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Rainfall Variability in the Drought Prone Area of Satara District (Maharashtra State)

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Abstract:

In the overall environmental change situation, to adapt to dry season, it is important to comprehend the attributes of meteorological dry seasons in water-scarce districts to figure legal designs for the usage of water assets. In the present research study, four semiarid tahsils in Satara district (Maharashtra State) during 1951 to 2015 are studied. The examination was completed with the use of Standardized Precipitation Index (SPI) method. The actual rainfall is measured on Standardized Precipitation Index (SPI) and it shows the standardized departure in rainfall with respect to probability distribution function. SPI quantifies he precipitation deficit and its value changes as the length of the record grows. Therefore the index has got significance in recent years which potentially indicates the drought and allows comparisons across space and time.

Introduction

Much of the rainfall in India is received from June to September. However, the seasonal and regional allotment of rainfall is not equal in India, for example, annual rainfall of Jaisalmer is less than 9 cm whereas Mawsynram (near Cherapunji), has more than 1140 cm of yearly rainfall (IMD, 2005). This inter-annual variation of the summer monsoon rainfall clearly has an adverse effect on agriculture and allied activities. For example, the impact of the 2015 drought has been particularly large in the state of Maharashtra, India. The state faced unprecedented water scarcity and more than one thousand farmers committed suicide. Some of the studies have attributed this large deficit in rainfall as a manifestation of climate change.

With this in background, the present study focuses on the drought-hit areas of Satara District focuses Maharashtra state. At the time of drought period and later period of drought, the drought prone areas face various problems. The shortage of food and fodder, the want of drinking water and unemployment are some of the major problems. The Government of India and the State Government has taken various measures to overcome these problems. However, the problems and the sufferings of the people still continue. In order to solve these problems along with other problems of drought prone areas, it is very important to study this condition of drought prone area. The drought affected area is divided into two types by the Irrigation Commission. The amount of rainfall and its variability decides the types of drought affected area.

Drought is a damaging environmental disaster and affects more people than any other natural hazard (Wilhite and Glantz, 1985). There are numerous conceptual and operational drought definitions proposed according to different disciplinary perspectives (Heim, 2002). Fundamentally, drought is a temporary water supply deficit relative to some long-term average condition. Dracup and Lee (1980) and Wilhite and Glantz (1985) proposed a drought typology based on four distinct types, namely meteorological, agricultural, hydrological and socio-economic. The various drought types represent different stages of a continuous meteorological process and reflect the outlook of different sectors on water supply deficits (Smakhtin and Schipper, 2008). Although drought types occur at different timescales, they are intimately interrelated with each other: the longer the meteorological drought (lack of precipitation) is, the more likely other types of droughts (commonly agricultural and hydrological) will occur as a result (Carrão et al., 2016).

Meteorological drought results from the deficiency of rainfall, so precipitation is considered as a fundamental driver. Thus, many signs of drought monitoring are based on rainfall. The rainfall is primary source of water and it affects the situation of irrigation. The irrigation has great impact on the agricultural landuse. Thus, the rainfall has great concern with the agricultural landuse. Many indices have been used to study droughts across the world. Most of these indices require elaborate data of different parameters. While the computation of SPI needs a long term data on precipitation to decide the probability distribution function. Hence, SPI is recommended by WMO and many national hydrometeorological organizations across the world due to its simplicity and versatility. Further, SPI can be calculated for different monthly timescales (3, 6, 12, 24, and 48 months) to reflect the temporal behavior of drought. Based on these results, the type of drought can be defined.

In drought prone areas people face problems of shortage of food and water. The serious problem is shortage of drinking water and unemployment. It affects local migration and increases poverty. Satara district is marked as one of the drought districts of Maharashtra, particularly the eastern part of Satara district is designated as drought prone area. Out of 11 tahsils, 4 tahsils displays dominant drought characteristics and one tahsil (i.e., Koregaon) is partially affected by drought. The four tahsils of Khandala, Phaltan, Man and Khatav have low rainfall between 300 to 600 mm. Ground-water levels went down in these tahsils, so there is a need for more water in this area. With this in background, the present research study tries to understand the characteristics of droughts using SPI in four tahsils of Satara, namely Khandala, Phaltan, Man and Khatav.

Study area:

The drought prone area of Satara district lies in the eastern part of the district, between 17º39' N to 18º03' N latitudes and 74º 01'E to 74º54'E longitudes (Figure 1). It covers four tahsils namely Khatav, Man, Phaltan and Khandala. All these four tahsils are studied in the present research. The study area occupies an area of 4537.73 sq. km.

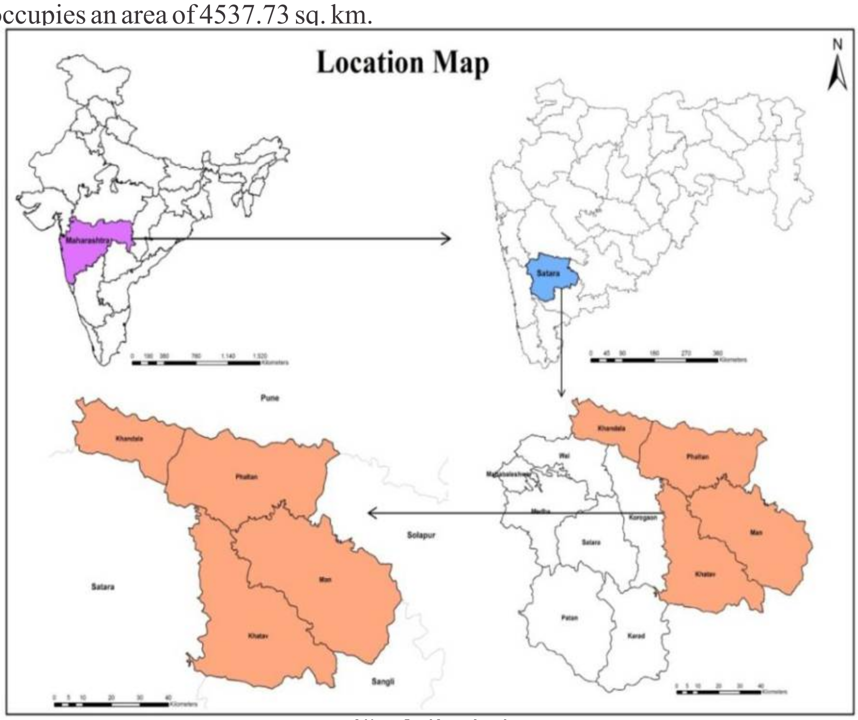

Fig. 1: Study Area

Objectives:

1. To understand the month-wise rainfall pattern in the study area.
2. To calculate month-wise SPI from 1951 to 2015 for the classification and explanation of the study area.

Methodology:

As the present study is mainly focused on the study of meteorological drought, monthly monsoon rainfall data (June–September) of 65 years were collected from the India Meteorological Department (IMD). Standardized Precipitation Index (SPI) developed by McKee et al. (1993, 1995) used in the present study requires only precipitation data and it also gives a better representation of abnormal wetness and dryness. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. Thus, the understanding that a shortage of precipitation has different effect on groundwater, soil moisture, reservoir storage, stream flow and snowpack has led to development of SPI (Mckee,; Doesken & Kleist, 1993).

For calculation of SPI, the four seasons of monsoon rainfall (June to September) were considered. The total seasonal rainfall was calculated for each year from 1951 to 2015. Conceptually, SPI is equivalent to the Z-score used in statistics and is expressed as:

$$\mathrm{SPI} = \frac{X - \mu}{\sigma}$$

Where, SPI is the Standardized Precipitation Index of a given time period

X is the precipitation total for the given time period

μ is the long-term precipitation mean

σ is the standard deviation

Since precipitation has a skewed distribution, the precipitation data was first transformed to a more Gaussian curve or transformed to a normal probability distribution. The procedure and formula for computation of SPI is as follows:

- The precipitation values is converted to log normal (ln) values and the statistics U, shape parameter (β) and scale parameter (α) of gamma distribution are computed with the help of following formulas: log mean=$\overline{X}\ln$

$$U = \overline{X}\ln - \frac{\Sigma \ln (X)}{N}$$

$$\beta = \frac{1 + \sqrt{1 + \frac{4U}{3}}}{4U}$$

$$\alpha = \frac{\overline{X}}{\beta}$$

- The resultant parameters are then used to find the cumulative probability of an observed precipitation event. The cumulative probability is given by:

$$G = \frac{\int_0^x x^{a-1} e^{\frac{-x}{\beta}} dx}{\beta^{\alpha} \Gamma(\alpha)}$$

- Since the gamma function is undefined for x = 0 and a precipitation distribution may contain zeroes, the cumulative probability becomes:

$$H(x) = q + (1 - q)G(x)$$

where 'q' is the probability of zero.

- The cumulative probability H(x) is then transformed to the standard normal random variable Z with mean zero and variance of one, which is the value of the SPI following Edwards and McKee (1997), with the help of graphical method.
- The approximate conversion of these graphical values is then done using the alternative provided by Abramowitz and Stegun (1965) as follows:

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \ldots \ldots \text{in case } 0 < H(x) \leq 0.5$$

$$Z = SPI = +\left(t - \frac{c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \ldots \ldots \text{in case } 0.5 < H(x) \leq 1$$

where,

$$t = \sqrt{\ln\left(\frac{1}{H(x)^2}\right)} \ldots \ldots \text{in case } 0 < H(x) \leq 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{1.0 - H(x)^2}\right)} \ldots \ldots \text{in case } 0.5 < H(x) \leq 1$$

The values of c0, c1, c2, d1, d2, and d3 given in the above equations are constants widely employed for SPI computation (Abramowitz and Stegun, 1965).

c_0=2.515517
c_1=0.802583
c_2=0.010328
d_1=1.432788
d_2=0.189269
d_3=0.001308

In the analysis obtained, positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. As the SPI is normalized, it is a better indicator for drought intensity assessment, where results can be further used to correlate with food grain productivity in future, particularly during dry monsoon years.

Analysis and Findings:

The SPI values for all the four months of the summer monsoon season from 1951 to 2015 were calculated and tabulated (Table 1.1).

Table 1 SPI of the Study Area

Sr. No.	Years	SPI values	Sr. No.	Years	SPI values
1	1951	-0.53	33	1983	-0.05
2	1952	-1.09	34	1984	-0.41
3	1953	-0.38	35	1985	-0.93
4	1954	-0.59	36	1986	-0.61
5	1955	-0.1	37	1987	-0.07
6	1956	-0.22	38	1988	0.55
7	1957	-0.24	39	1989	0.39
8	1958	-0.46	40	1990	-0.69
9	1959	0.07	41	1991	0.29
10	1960	0.61	42	1992	-0.39
11	1961	-0.03	43	1993	-0.71
12	1962	1.46	44	1994	-0.3
13	1963	-0.51	45	1995	-0.42
14	1964	0.81	46	1996	0.05
15	1965	-0.38	47	1997	-0.41
16	1966	-0.02	48	1998	0.65
17	1967	-0.09	49	1999	-0.02
18	1968	0.09	50	2000	-0.37
19	1969	0.42	51	2001	-0.6
20	1970	-0.74	52	2002	-0.98
21	1971	-0.33	53	2003	-1.63
22	1972	-1.67	54	2004	0.5
23	1973	0.51	55	2005	4.4
24	1974	0.35	56	2006	0.23
25	1975	0.27	57	2007	1.04
26	1976	0.08	58	2008	-0.07
27	1977	-0.13	59	2009	1.82
28	1978	-0.26	60	2010	0.89
29	1979	0.97	61	2011	-0.75
30	1980	-0.1	62	2012	-1.18
31	1981	1.06	63	2013	0.67
32	1982	-0.47	64	2014	0.14
			65	2015	-0.6

The table depicts the trends in SPI in the four month growing period of June-September over the four tahsils covered under the study region. The SPI values are also shown graphically in Figure 2. The figure indicates that out of 65 years, 40 years reflect negative Thus; the SPI values signify the predominance of drought characteristics in the study region. However, it should also be noted that there are high magnitude positive SPI values, thereby demonstrating the higher degree of rainfall variability in the region.

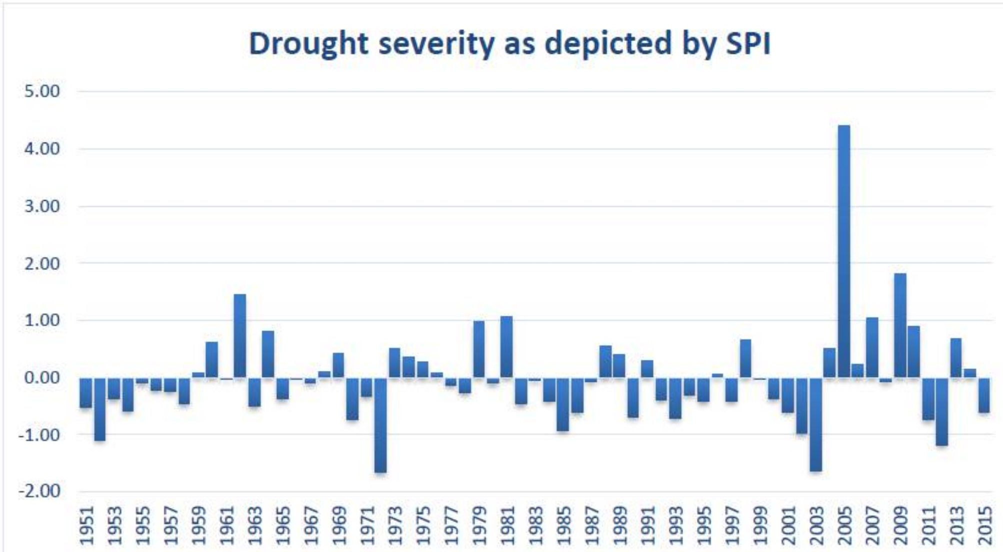

Fig. 2 SPI values from 195 to 2015

The SPI values are further classified according to its magnitude, showing the different categories of droughts, based on their severity (Table 2).

Table 2 Classification Scheme: Drought Severity Classification (Modified)

Category	Description	SPI
D0	No Drought	> -0.5
D1	Abnormally Dry	-0.5 to -0.7
D2	Moderate Drought	-0.8 to -1.2
D3	Severe drought	-1.3 to -1.5
D4	Extreme Drought	-1.6 to -1.9
D5	Exceptional Drought	Less than -1.9

In the present study, the tahsil-wise SPI values were also analysed and were tabulated according to the criteria given above for assessing the severity of droughts (Table 3).

Table 3 Number of Years in Different Categories of Drought (1951 To 2015)

Category	Khatav	Man	Khandala	Phaltan
D0	48	45	48	47
D1	3	4	3	7
D2	10	10	14	9
D3	1	3	0	1
D4	2	1	0	1
D5	1	2	0	0
	65	65	65	65

Conclusion:

In a span of 65 years (1951 to 2015), about 30 percent of years experience drought conditions in the four tahsils of Khatav, Man, Khandala and Phaltan. From the SPI values, we can conclude that most of the drought fall in D1 (abnormally dry) and D2 (moderate drought) categories.

In the study area, it is observed that abnormal drought conditions prevailed for seventeen years, moderate droughts were experienced for forty-three years, four years experienced extreme drought and three years experienced Exceptional drought condition. This analysis will thereby help in addressing the issue of droughts arising in the study region and can be further used in hazard management strategies.

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