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Comparison of two hydrological drought indices☆

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Summary Drought is a naturally occurring periodical event associated with significant decrease of water availability over a region. Drought, being a complex in nature it is difficult to define, quantify and monitor. Drought is mainly classified into meteorological drought, hydrological drought and agricultural drought. Among these classifications, assessment of hydrological drought has more importance in the water resources management perspective. Objective of this study is to analyse multi-time step hydrological drought by Stream flow Drought Index (SDI) and Standardized Runoff Index (SRI). To obtain these indices, 36 years (1972—2007) of daily discharge data, measured in Ghataprabha river basin (a sub basin of Krishna river) is considered. Results of both indices indicate moderate drought between 1986—1988 and 2001—2005 continuously. While comparing both indices, there is a good correlation between 9-month SRI and SDI is observed and it increases for 12-month SRI and SDI. This study may help to choose the appropriate drought indices among SRI and SDI for different lengths of drought studies.

Introduction

Among all natural hazards drought takes first priority, because it is very complicate to quantify its impact. Drought occurs due to decrease in rainfall over a certain period and intern leads to water scarcity. Hydrological drought is defined as decrease of available water in all its forms (Ma et al., 2015). Assessment of hydrological drought plays an important role in water management (Weng et al., 2015). Hydrological drought is too important because most of our daily activities depend on either surface water resources (Santos et al., 2011) or ground water resources.

Stream flow data is generally used for the analysis of hydrological drought (Bao et al., 2011). The aim of this study is to assess hydrological drought by Standardize Runoff Index (SRI) and Stream flow Drought Index (SDI) in Ghataprabha river basin and comparison of those indices for long-term drought studies.

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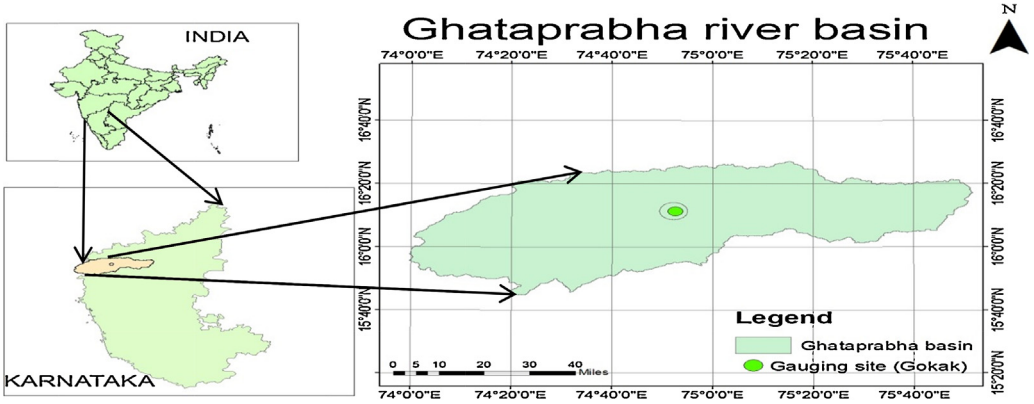

Figure 1 Location map of the study area.

Study area and data used

The study area is the Ghataprabha river basin, a subbasin of Krishna river in India. It lies between latitude 15° 45′ and 16° 25′ N and longitude 74° 00′ and 75° 55′ E (Fig. 1). Ghataprabha river originates in Western Ghats in Maharashtra state at the height of 884 m and flow eastern side for length of 283 km and finally it joins to Krishna river at Bagalkot in Karnataka state. The basin area is 8829 sq km. Population density of basin is 251 (persons/km^2), and the major land use is agriculture land. In this study, 36 years (1972—2007) of daily discharges data measured at Gokak are collected from Central Water Commission and the same is used for the analysis.

Methods

Standardize Runoff Index (SRI)

SRI is developed by Shukla and Wood (2008) to assess hydrological drought considering stream flow data. It involves fitting of suitable distribution to flow records of a particular location. After this, PDF — Probability Density Function and CDF — Cumulative Distribution Function are calculated and it is transformed to standardized Gaussian distribution with mean zero and unit variation that gives SRI. Using this index 3, 6, 9 and 12 months SRI is calculated.

Streamflow Drought Index

To characterize hydrological drought Nalbantis and Tsakiris (2009) developed SDI by considering monthly stream flow value (Q_{ij}), where i is hydrological year and j is months with in the hydrological year, then

$$V_{ik} = \sum_{i=0}^{k} Q_{ij}; \quad \text{for } i = 1, 2, 3, \ldots,$$

$$j = 1, 2, 3, \ldots, 12, \quad k = 1, 2, \ldots$$

where, V_k gives ith year volume of cumulative stream flow. For 3 months SDI (July—September) the value of $k = 1$ similarly $k = 2$, $k = 3$ and $k = 4$ for 6 months, 9 months and 12 months SDI respectively. From cumulative flow values, for each k, SDI is defined for the ith hydrological year as below:

$$SDI_{i,k} = \frac{V_{ik} - \overline{V_k}}{S_k}; \quad \text{for } k = 1, 2, 3\ldots \quad i = 1, 2, 3, \ldots$$

$\overline{V_k}$, mean value of cumulative stream flow for kth period.
$S_k = \sigma$ of cumulative stream flow of kth period.

Results and discussion

Since both the indices use same data of same period, it is necessary to compare the short-term and long-term behaviour of SRI and SDI. Values of 12-month SRI and SDI show the moderate drought between 1986 to 1988 and from 2001 to 2005 (Fig. 2). There is a linear relationship exists between normalized flow value and SDI, whereas SRI values are more scattered w.r.t. normalized flow value. Graph of SRI and SDI verses normalized flow value is plotted for 9month and 12 month periods (Fig. 3).

Correlation coefficient between SRI and SDI is increasing with respect to duration (Table 1) meanwhile angle between trend lines is reducing (Fig. 3). It means that these two indices are becoming same for longer period of drought analysis. Variation of SRI values is more hence more variation of trend but for SDI variation of trend is minute. This indicates that SRI is having more tendency to move towards SDI for higher duration of drought.

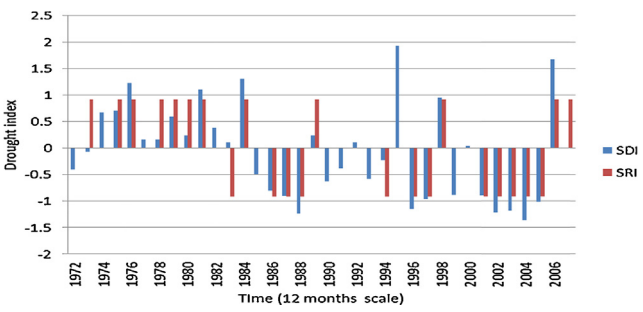

Figure 2 Time series of SRI and SDI values for 12 months.

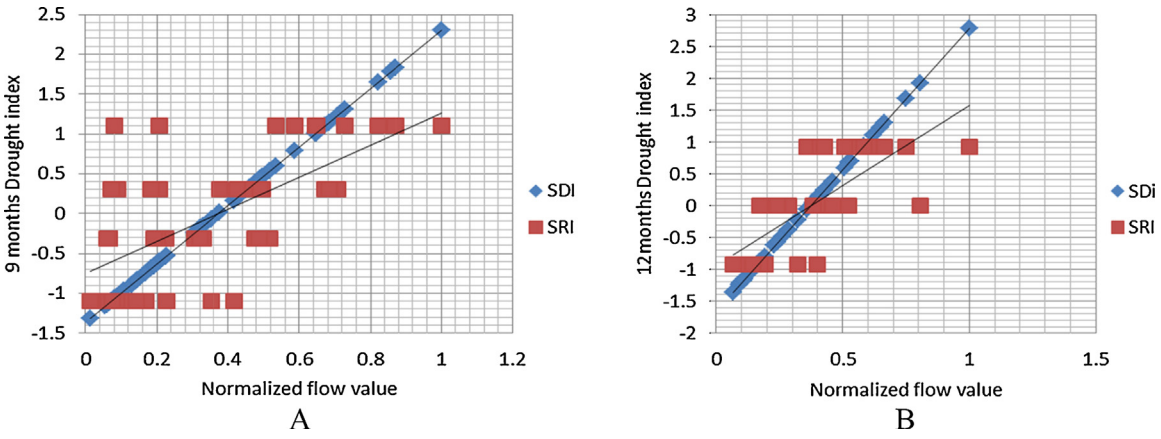

Figure 3 Comparison of SRI and SDI for (A) 9 months, (B) 12 months.

Table 1 Correlation between SRI and SDI.

Drought duration	3-months	6-months	9-months	12-months
Correlation between SRI and SDI	0.3634	0.4518	0.6735	0.7491
Angle between SRI and SDI trend line	23.759°	20.347°	11.142°	8.923°

Conclusion

Moderate drought occurred between 1986 to 1988 and from 2001 to 2005 in Ghataprabha river basin. Correlation coefficient shows that there is no significant change between SRI and SDI if those are used for long-term drought analysis. As the time period increases the tendency of transformation of SRI to SDI is more and vice versa. For shorter period of analysis these two indices can be used according to their importance.

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