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Temporal analysis of drought using standardized precipitation index for Wainganga sub-basin, India

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Abstract
Drought monitoring is a key component of drought preparedness and SPI is a very flexible tool to analyze drought at different time scales accurately. The present study aims to identify drought using Standardized Precipitation Index (SPI) for Wainganga sub-basin using rainfall data from India Meteorological Data (IMD) Pune, Maharashtra. Result from the analysis shows that the year 1972 was the year of severe and extreme drought for different time scales.

Keywords: Drought, standardized precipitation index, India meteorological data, Wainganga sub-basin

Introduction
The long term records of hydrological and meteorological observation are very essential component of water resource management, crop production as well as for economic status. Climate irregularities are detected in many places over the world resulting in erratic precipitation, temperature variation and sometimes combination of above introducing natural hazards like drought, floods etc. Present study focuses on drought characteristics of the study area.

Drought is universally observed as a natural hazard of countless severity that can happen under any climatic condition. It is differentiated from other natural disasters because its implications lack structure and disperse in vast geographical regions (Καραμπατάκης, Θ. Μ.2017) [9]. Drought can be defined in a number of ways. In general terms, drought is a “prolonged absence or marked deficiency of precipitation”, a “deficiency” that results in water shortage for some activity. According to the India Meteorological Department (IMD), an area or region is considered to be under drought, if it receives total seasonal rainfall less than 75% of its normal value. There are several indices to evaluate drought. Many drought indices are available to analyze drought but standardized precipitation index (SPI) is generally used to evaluate meteorological drought quantitatively due to its simplicity and capability for calculating drought at different timescale. But, for precise result long term rainfall data is required.

Material and Method
Study area- The Wainganga sub-basin is part of Godawari basin which lies between latitude of 19°60′ to 22°07′ N and longitude of 78°00′ to 81°00′ E at an elevation which ranges from 146 to 1048 m above mean sea level. The study area covers an area of 43,658 km^2.

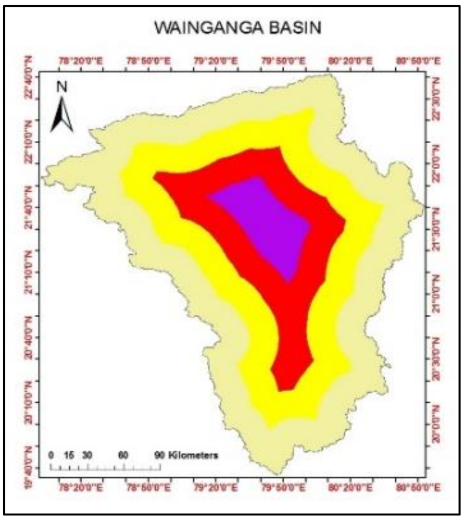

Fig 1: Location Map

Standardized Precipitation Index (SPI)

The SPI method was introduced by McKee *et al*. in 1993[5] in University of Colorado. This effort was accomplished by quantifying the rainfall deficit at multiple time scales. More specifically, McKee *et al.* (1993) [5] estimated the SPI for the time scales of 3, 6, 12, 24, and 48 months. Short time scales (not more than 3 months) are suitable to reveal the effect of drought on soil moisture, snowpack, and stream flows of small rivers; medium term aggregated values (3–12 months) are appropriate to evaluate the drought on stream flow and reservoir storage however long time scales (12–24 months) can be used for long-term processes (e.g. groundwater recharge) (SPInoni *et al*, 2013) [7]. Therefore, this multi-temporal approach of SPI provides “a macroscopic insight of the impacts of drought on the availability of water resources” (Angelidis *et al*., 2012; Καραμπατάκης, Θ. Μ.2017) [2, 9]. The advantage of SPI is, it needed only precipitation data and can be used for both dry and rainy seasons while some indices using specific data as per designed. It can describe drought conditions that are important for a range of meteorological, agricultural, and hydrological applications. Studies have shown that the SPI is suitable for quantifying most types of drought events (Guenang & Kamga, 2014) [2].

The computation of standardized precipitation index consists of following steps:

(1) Calculation of the mean for the normalized precipitation values of the log-normal (L_n) rainfall series and computation of the shape and scale parameters β and α respectively by the equation given here under,

Log mean $$\overline{X}_{\ln} = \frac{\sum \ln X}{N} \qquad \dots \text{(i)}$$

Shape parameter $$\beta = \frac{1}{4U}\left[1+\sqrt{\frac{4U}{3}}\right] \qquad \dots \text{(ii)}$$

Scale parameter $$\alpha = \frac{\overline{X}}{\beta} \qquad \dots \text{(iii)}$$

Here, U is the constant $U = \ln\left(\overline{X}\right) - \overline{X_{\ln}}$

(2) The resulting parameters are then used to find the cumulative probability of an observed precipitation event for the given month and time scale for the station in equation. The cumulative probability as given by gamma distribution is as follows:

$$G(x) = \frac{1}{\alpha^{\beta}\Gamma\beta}\int_0^x x^{\beta-1} e^{\frac{-x}{\alpha}} dx \qquad \dots \text{(iv)}$$

Letting $t = \frac{-x}{\alpha}$, this equation becomes the incomplete gamma function;

$$G(x) = \frac{1}{\Gamma\beta}\int_0^{t\alpha} t^{\beta-1} e^{-t} dt \qquad \dots \text{(v)}$$

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

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

Where, q is the probability of a zero.

Thom (1966) [8] states that q can be estimated by m/N where m is the number of zero in a precipitation time series. He used the table of the incomplete gamma function to determine the cumulative probability G(x). McKee *et al*. (1993) [5] used an analytic method to determine the cumulative probability.

The cumulative probability H(x) is then transformed to the standard normal random variable Z with mean zero and variance one, which is the value of the SPI.

The Z or SPI value can be easily obtained computationally using an approximation provided by Abramowitz and Stegun, (1965) that convert cumulative probability to the standard normal random variable Z.

$$Z = SPI = -\left[t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 d_3 t^3}\right] for 0 < H(x) \le 0.5 \cdots \text{(vi)}$$

$$Z = SPI = +\left[t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 d_3 t^3}\right] for 0.5 < H(x) \le 1.0 \quad \dots \text{(vii)}$$

Where,

$$t = \sqrt{\ln\left\{\frac{1}{(H(x))^2}\right\}} for 0 < H(x) \le 0.5 \qquad \dots \text{(viii)}$$

$$t = \sqrt{\ln\left\{\frac{1}{(1-H(x))^2}\right\}} for 0.5 < H(x) \le 1.0 \qquad \dots \text{(ix)}$$

$c_0 = 2.515517$, $c_1 = 0.802853$ and $c_2 = 0.010328$
$d_1 = 1.432788$, $d_2 = 0.189269$ and $d_3 = 0.001308$

Negative value of SPI shows the drought occurrence anytime until it becomes positive. In order to evaluate the drought severity in different areas using SPI, one of the most commonly used classifications presented by (Hayes *et al*. 1999) [3] is given in table 1.

Table 1: Standard ranges of SPI values and their classification

S. No.	SPI	Classification
1.	≥ 2.0	Extremely wet
2.	1.5 to1.99	Very wet
3.	1.0 to 1.49	Moderately wet
4.	-0.99 to 0.99	Near normal
7.	-1.0 to -1.49	Moderate dry
8.	-1.5 to -1.99	Severe dry
9.	≤ -2.0	Extreme dry

Results

The analysis shows the drought severity at 1, 3, 6, 9 and 12 month time scale for Wainganga sub-basin, India. For the present study the last month of Indian summer monsoon i.e. September month was selected for calculating SPI for above monthly time as negative SPI values in the wet season will indicate drought throughout the year (Palchaudhuri & Biswas, 2013) [7].

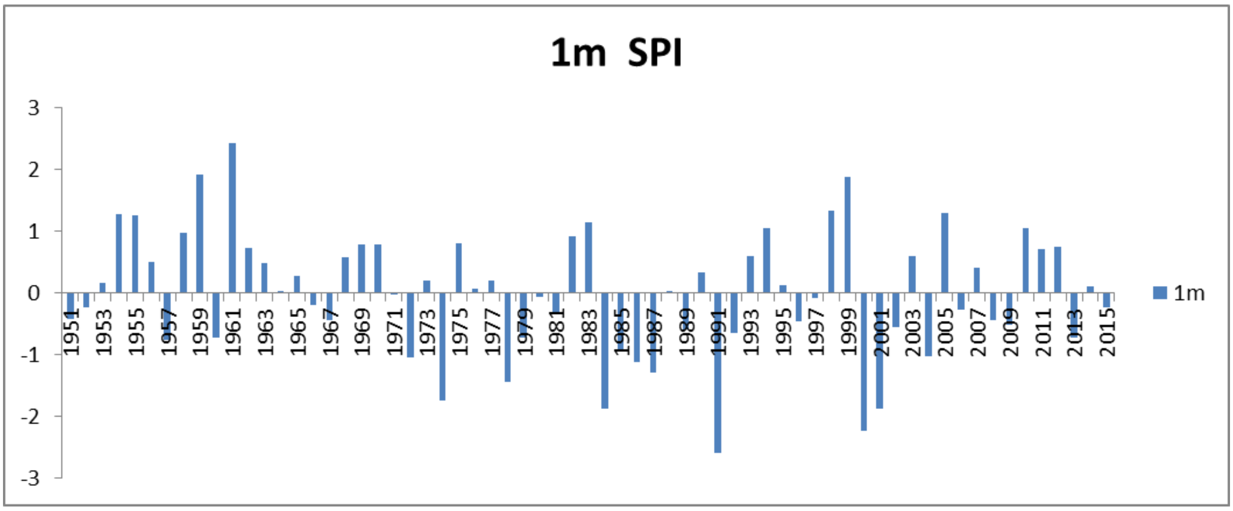

Fig 2: 1m SPI

1m SPI: Figure 2 shows 1m SPI value from for the studied period of 55 years. The result shows that 36 years comes under normal category while 2 years i.e. 1991 and 2000 were under extremely dry condition. Four years which are 1972, 1978, 1986 and 2004 were affected by moderate drought. The years 1974, 1984 and 2001 were under severe dry condition. Seven years, two years and 1 years over the study period comes under moderate wet, very wet and extreme wet condition according to classification respectively.

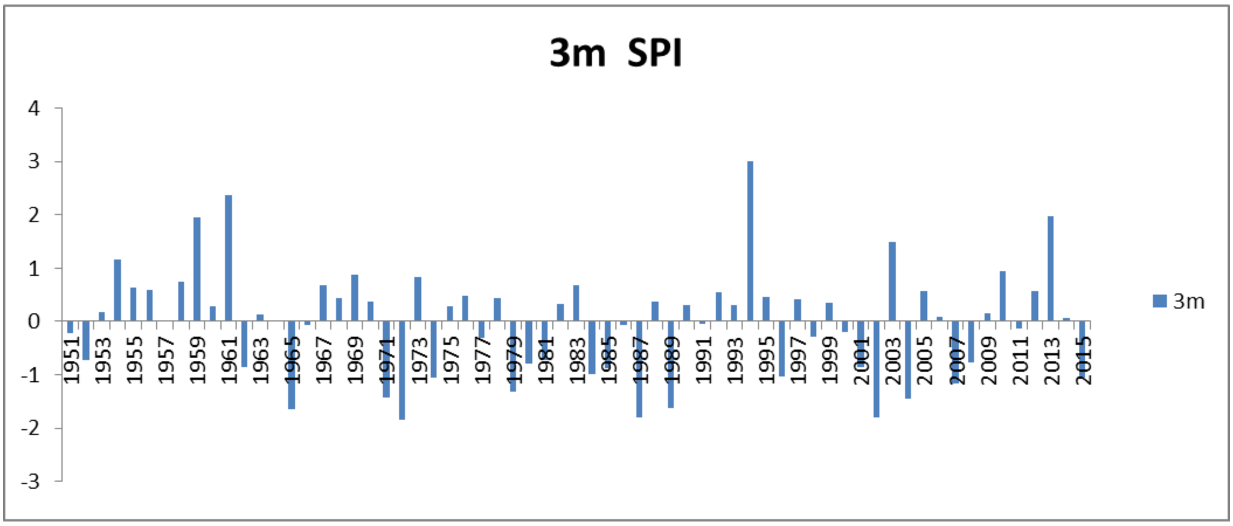

Fig 3: 3m SPI

3m SPI: 3m SPI value from figure 3, indicates that the SPI values ranges from -0.99 to 0.99 for 37 years that comes under normal condition. In the study 6 moderate drought and 6 severe droughts event was experienced but the occurrence of extreme drought event was not justified. Moderate wet, very wet and extreme wet events were experienced 2 years each.

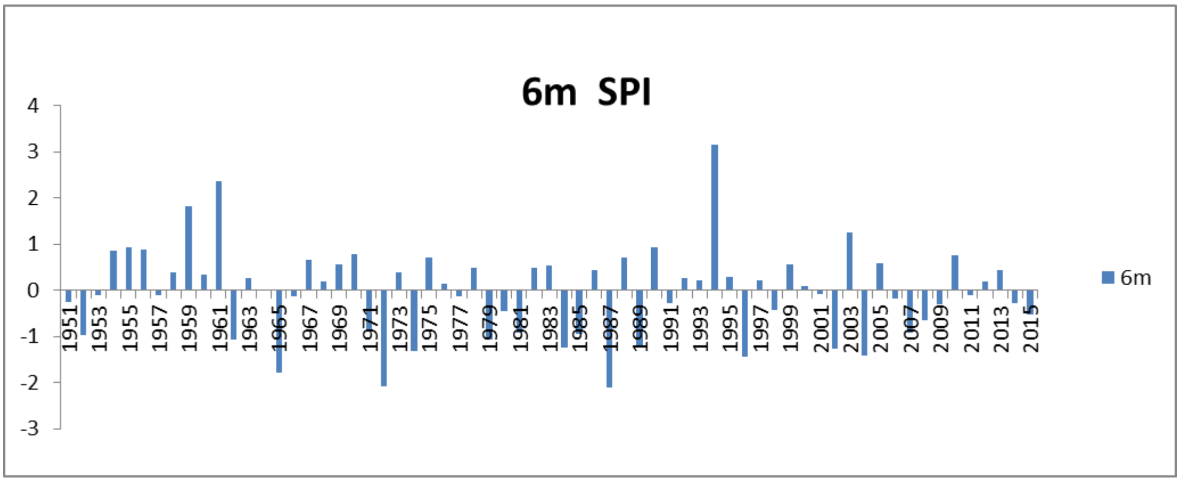

Fig 4: 6m SPI

6m SPI: 6m SPI results as shown in figure 4 reflects that in the study area 40 years were normal years that means the rainfall received during these years did not deviate much from normal annual rainfall. Eight years, one year and two years over the study period comes under moderate dry, severe dry and extreme dry condition respectively whereas four years were under wet condition with maximum positive SPI value of 3.14 in 1994.

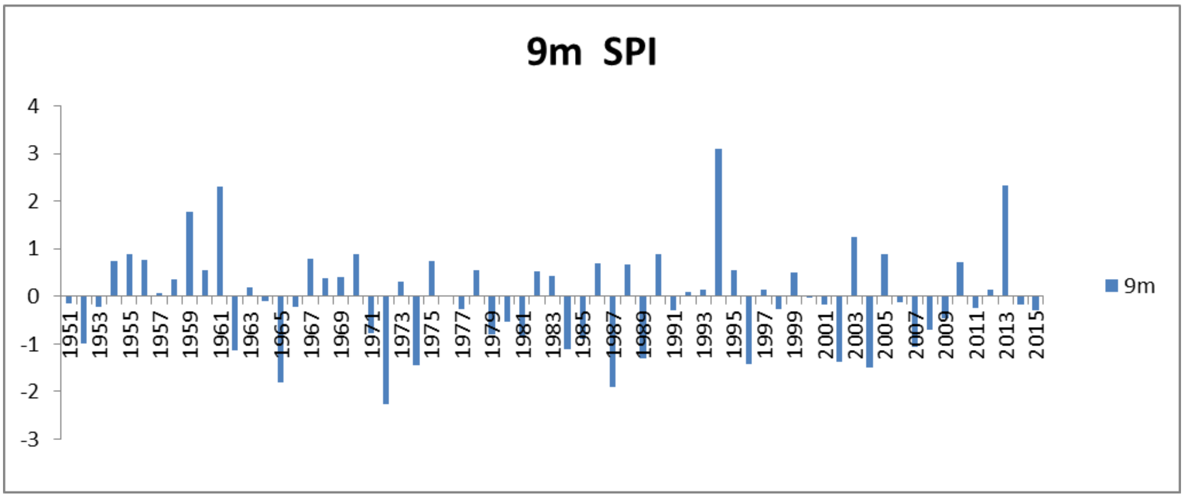

Fig 5: 9m SPI

9m SPI: 9m SPI results shows the total 12 drought events happened under which one year was extremely dry with SPI value -2.26 (1972) and 2 years were severely dry in the years 1965 and 1987. 9m SPI reveals that there were 5 wet years over the study period and 38 years were having normal rainfall (Figure-5).

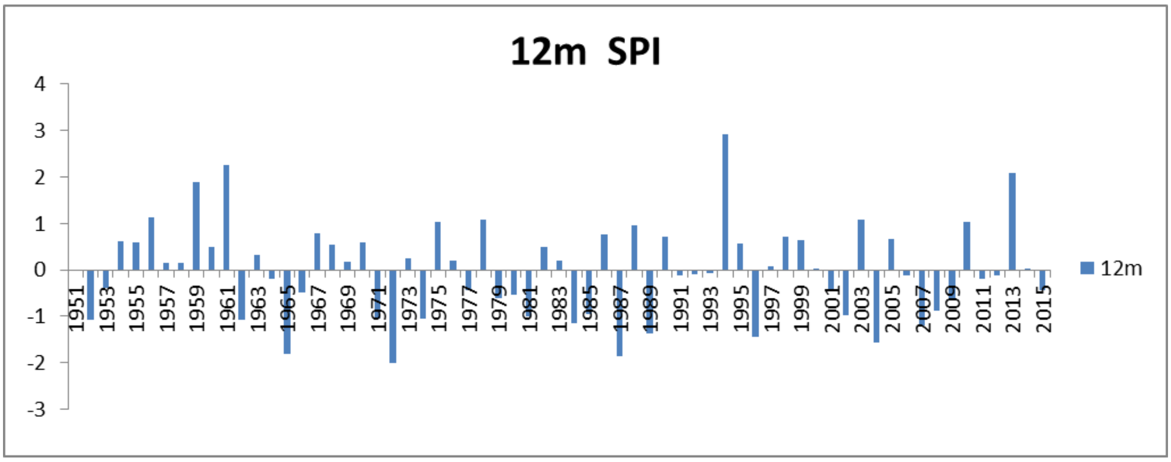

Fig 6: 12m SPI

12m SPI: For the study period of 55 years 12m SPI value as shown in figure 6, shows that 31 years had normal precipitation. Nine years, four years and three years were affected by moderate drought, severe drought and extreme drought respectively. The years 1956, 1975, 1978, 2003 and 2010 were under moderate wet condition. The years 1959 comes under very wet and three years extreme wet condition with maximum SPI value 2.92 in 1954.

Conclusion

The present study tries to identify the temporal extent of drought over Wainganga sub-basin using SPI for duration of 55 years i.e. from 1961 to 2015 using SPI. SPI is a powerful as well as flexible tool to monitor drought at different time scales exactly. From the study it was concluded that for each time scale shows more than 30 years over 55 years have normal rainfall while each time scale for the year 1972 shows the occurrence of drought event. The result of 1m SPI shows that 2 years i.e. 1991 and 2000 comes under extremely dry condition while in 1972 there was severe drought. The results of 3m, 6m, 9m and 12m SPI shows the extreme dry condition in year 1972 which was also justify the findings of Ladejinsky (1973) [4].

References

1. Abramowitz M, Stegun IA. Handbook of mathematical functions: with formulas, graphs, and mathematical tables. Courier Corporation, 1964, 55.
2. Angelidis P, Maris F, Kotsovinos N, Hrissanthou V. Computation of drought index SPI with alternative distribution functions. Water resources management 2012; 26(9):2453-2473.
3. Guenang GM, Kamga FM. Computation of the standardized precipitation index (SPI) and its use to assess drought occurrences in Cameroon over recent decades. Journal of Applied Meteorology and Climatology. 2014; 53(10):2310-2324.
4. Hayes MJ, Svoboda MD, Wiihite DA, Vanyarkho OV. Monitoring the 1996 drought using the standardized precipitation index. Bulletin of the American meteorological society. 1999; 80(3):429-438.

5. Ladejinsky W. Drought in Maharashtra (Not in a Hundred Years). Economic and Political Weekly. 1973, 383-396.
6. McKee TB, Doesken NJ, Kleist J. The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference on Applied *Climatology*. Boston, MA: American Meteorological Society. 1993; 17(22):179-183.
7. Palchaudhuri M, Biswas S. Analysis of meteorological drought using Standardized Precipitation Index: a case study of Puruliya District, West Bengal, India. International Journal of Environmental Earth Science and Engineering. 2013; 7(3):6-13.
8. SPInoni J, Antofie T, Barbosa P, Bihari Z, Lakatos M, Szalai S *et al*. An overview of drought events in the Carpathian Region in 1961–2010. Advances in Science and Research. 2013; 10(1):21-32.
9. Thom H Some methods of climatological analysis. WMO Technical Note Number 81, Secretariat of the World Meteorological Organization, Geneva, 1966, 53
10. Καραμπατάκης Θ, M Drough analysis using meteorological drought indices, in Thessaly region, Greece (Master's thesis), 2017.