

Original Research Article

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Application of Standardized Precipitation Index (SPI) for Meteorological Drought Assessment in Tripura, Northeast India

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ABSTRACT

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Drought is one of the natural climatic extreme events that may cause significant damage to environments and claim human lives. Drought greatly affects many aspects of environment and society, and any future increases in the demand for water will be most critical in periods of severe drought. Analysis of drought events and their causes can be used to mitigate the drought impacts and development of preparedness plans. The main purpose of this study is to investigate the drought persistence and severity in the Tripura state of India during the period 1980-2013, using Standardized Precipitation Index (SPI). Gridded monthly precipitation data distributed over the four districts of Tripura was used. SPI series of 3, 6 and 12 month time scales have been calculated and used for drought analysis. Several drought events were detected during the rainy season (June to September). Annual analysis of SPI time series showed that the study area received the intense drought during the year 1985. Geospatial technique was used to generate the SPI drought map for the year 1985.

Introduction

The unique geophysical setting and socio-economic conditions of Indian sub-continent has enhanced vulnerability to drought hazard. India, on an average, encounters drought at least once in five years. The occurrence of drought is common over all types of climatic conditions and not endemic to the arid and semi-arid region only. The deviation from the normal rainfall with 75% less than normal is declared drought as per India Meteorological Department (IMD). The north-eastern region of India records more number of drought events in comparison with western region of

the country (Parida and Oinam, 2015). Globally, drought has been explained from simple rainfall deviation method to the complex method involving several parameters. Numerous methods have been implemented by various researchers in an attempt to identify the droughts such as Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Effective Drought Index (EDI), China Z Index (CZI), Rainfall Anomaly Index (RAI), Percent of Normal Index (PNI), etc. Monitoring of drought should be at the highest priority to implement appropriate measures to control its negative impacts.

However, limited studies have been reported on the study of drought occurrences in northeast region of India.

McKee *et al.*, (1993) developed probability based standardized precipitation index (SPI) for drought classification on any time scale using precipitation data. Over the years, the SPI got popularized as it is simple, spatially invariant and is probabilistic in nature. Drought climatology for Europe was studied by Hughes and Saunders (2002) using SPI at multiple time scales for the period of 1901–1999 and concluded that SPI is a simple and effective tool in analyzing European drought. Mihajlović (2006) analyzed the meteorological drought over Pannonian part of Croatia using SPI at multiple time for the period of 2003–2004 at 32 stations. Observation was made that the drought progression from start to its end at multiple time scales. The effects of drought aggravate over time. Severity and duration are two important drought characteristics that are correlated variates and their combination may generate quite different drought effects. Therefore, it is useful to construct a joint probability distribution from these two variates for drought risk assessment and perform frequency analysis. The study aims to investigate the Meteorological drought, its spatial and temporal variation by the SPI at multiple time scales over the Tripura state. The computation of SPI values will consider time scales of 3, 6 and 12 months to identify the worst event.

Materials and Methods

Study area and data

The State of Tripura having an area of 10,492 km² is situated between the latitudes of 22° 56' N and 24° 32' N and the longitudes of 90° 09' E and 92° 10' E with elevation ranging from 600 to 900 m above mean sea level. The

average precipitation of the area is about 2100 mm and climate is humid tropical. The study was carried out district wise, which includes four districts viz. North Tripura, West Tripura, Dhalai and South Tripura. The details of the districts are given in Table 1 and the location of study area is shown in Fig. 1. The gridded rainfall data having spatial resolution of 0.3° × 0.3° for the period 1980–2013 were acquired from Global Weather Data for SWAT.

Standardized precipitation index (spi)

The SPI is one of the Drought Index (DI) which has been used in different parts of the world by various authors. Standardized Precipitation Index (SPI) is developed to monitor drought for a several time scales by assembling the precipitation time series over the time period of interest (Trambauer *et al.*, 2014). It can be calculated in various timescales, such as, SPI-1, SPI-3, SPI-6, etc. describing different types of drought conditions. Hence, SPI possess a good indicator quality for meteorological drought, hydrological drought, agricultural drought and groundwater drought; wherein short term SPI scale i.e., 3 and 6 months are effective for detecting droughts on vegetation and agriculture and long term SPI like 12 months are effective for water resources related drought (Edwards and McKee 1997; Bonaccorso *et al.*, 2003). SPI provides advantages such as indicating the initiation and termination of drought, and minimum input data requirement i.e., precipitation solely to compute drought for any region (Buttafuoco *et al.*, 2015). The procedure related with the SPI-3 time scale used in this paper is as follows. First, rainfall values of three years are being fitted with the Gamma distribution. Then the fitted Gamma distribution is transformed to the standard normal distribution with mean zero and standard deviation one. This final normalized

format is known as the SPI. The right hand (left hand) side of the standard normal distribution curve indicates wet (dry) conditions. The climate type is classified from extremely wet to extreme dry based on the SPI values, as given by McKee *et al.*, (1993). The SPI values and the corresponding climate conditions are summarized in Table 1.

Drought analyses

Drought was analyzed for the entire state of Tripura during the period 1980-2013, using SPI index for numerous time scales (3, 6, and 12 months). SPI index was calculated using monthly precipitation of the four districts of Tripura. Monthly rainfall distribution over station during the study period processed to identify the rainy season. Months of September and October were selected for calculating SPI for 3 and 6 month time scale, respectively; while December for SPI 12 months. These months were chosen to signify the wet season to the specific time scale (Elkollaly *et al.*, 2018). Drought is detected when SPI value is less than -1, so the time between the consecutive negative zero value can considered as duration of the event. Two

most effective drought characteristics adopted by different researcher to assess the cumulative effect are severity and duration (Shiau and Modarres, 2009; Shiau *et al.*, 2012). Drought severity is defined as the cumulative deviation for SPI values below a threshold level, while the time period when this occurs is termed as the drought duration (Kwak *et al.*, 2012).

Results and Discussion

Meteorological drought vulnerability of Tripura was evaluated by investigating the historical occurrences of droughts, using SPI approach based on several time scales. The main objective is to help the decision makers for developing strategies of water resources management in the context of drought to mitigate of the drought impacts and development of preparedness plans. SPI values were calculated for three different time scales namely 3, 6, and 12 months for North Tripura, West Tripura, South Tripura and Dhalai (Figs. 3, 4, 5 and 6). These time scales detected several intense drought in numerous years as shown in table 2, 3, 4, 5 and 6.

Table.1 Detail of Districts of Tripura

District	Latitude °N	Longitude °E	Elevation (m)
North Tripura	24.19	92.18	56
West Tripura	23.88	91.56	74
Dhalai	23.88	91.87	97
South Tripura	23.57	91.56	97

Table.2 SPI value for different drought class

Drought Class	SPI value
Moderate drought	- 1.00 to - 1.49
Severe drought	- 1.50 to - 1.99
Extreme drought	- 2.00 and less

Table.3 SPI value at different time scale in North Tripura

Station	Year	SPI 3	SPI 6	SPI 12
North Tripura	1983	-1.78	-	-
	1985	-1.18	-1.56	-1.41
	1987	-1.30	-2.04	-1.61
	2005	-1.58	-1.48	-1.81
	2010	-1.45	-	-

Table.4 SPI value at different time scale in West Tripura

Station	Year	SPI 3	SPI 6	SPI 12
West Tripura	1982	-	-	-1.01
	1984	-1.20	-1.34	-
	1985	-2.16	-2.81	-2.45
	1987	-	-1.37	-1.27
	1992	-1.02	-1.00	-1.18
	2005	-	-1.17	-1.21
	2006	-1.05	-	-1.19
	2011	-1.43	-1.30	-1.69
	2013	-1.21	-	-

Table.5 SPI value at different time scale in Dhala

Station	Year	SPI 3	SPI 6	SPI 12
Dhalai	1984	-	-1.39	-1.01
	1985	-1.75	-2.19	-1.58
	1987	-1.19	-1.48	-
	2005	-1.30	-1.32	-
	2006	-1.49	-1.12	-1.34
	2011	-2.32	-1.84	-2.26
	2012	-1.17	-1.26	-1.18
	2013	-	-	-1.76

Table.6 SPI value at different time scale in South Tripura

Station	Year	SPI 3	SPI 6	SPI 12
South Tripura	1982	-1.09	-1.37	-1.52
	1984	-1.34	-1.79	-
	1985	-2.27	-2.77	-2.55
	1986	-	-1.33	-1.42
	1987	-	-1.33	-1.38
	1991	-1.37	-	-
	1992	-1.21	-	-1.26
	2003	-1.28	-	-
	2005	-	-1.07	-1.09
	2006	-1.06	-	-1.31

Fig.1 Location of study area

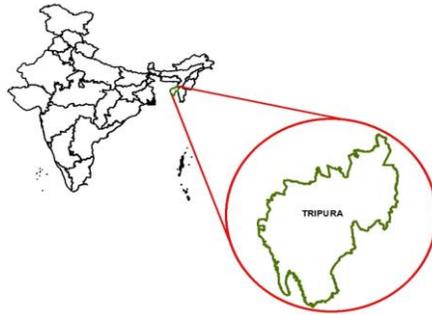


Fig.2 Monthly rainfall distribution over the study area

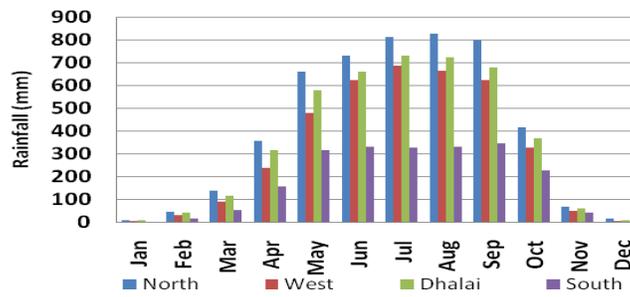


Fig.3 North Tripura

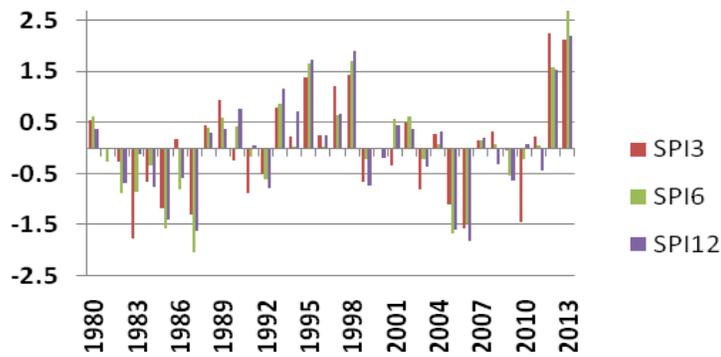


Fig.4 West Tripura

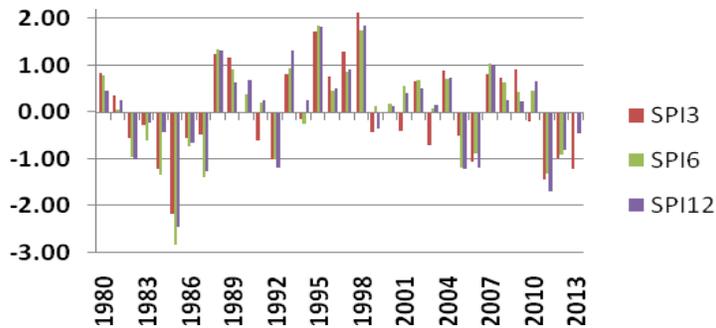


Fig.5 Dhalai

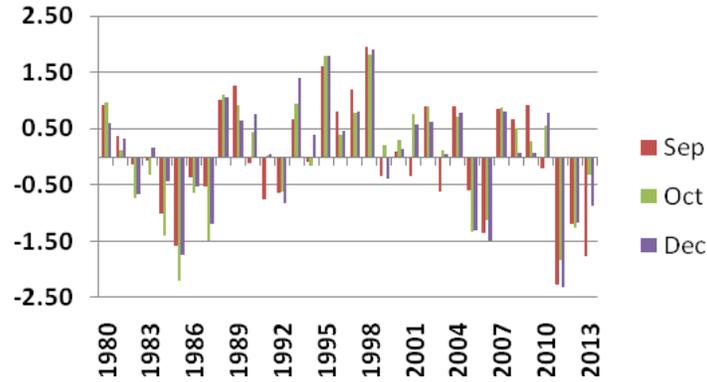
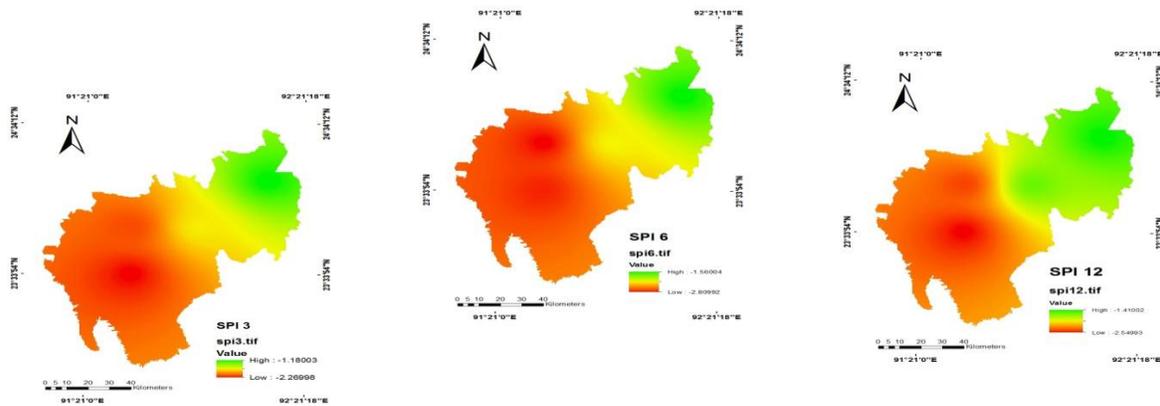


Fig.6 South Tripura



Fig.7 Spatial map of different SPI timescale of 1985



Drought analysis

Analysis of SPI for drought occurrence resulted in observation of distributed drought events. On analysis of SPI 3, the study area

encountered 24 drought events which comprised of 17 moderate droughts, 4 severe droughts and 3 extreme droughts. The worst drought in 3 months time scale occurred at a magnitude of -2.32 in the year 2011 in Dhalai

district. In case of SPI 6 analysis, 22 drought events were observed with 14 moderate, 4 severe and 4 extreme drought conditions. The highest magnitude of -2.81 was observed in the year 1985 in West Tripura district in this time scale. The highest time scale (SPI 12) in the study resulted with 23 drought events constituted with 14 moderate, 6 severe and 3 extreme conditions. In this time scale a magnitude of -2.55 was encountered in the year 1985 in South Tripura district. From the above analysis it can be briefed that three districts (West Tripura, Dhalai and South Tripura) had received extreme drought conditions and also it can be highlighted that the year 1985 has received the most consistent drought events in all the time scale.

Spatial drought severity map

The Inverse Distance Weighting (IDW) method is employed for spatial interpolation of SPI values over the entire study area. IDW weights the influence of each SPI value by a normalized inverse of the distance from the rain gauge station to the interpolated point. It is assumed by IDW method that SPI value has more influence at the rain gauge station and it diminishes with distance. The SPI value of neighboring stations is also considered by the IDW approach. The spatial display maps for SPI values were prepared by using Spatial Analyst tool of Arc GIS for drought year and are displayed in Figure 7. The year 1985 was observed as most consistent drought occurring year in all considered timescale for the recorded station and severity is represented by spatial coverage of red color.

In conclusion the drought condition in Tripura was well described with SPI approach. Several drought events with numerous severities were detected in all the four districts during the period 1980-2013. The result showed 1985 received the most consistent drought event during the study

period. Moderate to extreme droughts occurred over the districts in the considered time scales. The maximum number of droughts was observed in the South Tripura district however, North Tripura faced minimum numbers of droughts during the study. Spatial visualization of SPI with GIS technique aids to better depict drought conditions all over the Tripura territory and help stakeholders to lay drought contingency plans leading to holistic drought management strategies.

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