Analyzing the translation from Metrological to Hydrological Drought for Wainganga River of Central India

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Abstract

Drought is one of the most devastating climate related hazards, occurs when water availability is significantly below normal level during a significant period of time. The present study deals with precipitation anomalies and its translation to runoff anomalies. There are number of processes which influences the development and recovery of hydrological droughts. This study contrasts the behavior of standardized runoff index (SRI) with well-known standardized precipitation index (SPI) during drought events for Wainganga River of central India. 50 years (1965 – 2015) of discharge and precipitation data was used for this study. Using threshold level method, drought characteristics such as precipitation and runoff deficits were derived. The study considered on both catchment-controlled and climate-controlled drought propagation characteristics. However, the SRI and SPI are similar i.e. both are built on long accumulation periods. The SRI includes hydrologic processes that determine seasonal lags due to the effect of climate on streamflow. Therefore, for monthly and seasonal time scales, the SRI is beneficial to depicting hydrologic aspects of drought. Variability of these characteristics over the course of time was also analyzed. Results show a dominance of climate controlled characteristics on drought propagation.

***Key Words*:** Drought propagation, SPI, SRI.

1. Introduction

Drought is insidious disaster among extreme climate events that affect society, economy, social life and agricultural sector (Mishra and Singh, 2010). Drought differs from other natural disasters as it is difficult to locate a drought in time. Definition of drought have been proposed in many ways (Mishra and Singh, 2010) such as a sustained, extended deficiency in precipitation (WMO, 1986), the percentage of years when crops fail from the lack of moisture (FAO, 2002), and a significant deviation from the normal hydrologic conditions of an area (Palmer, 1965). No single definition applies to all circumstances, however, most of these definitions are based on an expression of deficiency in precipitation leading to water shortage.

In recent years, droughts have gained huge attention from society and policymakers also research on droughts has made appreciable process. Water resource planners bank upon the quantitative indices to decide the existence of drought or drought-like conditions in an area. Impact of droughts firstly reflects upon agricultural sector and then gradually on other water-dependent sectors. Risk of droughts is a major concern in many parts of India especially in arid and semiarid regions such as Madhya Pradesh (Figure 1) where climatic conditions are extremely variable spatially as well as temporally. The combination of precipitation deficits with other climatic factors risks for severe drought conditions in central India where agriculture is the main occupation for most of the population. Drought impact in central India is extensive, affecting agriculture, irrigation, and economy. This study investigates the susceptibility of Wainganga River of Central India (Vidharb region) towards the droughts due to precipitation deficits.

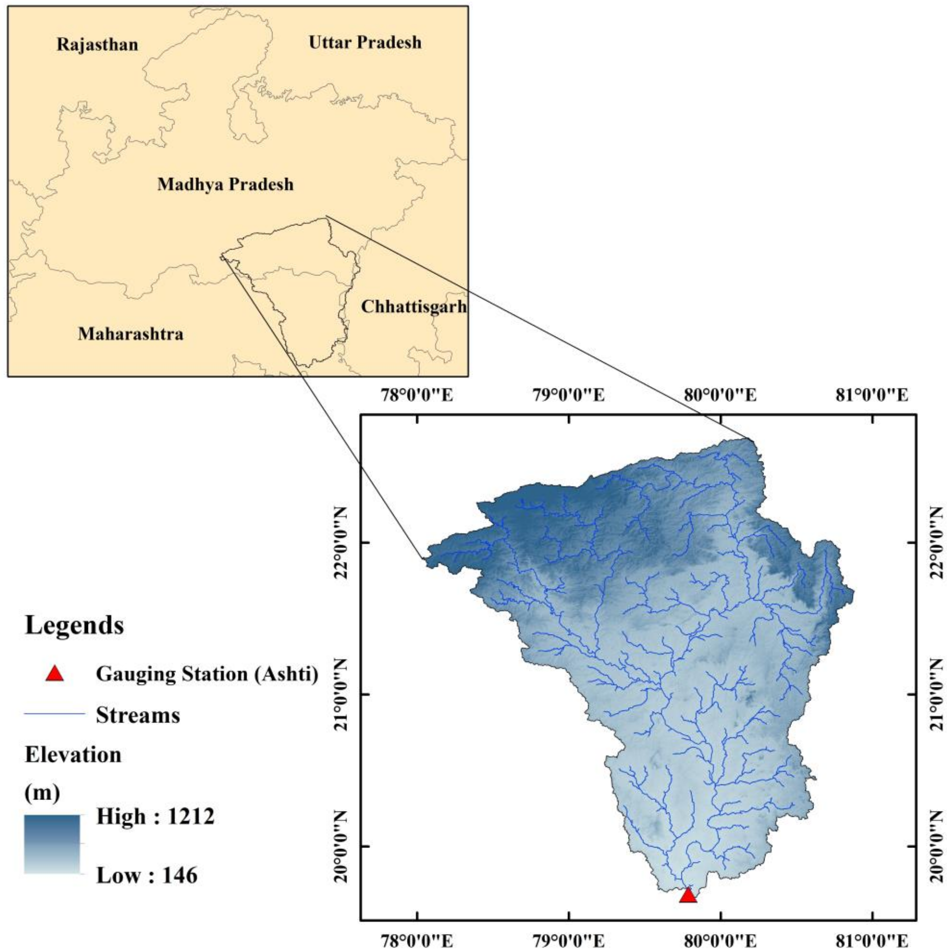

Figure 1: Location map of study area

Droughts are largely driven by changes in climatic conditions, such as low precipitation, which develops slowly and can last months, even years (Tallaksen and van Lanen, 2004). The lack of a formal definition of drought (Wilhite et al., 2007) in combination with the difficulty in investigating its development in a region over a course of time, have resulted in classification of drought indices based on event type (for example, hydrological drought: PDSI, SRI; meteorological drought: SPI; groundwater drought: SGI (Bloomfield and Marchant, 2013)). The term "*Hydrological Drought*" generally refers to the negative anomalies in surface and subsurface water. There are a many underlying processes which affects the development and recovery of hydrological droughts. Occurrence of a hydrological drought is much more complex, as it dependent not only on the atmosphere, but also on the other hydrological processes causing moisture depletion, storage of water and runoff to the streams (Mishra and Singh, 2010).

2. Data

Daily observed precipitation dataset gridded at a resolution of 0.25° × 0.25° for the time period 1965 to 2015 was provided by Indian Meteorological Department (IMD). Precipitation dataset was used for the estimation of SPI values on time steps of 1-, 3-, 6-, 12-, and 24- months. Total 74 rainfall grid are found to be falling within the study area. Daily runoff dataset was downloaded from Water Resources Information System: India (WRIS: India) for the time period 1965 to 2016. Stream gauging station named Ashti is located in Gadchiroli district of Maharashtra at 141.42 msl, where the stream width is 760m.

3. Method

3.1. Standardised Precipitation Index (SPI)

The response of different water storages in hydrological system remarkably varies temporally on the amount of precipitation deficit. While the response of soil moisture is immediate, reservoirs, streamflow and groundwater shows delay in the impact. McKee et al. (1993) developed index called Standardized Precipitation Index (SPI), which quantifies long-term precipitation anomalies on multiple time steps. Standardized precipitation is calculated by dividing the difference of precipitation from the long term mean by the standard deviation, where the mean and standard deviation are determined from long term past records. This standardized precipitation was then normalized to reflect the variable nature of the precipitation and SPI values were obtained.

3.2. Standardised runoff Index (SRI)

SRI works on the concept of SPI of McKee et al. (1993) as the unit standard normal deviate associated with the percentile of hydrologic runoff cumulated for a specific duration. The procedure for calculating SPI and SRI include following steps: (1) Runoff observed, and a probability distribution is fit to the sample represented by the time series values. (2) The distribution is used for the estimation of cumulative probability of the runoff. (3) The cumulative probability is converted to a standard normal deviate.

4. Analysis and Results

Behavior of the SPI and SRI using observed average precipitation and observed runoff in the catchment of Wainganga River. Figure 2 shows the monthly time series of the indices at five different time step (1-, 3-, 6- , 12- and 24- month) for the years 1965–2015. The 6-month SPI and SRI values are very similar due to the high correlation between semiannual precipitation and stream flow (R^2 = 0.8112). The differences between the SPI and SRI index values increases as the time step decreases. SPI to SRI correlation values dropped from 0.81 for the 6-month period to 0.77 and 0.68 for the 3-, and 1-month period. At shorter time steps, the SRI is less variable than the SPI due to detention of moisture in soil which regulates streamflow. The 12-month indices both SPI and SRI integrate over an entire water year. A long accumulation, however refer to values that are based on earlier events and that are influencing current land surface conditions. For example, a hydrological deficit event of early 1988 (SRI = -1.813) seems to be a response of 1-, 3- and 6-month precipitation deficits of 1987 (i.e., SPI = -0.64, -0.92 and -1 respectively).

SRI shows a complete sync with SPI at all points and at every time step. Pooling of different meteorological drought events to form a hydrological drought can be seen may times in the Figure 2. 12- and 24- month SPI and SRI describes Pooling of events very effectively.

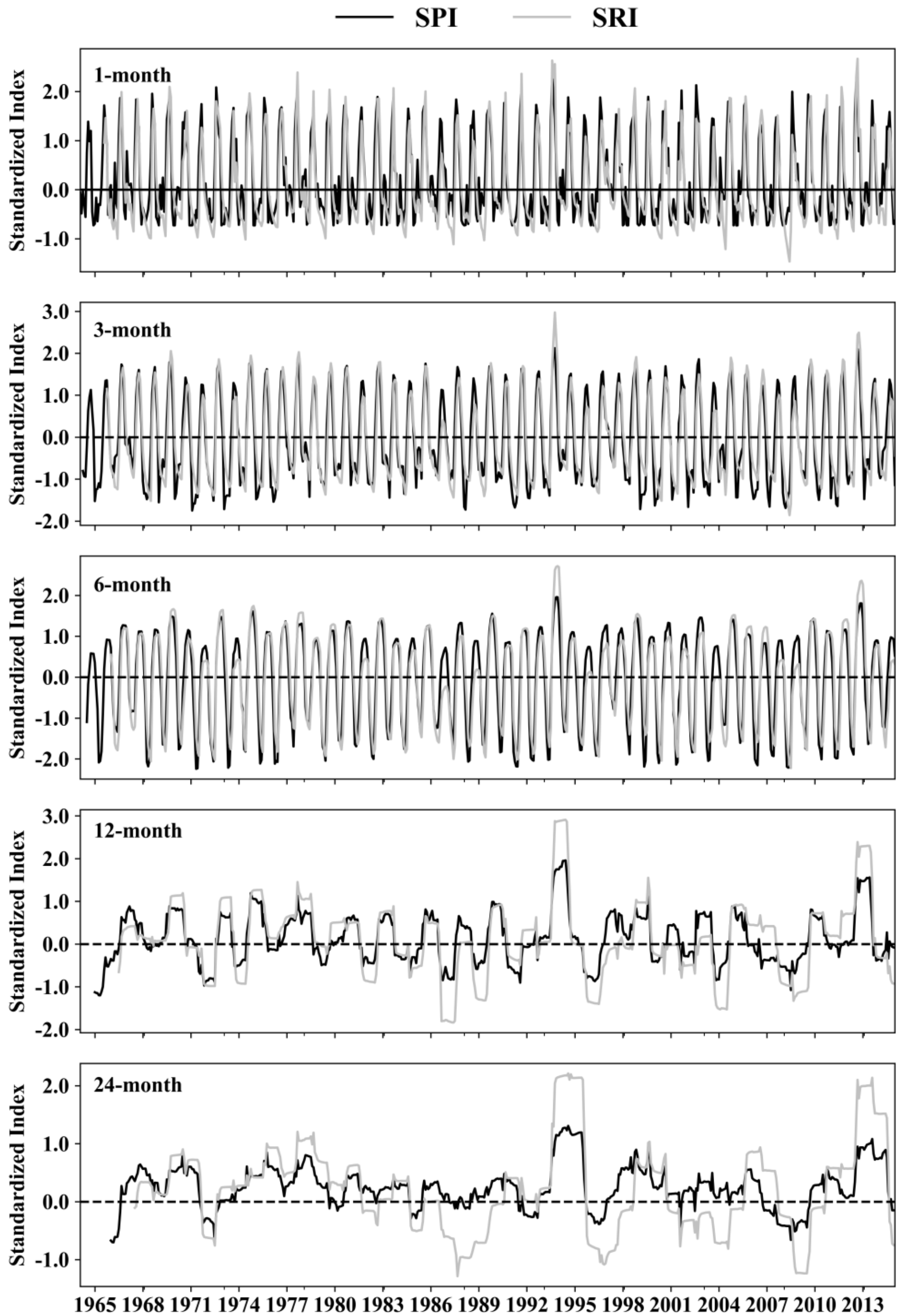

Figure 2: Historical time series of the SPI and SRI at 1-, 3-, 6-, 12 and 24-month time steps, based on observed precipitation and observed runoff in the Wainganga river.

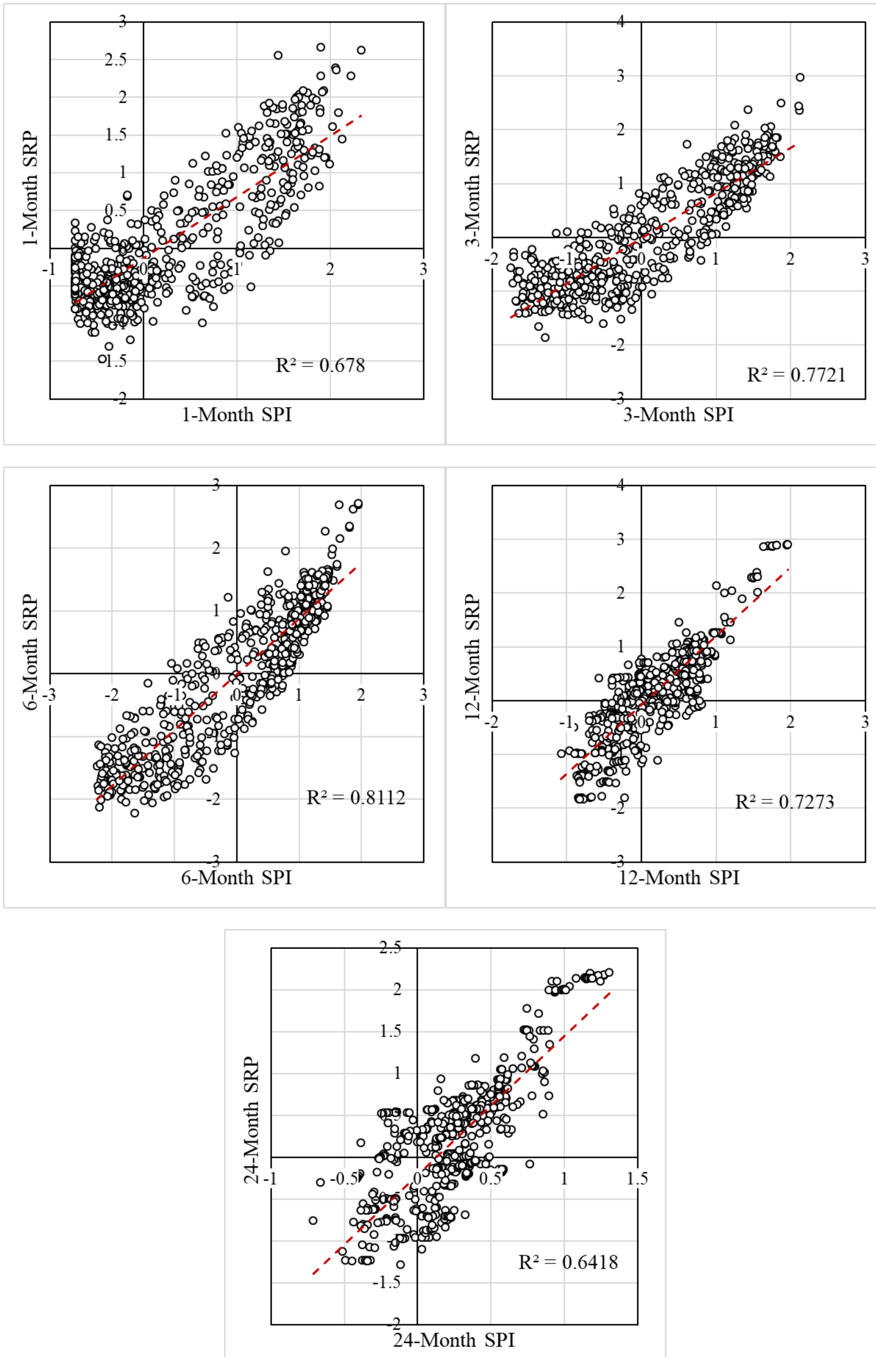

Figure 3: SPI and SRI correlation plots at 1-, 3-, 6-, 12-, and 24- month time step.

5. Conclusion

The foregoing study demonstrate that observed runoff very effectively provided a precise response of precipitation deficits of the Wainganga catchments. High correlation values of SPI and SRI indicates that Wainganga catchment is highly sensitive to climate changes, even a small precipitation anomaly reflects itself well on the runoff. 6- month SPI and SRI correlation value of 0.8112 show that catchment has a response time of 6 months to the precipitation anomalies. Wainganga catchment is majorly forest covered and hence abstraction to precipitation is quite high, which seems to the region behind the response time to be as high as 6 months. If the cover type had been different such as open forest of barren land the response time to precipitation anomalies would have been less and the catchment would have less sensitive.

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