistent effect was there. 2016 was a little bit severe than 1992 but still not as severe as 1986.

In SPI6, As the difference of drought years in SPI12 and SPI6 should be known, the same drought years are considered. There is consistent severity in all the districts. A little change can be seen but not significant change. In 1973, start of the year is extremely dry following start of the year of 1986. As all the districts are similarly severe difference cannot be known. Similarly in 1992 and 2016 are same severe as mentioned above (Table 8-13).

Conclusions

- To deal with drought suffering, one must first comprehend its features, such as its potential duration, intensity, severity, frequency, and aerial extent (spatial distribution). In assessing the hydrology of extreme events, the choice of time step is very crucial.

- The SPI is a method that can be used to identify dry spells in the Marathwada region. Drought is a recurring phenomenon in the studied region as a result of below-normal precipitation.

- During the 1980s, however, a series of severe droughts resulted in huge economic losses. In a case study based around 1986, one of the most severe drought years during the above dry period, the performance and monitoring capabilities of the index (SPI) were explored. Because different features of drought can be examined using multiple time frames, the SPI can be calculated with several time scales i.e., SPI12 and SPI6 giving the index flexibility for monitoring.

- According to study results, there are six droughts i.e., 1973, 1985, 1986, 1992, 2016 which taken into consideration. In Drought year 1973, Jalna, Hingoli and Parbhani are most affected district In 1985, Osmanabad has most severity as aurangabad and beed follows. From all drought years 1986 has most horrible drought till now. All the districts were affected where Jalna tops it following all the remaining districts.

- In SPI6, As the difference of drought years in SPI12 and SPI6 should be known, the same drought years are considered. There is consistent severity in all the districts.

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