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ON THE USE OF STANDARDIZED PRECIPITATION INDEX TO UNDERSTAND DROUGHT PATTERNS

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Abstract

Drought, as a multifaceted natural hazard, poses significant challenges due to its slow onset and complex spatio-temporal variability. Drought indices are an attempt to quantify and capture the severity of drought on the landscape by using rainfall data. This research explores the characterization of meteorological drought in Maharashtra, India, during the Southwest Monsoon of 2015, utilizing the Standardized Precipitation Index (SPI). SPI, acknowledged as a universal and effective tool for drought assessment, provides a comprehensive analysis of both wet and dry periods. The study spans 35 years (1980–2015) and examines 33 meteorological stations across Maharashtra. Monthly precipitation data of 2015 was employed to calculate SPI, revealing the spatial and temporal progression of drought severity as experienced over the state during 2015. The analysis, focusing on June to September 2015, indicates significant spatial and temporal variations in rainfall distribution, impacting agricultural regions differently. The findings highlight the utility of SPI in assessing drought severity, offering valuable insights for drought mitigation and water resource management.

Keywords*: Drought index, Standardized Precipitation Index, 2015 summer monsoon, spatio-temporal variability*

1. Introduction

Drought is a slow-onset creeping natural hazard and a recurrent phenomenon. It is considered by many to be the most complex and least understood of all-natural hazards, affecting more people than any other hazard. In general, large-scale spatio-temporal variability in timing and duration of drought impact hinders a universal definition of drought. The definition and identification of droughts has been the object of many studies. Wilhite and Glantz (1985) reviewed more than 150 published definitions and grouped them into four types – meteorological (lack of precipitation), agricultural (lack of root zone soil moisture), hydrological (drying of surface water storage) and socio-economic (lack of water supply for socio-economic purpose). There is an agreement among authors that there is no universally accepted definition of drought (Tate and Gustard, 2000). According to recent studies and investigations, droughts should be defined as a natural but temporary imbalance of water

availability, consisting of a persistent lower than average precipitation, resulting in diminished water resources availability (Paolo and Pereira, 2006).

In India, several studies related to drought using drought indices based on rainfall data have been carried out. These studies mainly dealt with droughts during the southwest monsoon season (June–September), which is the primary rainfall season that contributes about 75–90% of the total annual rainfall over most parts of the country. Ramdas (1950) defined drought as the condition when weekly rainfall is half of normal or less. Based on subdivision-wide areas, Banerji and Chabra (1964) found that severe drought conditions in the state of Andhra Pradesh, India coincided with the Percent of Normal values of less than 50%. Appa Rao (1991) classified the drought-prone areas and chronically drought-affected areas and found that most of the drought-prone areas were either in arid or in semiarid regions where droughts occur more frequently. Using long time series (1875–1987) of subdivision rainfall data over India, Chowdhury et al. (1989) examined various statistical features of country-wide drought incidences.

Meteorological drought often precedes and causes other types of droughts. It is a period of months to years with below-normal precipitation and often accompanied with above-normal temperatures. Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region (Sivakumar et al. 2011). India Meteorological Department had defined meteorological drought as a condition when there is significant (more than 25 per cent) decrease from normal precipitation over an area. Meteorological drought is most often expressed in terms of rainfall in relation to some average amount and the duration of the dry period and can be defined as a period with a lack of precipitation or with rainfall lower than average, lasting sufficiently to cause hydrological and agricultural hazards.

In 2007, one of the research studies, Patel et al. (2007) has investigated the usefulness of the Standardized Precipitation Index (SPI) in characterizing the spatio-temporal variability of seasonal drought events in Gujarat. SPI is the one of the most important indices used for drought monitoring throughout the world. It has a universal application and helps in the study of all types of drought. It was developed by American scientists McKee, Doesken and Kleist Standardized Precipitation Index (SPI) at Colorado State University, 1993. Precipitation is the only parameter required for its computation. It is effective in analyzing wet periods/cycles as

well as analyzing dry periods/cycles. On 11th December 2009 the "Lincoln Declaration on Drought Indices" was signed and the Standardized Precipitation Index (SPI) was declared as an effective tool for meteorological droughts study around the world by the WMO, US National Drought Mitigation Centre (NDMC) and NOAA at university of Nebraska, USA (Sivakumar et al. 2011). Hence, the present study focuses on studying meteorological drought that occurred during 2015 using Standardized Precipitation Index. One of the states in India that was severely affected by 2015 drought was Maharashtra. Thus, the research aims at understanding the spatial and temporal characteristics of droughts during southwest monsoon 2015 over different parts in Maharashtra.

2. Data and Methodology

Daily precipitation data (June to September) were collected for 33 stations (whose long-term data was available) over the state of Maharashtra from the India Meteorological Department for a period of 35 years (1980 – 2015). These 33 stations were well distributed throughout the state of Maharashtra (Fig.1).

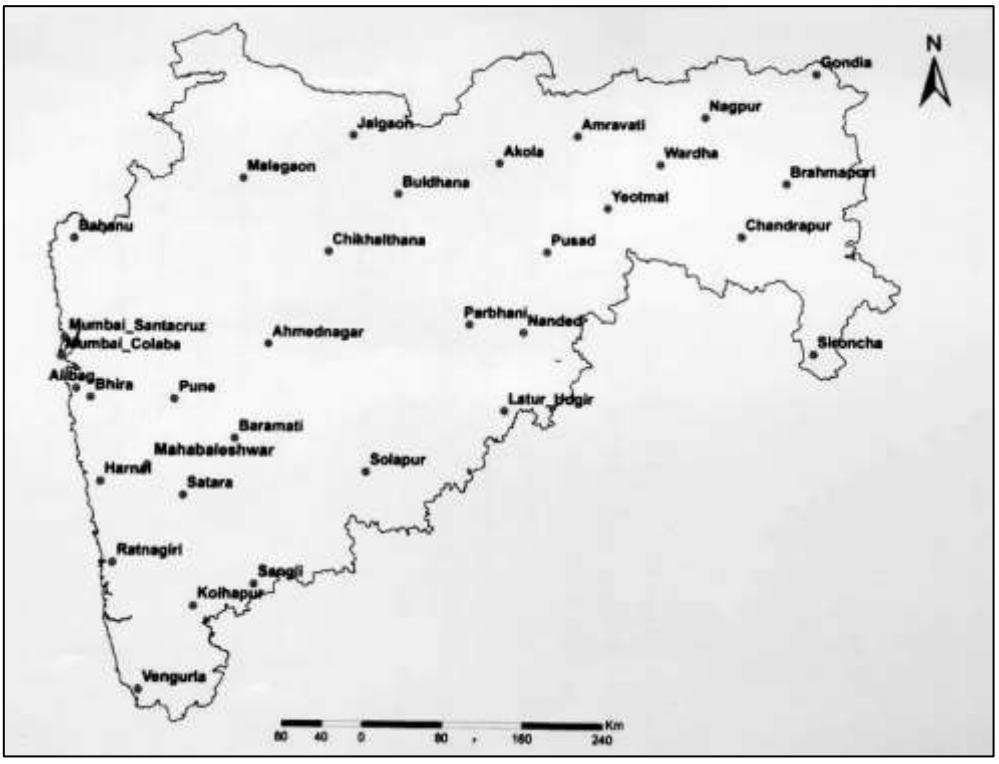

Fig. 1: Study area showing the locations of rain-gauge stations

From the daily precipitation values obtained from 33 stations, monthly totals and their climatological means were found out. Using these totals, Standardized Precipitation Index (SPI) was computed using the following formula:

$$SPI = (X - Xm) / \sigma \quad (1)$$

Where,

X = Actual monthly precipitation during 2015

Xm = long-term monthly mean (1980 – 2015)

σ = long-term standard deviation (1980 – 2015)

Using the computed SPI values, each station was categorized into different classes as given in Table 1.

Table 1: Classification of SPI

SPI Values	Classification
Less than -2.0	Extremely Dry
-1.50 to -1.99	Severely Dry
-1.00 to -1.49	Moderately Dry
-0.99 to 0.99	Normal
1.00 to 1.49	Moderately Wet
1.50 to 1.99	Severely Wet
More than 2.0	Extremely Wet

3. Results and Discussion

The rainfall distribution during monsoon 2015 not only varied spatially but also depicted wide range of temporal variability. All the summer monsoon months (June to September) were analyzed to get the temporal variation in rainfall and consequently the progression of drought was assessed. As standardized precipitation index (SPI) is the most reliable index, our major focus was calculating and obtaining accurate SPI for this study. Huge amount of variability in drought severity was seen between all the months i.e. June, July, August, and September.

3.1 Analysis of June month

The onset of monsoon over Maharashtra occurs somewhere in the second week of June. After a long dry summer season, farmers are eager to get enough rains in June, so that crop sowing can be started. From Fig. 2, it is clear that during 2015 Maharashtra received normal amount of summer monsoon rainfall, which in tuen proved to be very beneficial for cultivation of crops, particularly after the drought conditions experienced in the earlier year of 2014. Northern Konkan and Northern Madhya Maharashtra and some part of Vidarbha even experienced extremely wet conditions. However, it can be also seen from Fig. 2 that Marathwada region

experienced moderately dry conditions, which would have adversely affected the water levels of the region.

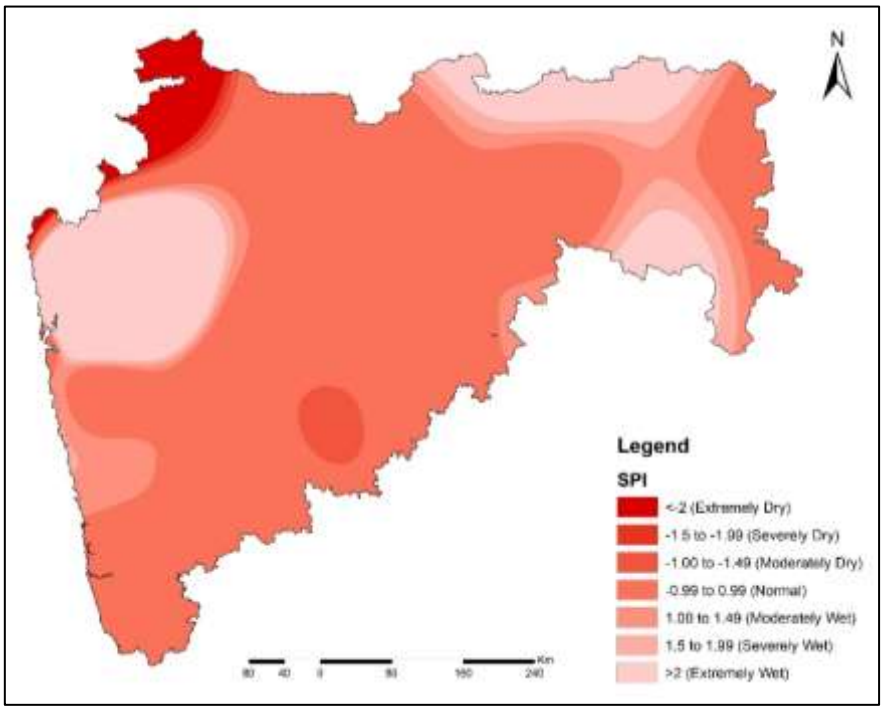

Fig. 2: SPI Map of Maharashtra for June 2015

3.2.2 Analysis of July month

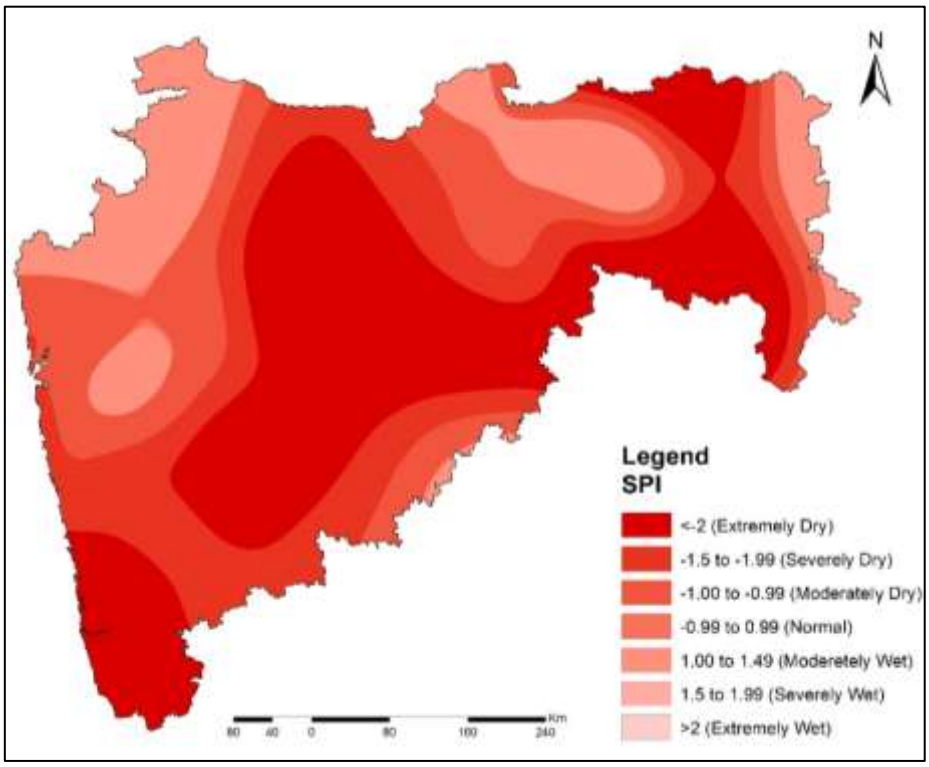

Fig. 3: SPI Map of Maharashtra for July 2015

With the end of June month, monsoon has arrived over the whole Maharashtra. July is the principal month which receives the highest amount of rains during the monsoon season. The entire agricultural mechanism of the state depends on the rains received in July. But, by observing Fig. 3, it is clearly evident that the entire state of Maharashtra was grappled by dry conditions during July 2015. Southern Konkan, Northern Madhya Maharashtra, Marathwada and some part of Vidarbha experienced extremely dry condition. The contiguity of the spatial extent of extreme dry conditions is clearly apparent, whereby it can be inferred that July 2015 experienced much below normal rains.

3.2.3 Analysis of August month

Fig. 4 depicts that August rains were inefficient in coping with the drought conditions produced during July. Extremely Dry conditions continued to prevail over Konkan, Madhya Maharashtra and some part of Marathwada, especially in Nanded. A pleasant scenario could be identified in the Vidarbha region, which experienced normal rainfall conditions in most of its districts, except its eastern part near Sironcha that experienced moderately dry.

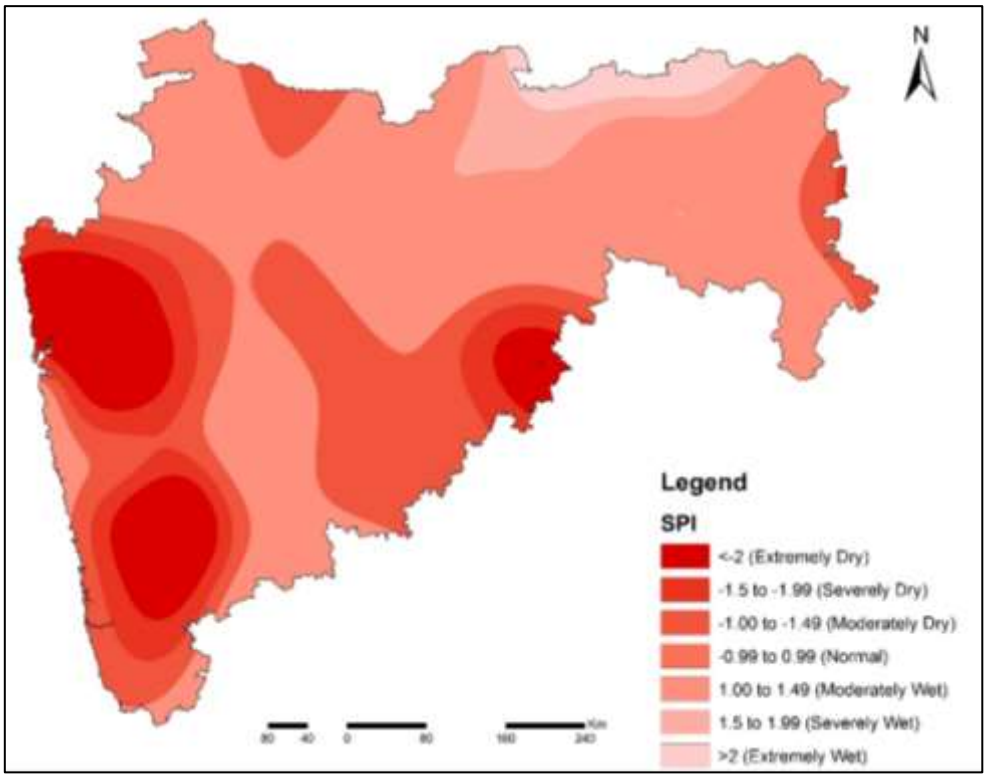

Fig. 4: SPI Map of Maharashtra for August 2015

3.2.4 Analysis of September month

September is the last month for the south-west monsoon. The monsoon activity revived to some extent during September 2015 (Fig. 5). The September SPI map indicates that the region

dominated earlier by extremely dry conditions had reduced in extent. Normal to extremely wet conditions were observed in Marathwada, Vidarbha and Madhya Maharashtra regions. Thus, the month of September provided some relief to the drought-affetced areas of Maharashtra. However, extremely dry conditions continued to pervade over some parts of Northern Konkan and North Madhya Maharashtra region. Thus, it can be concluded that summer monsoon rainfall of 2015 over Konkan meteorological subdivision was extremely deficient during the entire season.

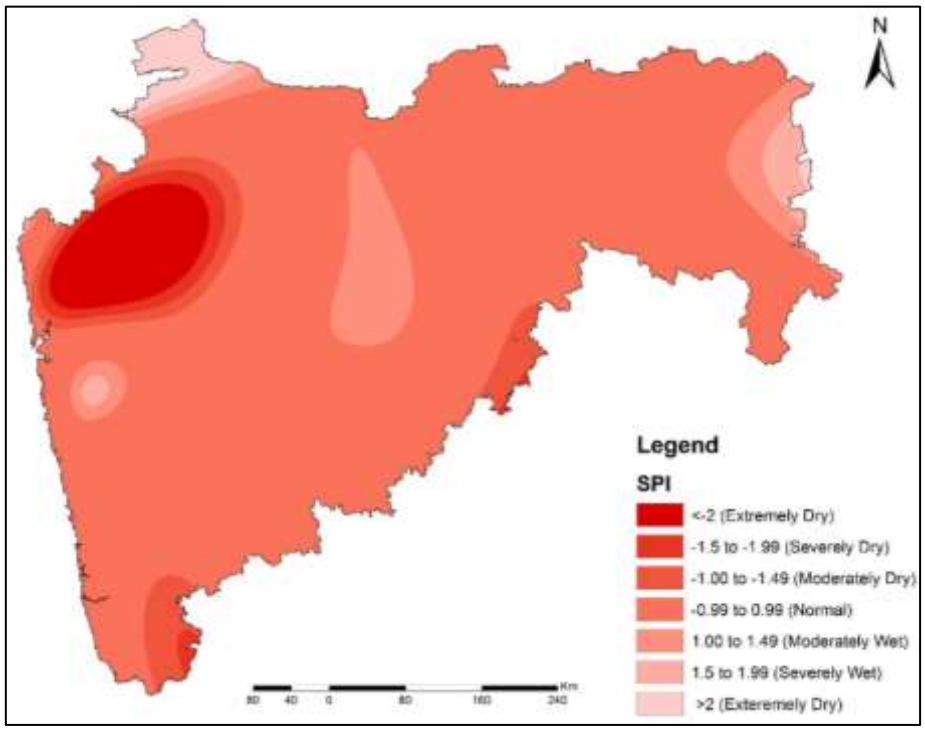

Fig. 5: SPI Map of Maharashtra for August 2015

4. Conclusion

Drought is a period of below-average precipitation in a given region, resulting in prolonged shortages in its water supply, whether atmospheric, surface water or ground water. A drought can last for months or years, or may be declared after as few as 15 days. In this paper, we have analyzed the monthly progression of 2015 drought that affected various regions of Maharashtra. The research highlights the usefulness of Standardized Precipitation Index (SPI) in characterizing meteorological drought. The study, spanning over three decades, provides a comprehensive analysis of precipitation patterns using SPI, revealing substantial variations in drought severity across the state. The monthly analysis of June to September 2015 highlights the temporal progression of drought, with July experiencing exceptionally dry conditions. Insights gained from this study contribute to a better understanding of drought dynamics,

informing policymakers, researchers, and stakeholders involved in water resource management and agricultural planning in drought-prone regions like Maharashtra.

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