Drought Analysis Based on Streamflow Drought Index (SDI) in Bhima sub-basin

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Abstract: Drought is a natural disaster that occurs when water availability is significantly below the normal levels during a significant period of time and cannot meet the demand. This work focused on hydrological drought assessment in Bhima sub basin, which receives rainfall annualy , but in dry season some of the areas start to become drought. This also due to the fact of large difference between river flows during the wet and dry seasons, which is significantly influenced by precipitation, resulting in hydrological drought. It consists of more reliable information's and the main factor in the decision making process. Indices for characterizing hydrological drought are, in general, data demanding and computationally intensive. A very simple and effective index, Streamflow Drought Index (SDI), has been recently proposed. It is based on cumulative streamflow volumes for overlapping periods of 3, 6, 9, and 12 months within each hydrological year at 5 hydrometric stations in Bhima sub basin over the period 1980-2010. Both long and short term drought has very severe impacts on basin. As per SDI methodology the exreme droughts occurred in long term scale (12 month scale) during period of 2008-2009.

Keywords: Hydrological Drought, Streamflow Drought Index (SDI), Bhima Sub Basin

I. INTRODUCTION

Droughts are characterized as an ecological destruction and have attracted the vision of environmentalists, ecologists, hydrologists, meteorologists, geologists and agricultural scientists. Droughts occur in practically all climatic zones, for example high as well as low precipitation zones and are mostly related to the diminishment in the measure of precipitation got over an augmented timeframe, such as a season or a year. Temperatures; high winds; low relative humidity; timing and features of rains, such as distribution of rainy days during crop growing periods, intensity as well as duration of rain, and onset and termination, play a significant role in this occurrence of droughts. Drought is allows a warning occasion between the first indications, usually several months and years, to the stage where the population will be affected more. Even though most of the area have drought problems and mitigation actions, it is necessary to understand the drought characteristics through analysis of drought conditions.

II. STUDY AREA

The Bhima River is a major river in South India. It flows southeast for 861 kilometres, with many smaller river tributaries. It originates near Bhimashankar Temple in the Bhimashankar hills in khed Taluka on the western side of the Western Ghats, known as Sahyadri, in Pune District, Maharashtra state. It is geographically located at 19°04′03″N 73°33′00″E. The total area of the Bhima basin is 70,614 km². The population living along the banks of Bhima is approximately 12.33 million people (1990) with 30.90 million people expected by 2030.75% of the basin lies in the state of Maharashtra.

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The precipitation in the basin differs from 450 to 5000mm in a time of 3 to 4 months and the normal precipitation in the basin is 711mm (32400Mm3) in a normal year.

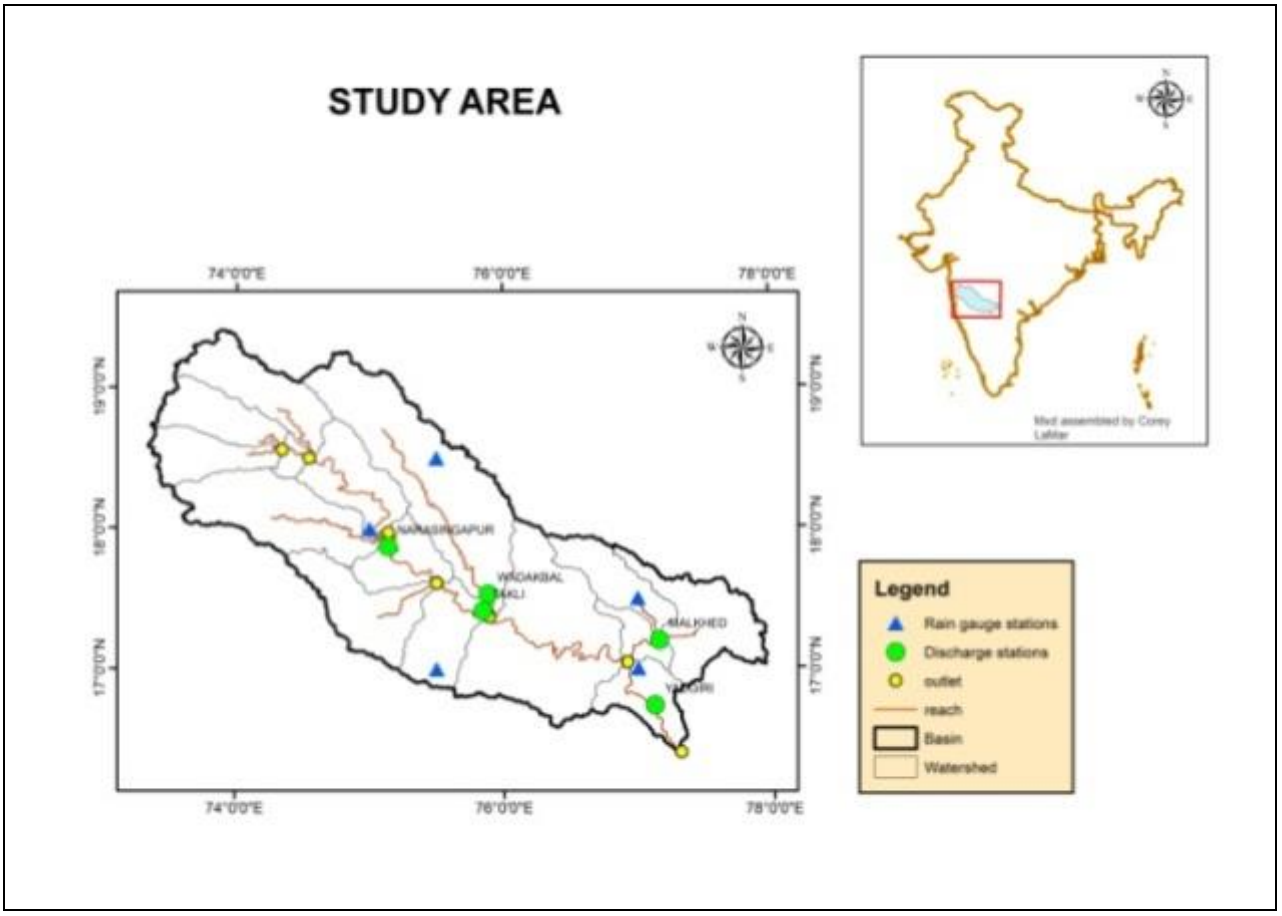

Figure 1: The study area with location of hydrometric station.

III. METHODOLOGY

According to Nalbantis (2008), if a time series of monthly streamflow volumes Qi,j is available, in which the hydrological year denoted by i and j the month within that hydrological year (j = 1 for October and j = 12 for September), the equation given by (Liu et al. 2012) using this equation we can obtain the Vi,k value.

$$V_{i,k} = \sum_{j-1}^{3k} Q_{ij} \qquad i = 1, 2,\ j = 1,2,\ldots, 12 \quad k = 1,2,3,4 \tag{1}$$

In which $V_{i,k}$ is the cumulative streamflow volume for the *i*-th hydrological year and the k^{th} reference period, k = 1 for October-December, k = 2 for October-March, k = 3 for October-June, and k = 4 for October-September.

Based on the cumulative streamflow volumes $V_{i,k,}$ the Streamflow Drought Index (SDI) is defined for each reference period k of the i^{th} hydrological year as follows: (Tabari et al. 2012)

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$$SDI_{i,k} = \frac{V_{i,k} - \bar{V}}{S_k} \qquad i = 1,2,\ldots. \quad k = 1,2,3,4 \qquad (2)$$

In which and S_k are the mean and the standard deviation respectively. Cumulative streamflow volumes of the reference period *k*, these are estimated over a long period of time.

According to Nalbantis and Tsakiris (2009), SDI as hydrological drought index is defined by states or classes are different than classes or states used to define RDI and SPI as meteorological drought index shown in Table 1.

Table 1: Definition of states of hydrological drought with the aid of SDI and corresponding probability

State	*Description*	*Criterion*	*Probability (%)*
0	Non drought	SDI ≥ 0.0	50
1	Mild drought	-1.0 ≤ SDI < 0.0	34.1
2	Moderately drought	-1.5 ≤ SDI < -1.0	9.2
3	Severely drought	-2.0 ≤ SDI < -1.5	4.4
4	Extremely drought	SDI < -2.0	2.3

IV. RESULTS AND DISCUSSION

The SDI values calculated from the time series of the monthly streamflow volume of the Bhima sub basin help to assess the temporal variation of hydrological drought and estimate the drought parameters. The calculated monthly SDI values were classified based on drought categories as presented in Table 1. The time scale series of occurrence of drought categories was calculated shown in graphs plotted year v/s SDI value for five hydrometric stations located in the basin. There is no extreme drought as occurred more frequently in 3, 6, and 9 month time scale. Whereas considering 12 month time scale there is a one extreme drought as occurred during 2008-09 to each station.

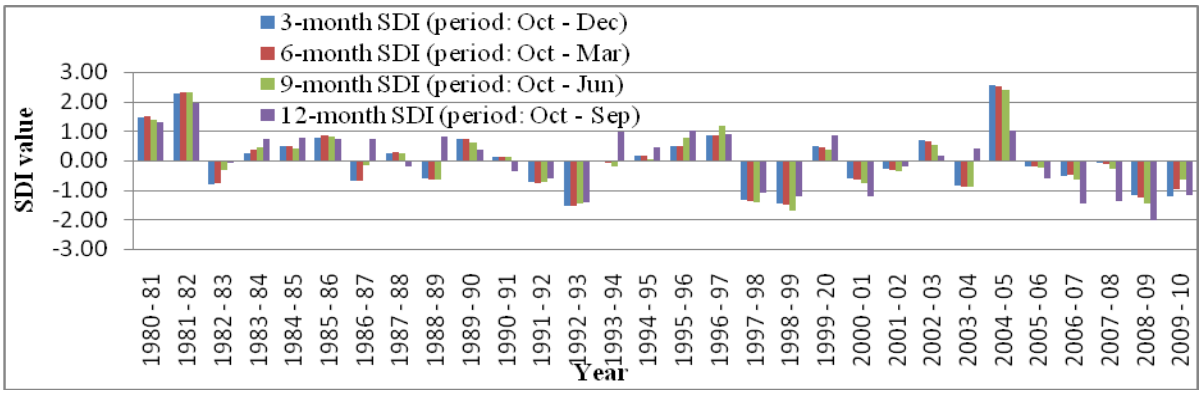

Figure 2: SDI values based on 3, 6, 9 and 12 month time step of Yadgiri station

The figure 2 depicts the SDI value. It can be seen that there were 4 moderately drought events for 3 month time scale, 2 severely and 2 moderately drought events for 6 month time scale, 1 severely and 3 moderately drought events for 9 month time scale, and 1 extremely and 6 moderately drought events for 12 month time scale. Over all 20 drought events occurred in this station considering extreme, severe and moderate droughts for all time scale.

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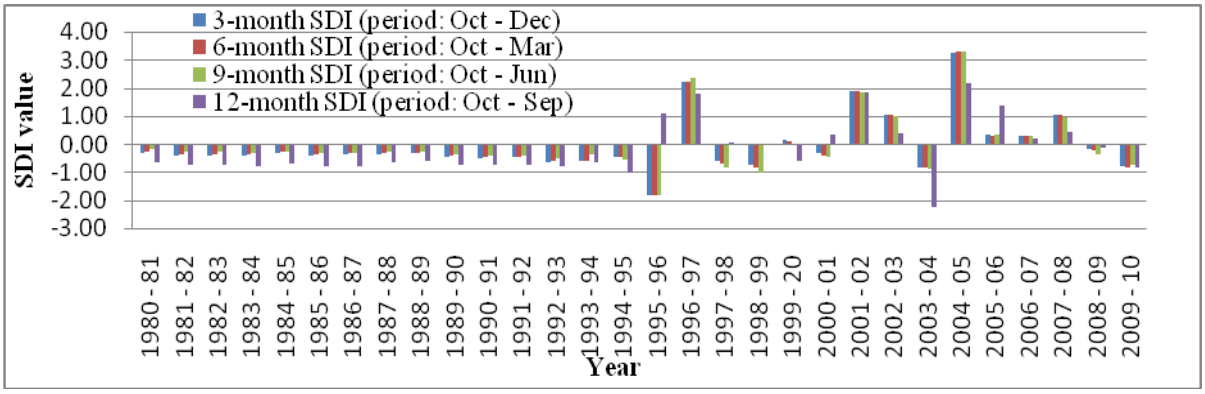

Figure 3: SDI values based on 3, 6, 9 and 12 month time step of Malkhed station.

The figure 3 depicts SDI value; there were 1 severely drought event for 3 month time scale, 1 severely drought event for 6 month time scale, 1 severely and 1 moderately drought events for 9 month time scale, and 1 extremely and 1 moderately drought events for 12 month time scale. Over all 6 drought events occurred in this station considering extreme, severe and moderate droughts for all time scale.

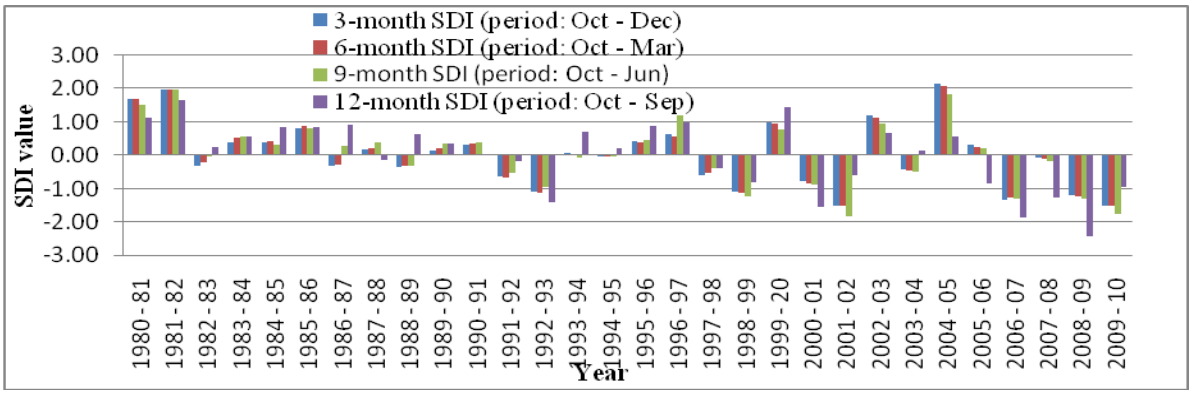

Figure 4: SDI values based on 3, 6, 9 and 12 month time step of Takli station.

The figure 4 depicts SDI value; there were 2 severely and 4 moderately drought events for 3 month time scale, 2 severely and 4 moderately drought events for 6 month time scale, 2 severely and 3 moderately drought events for 9 month time scale, and 1 extremely, 2 severely and 1 moderately drought events for 12 month time scale. Over all 21 drought events occurred in this station considering extreme, severe and moderate droughts for all time scale.

Figure 5 depicts the SDI value; there were 1 severely and 4 moderately drought events for 3 month time scale, 1 severely and 6 moderately drought events for 6 month time scale, 3 severely drought events for 9 month time scale, and 1 extremely and 4 moderately drought events for 12 month time scale. Over all 20 drought events occurred in this station considering extreme, severe and moderate droughts for all time scale.

The figure 6 depicts the SDI value; there were 7 moderately drought events for 3 month time scale, 1 severely and 5 moderately drought events for 6 month time scale, 1 severely and 5 moderately drought events for 9 month time scale, and 1 extremely and 4 severely drought events for 12 month time scale. Over all 24 drought events occurred in this station considering extreme, severe and

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moderate droughts for all time scale. Figure 7 shows percentage of drought occurrences in the basin with different time scales based on SDI.

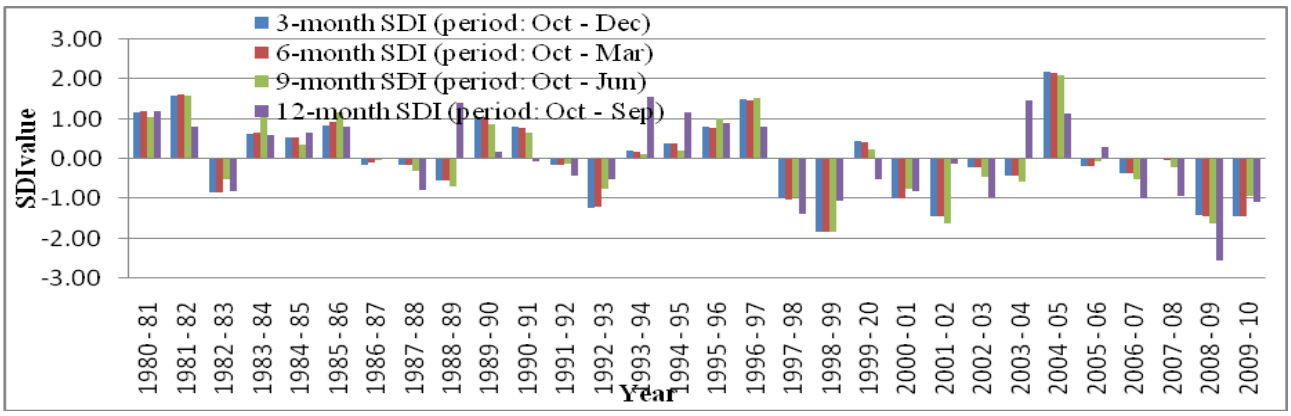

Figure 5: SDI values based on 3, 6, 9 and 12 month time step of Wadakbal station.

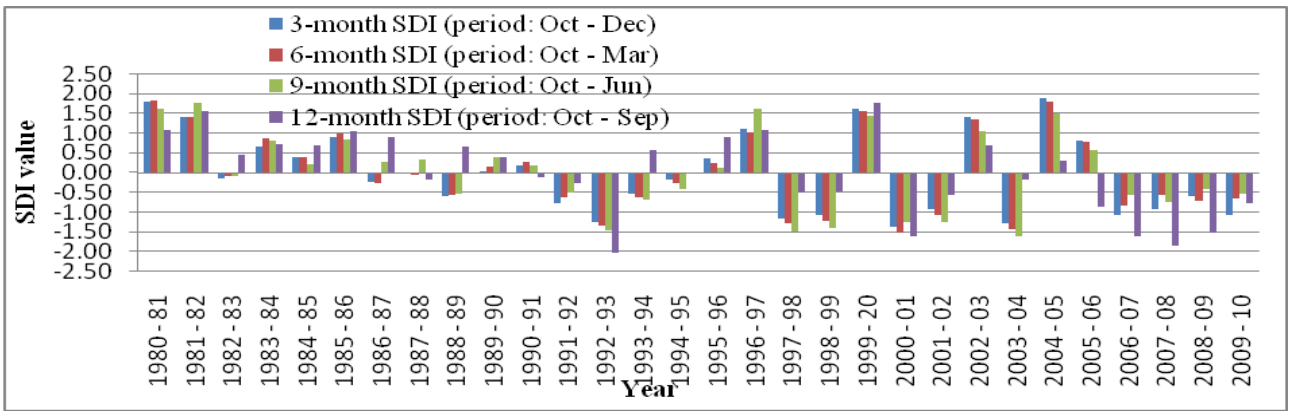

Figure 6: SDI values based on 3, 6, 9 and 12 month time step of Narsingpur station.

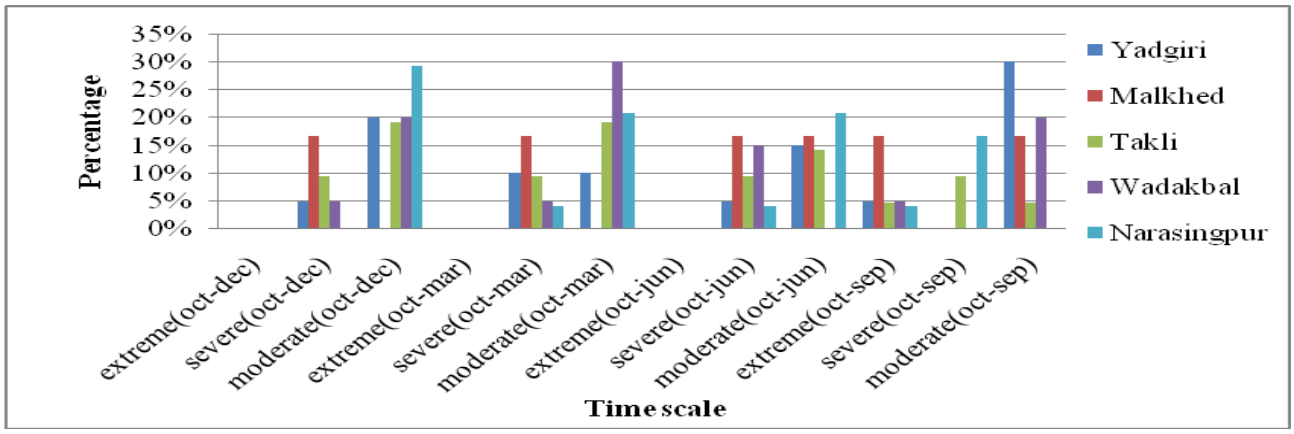

Figure 7: percentage of drought occurrence according to SDI.

V. CONCLUSIONS

This study estimated hydrological droughts by using the streamflow drought index in the five hydrometric stations located in Bhima basin over the period 1980-2010. The hydrological drought

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analysis based on the SDI for 3, 6, 9 and 12 months time scale indicated that almost all the stations experienced extreme, severe and moderate drought events during the study period. The extreme dry events occurred mainly in the period of 2008-09 by showing the negative index value less than -2.0. As indicated by SDI, hydrological drought occurred more in Yadgiri, Takli, Wadakbal and Narsingpur station during the period 1991 to 2010. The hydrological years of 1998-99, 2003-04 and 2008-09 were the driest years during the examined period.

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Conflict of interest: The authors declare that they have no conflicts of interest

Ethical statement: The authors declare that they followed ethical responsibilities

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