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Short communication

Assessment of meteorological drought in Amravati district of Maharashtra

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The reliable and accurate information of drought is essentially required for effective management. A drought index can be used to quantify the moisture condition of a region, to detect the onset of drought, to measure the severity of a drought event, to quantify the spatial extent of a drought event, thereby allowing a comparison of moisture supply conditions between regions (Alley, 1984). The drought indices can be used to predict crop yield (Kumar and Panu, 1997). Dabare and Satpute (2008) quantified meteorological droughts in Nagpur district by using decile drought index, evaluated the widespread drought years by compairing average yield of different crops and reported that decile drought index can also be used for agricultural drought charecterisation. Standardized precipitation index (SPI), decile drought index (DI) and effective drought index (EDI) are some of the widely used meteorological drought indices for drought quantification. Kim *et al.* (2009) compared the performances of the EDI and SPI for drought monitoring for Seoul, Korea. Oza *et al.* (2002) used SPI for North-West India, West Rajasthan and Saurashtra-Kutch. Morid *et al.* (2006) compared the performance of seven indices for drought monitoring in the Tehran province of Iran. The SPI and EDI were found to be able to detect the onset of drought, its spatial and temporal variation consistently, and it may be recommended for operational drought monitoring in the Province. The meteorological drought study has been carried out by different researchers by using three drought indices such as decile index (DI), effective drought index (EDI) and standardized precipitation index (SPI) at different locations. The present study was undertaken for comparative assessment of above three meteorological drought indices i.e., DI, EDI and SPI for assessment of meteorological drought in nine tehasils of Amravati district.

The study was conducted for nine tehasils of Amravati district in Vidharbha region of Maharashtra *viz.,* Achalpur, Anjangaon, Amravati, Chandur Bazaar, Chandur Railway, Chikhaldara, Dharani, Morshi and Warud. The average seasonal rainfall (1991–2012) of the selected tehasils ranges between 624.3 to 1313.6 mm. The 22 years (1991-2012) rainfall data and yield data of dry land crops *viz.,* soybean, sorghum, cotton and pigeonpea was used.

Determination of DI, EDI and SPI

The decile value for each monsoon month from June to September was calculated and compared with actual rainfall of that month to identify the severity of drought according to the classification given by Gibbs and Maher (1967). Using long-term monthly precipitation record, a cumulative frequency distribution is constructed by arranging and ranking from highest to lowest. The distribution is then split into ten parts (tenths of distribution or deciles). Each of these categories is a 'decile'. The first decile is the precipitation value not exceeded by the lowest 10 per cent of all precipitation occurrences. The second is between lowest 20 per cent occurrences. These deciles continue until the rainfall amount identified by the tenth decile is the largest precipitation amount within the long-term period. By definition, the fifth decile is the median and it is the precipitation amount not exceeded by 50 per cent of the occurrences over the period of record. After categorizing the months, the drought years were computed by critically analyzing the growing period using the criteria given by George and Kalyansundaram (1969).

The effective drought index (EDI) in its original form (Byun and Wilhite, 1999) is based on time dependent reduction factor and it is calculated with a daily time step. EDI is a function of precipitation needed for a return to normal conditions (PRN). PRN is precipitation, which is necessary for the recovery from the accumulated deficit since the beginning of drought. PRN, in turn, effectively stems from daily effective precipitation (EP) and its deviation from the mean for each day. EDI values are standardized, which allows drought severity at two or more locations to be compared with each other regardless of climatic differences between them. EDI varies in the range from -2 indicating extremely dry to 2 extremely wet conditions.

SPI was calculated following McKee *et al*. (1993) which is based on the probability distribution of precipitation.

Table 1: Drought severity indicated by various indices in historical drought years

Taluka	1991			1995			2000			2002		
	DI	EDI	SPI	DI	EDI	SPI	DI	EDI	SPI	DI	EDI	SPI
Achalpur	MoD	MIW	MIW	SD	MoD	SD	MoD	MID	MoD	MoD	MoD	ED
Anjangaon	SD	MID	MoD	MoD	Nor	MID	MoD	MID	MoD	MID	Nor	MID
Amravati	MoD	Nor	MID	SD	SD	ED	MoD	MoW	MIW	MoD	MoD	SD
Chandur Bazaar	MoD	MID	SD	SD	MoD	ED	SD	MID	MID	MoD	MoD	MID
Chandur Railway	MoD	MID	MoD	MoD	MoD	MoD	MoD	Nor	MID	MoD	MID	MoD
Chikhaldara	MoD	Nor	MoD	SD	SD	SD	SD	MoD	MoD	MoD	MID	MoD
Dharani	SD	Nor	MID	SD	Nor	MID	MoD	MoD	MoD	MID	MID	MID
Morshi	MoD	Nor	MID	SD	MID	MoD	SD	MoD	SD	MoD	MID	ED
Warud	SD	MID	SD	Nor	MoW	MID	SD	Nor	MoD	MoD	MoD	MoD

Mow – Moderate wet, MIW – Mild wet, Nor – Normal condition, MID – Mild drought, MoD- Moderate drought, SD – Severe drought, ED – Extremely dry

Table 2: Spearman rank correlation between various crop yield and drought severity by different drought indices for different talukas in Amravati district

Taluka	Decile				EDI				SPI			
	Soybean	Sorghum	Cotton	Pigeon pea	Soybean	Sorghum	Cotton	Pigeon pea	Soybean	Sorghum	Cotton	Pigeon pea
Achalpur	0.70	0.16	-0.03	0.32	0.42	-0.09	-0.004	0.02	0.7	0.09	-0.17	-0.02
Anjangaon	0.30	0.24	-0.29	0.28	0.46	0.045	0.048	0.37	0.3	0.3	-0.02	0.23
Amravati	0.71	-0.15	-0.10	-0.07	0.49	-0.13	-0.13	-0.03	0.58	-0.30	0.1	-0.2
Chandur Bazar	0.47	-0.04	0.05	0.33	0.49	-0.29	0.08	0.15	0.47	0.01	0.12	0.20
Chandur Railway	0.46	-0.08	-0.08	-0.14	0.36	-0.18	-0.44	-0.36	0.49	-0.16	-0.14	-0.25
Chikhaldara	0.57	0.41	-0.01	0.28	0.59	0.41	-0.04	0.11	0.49	0.47	-0.12	0.18
Dharani	0.37	0.39	0.23	0.13	0.26	0.45	0.14	0.24	0.35	0.38	0.10	0.20
Morshi	0.58	-0.15	0.05	-0.03	0.37	-0.28	0.07	-0.09	0.40	-0.18	0.18	-0.13
Warud	0.47	-0.007	0.35	0.25	0.37	-0.01	0.34	0.30	0.47	0.17	0.28	0.32

Extreme values in the SPI will, by definition, occur with the same frequency at all location. The drought part of the SPI range is arbitrary split into 'near normal' conditions (0.99 < SPI <-0.99), moderately dry (-1.0 < SPI < -1.49), severely dry (-1.5 < SPI < -1.99) and extremely dry (SPI < -2.0). The 3-month time scale SPI for September values were used to represent SPI index for *kharif* season of the year (Patel *et al.*, 2007), which uses the monthly rainfall data of July, August and September for estimating the 3-month SPI index.

The drought years identified by different indices were analyzed according to their severity class. The index, which is having more consistency with historical drought events, was characterized as good indicator of drought for this region. The three indices were checked with the well-known historic drought event of 1991, 1995, 2000 and 2002 in Amravati district (Table 1).

Due to the discrete variation of two variables (i.e. yield and drought year), Spearman rank correlation was chosen as a measure of how well years ranked by drought index value are compared to years ranked by yield of the area. For all drought indices, a positive index value indicates wetter than normal condition and negative index value imply dryer than normal conditions. Correlation between the drought years and yield of the year can range between -1 and 1 (Chandel, 1965). A positive correlation indicates a direct relationship between two variables.

The three indices used for drought characterization have identified four major historical droughts in Amaravati district viz., 1991, 1995, 2000 and 2002. Decile index and SPI are showing more consistency with historical drought events indicating the superiority of these two indices over EDI in identifying proper severity of drought in the region (Table1).

Spearman rank correlation coefficient

From Table 2, it can be revealed that for soybean crop, decile index gives highest positive correlation followed by SPI and EDI, for different taluka places in Amravati district. For sorghum, SPI gives highest positive correlation at six taluka places followed by decile index (4 taluka places) and EDI (3 taluka places) in Amravati district. For cotton, the EDI and SPI gives same positive correlation followed by decile index. For pigeon pea, the decile and EDI shows positive correlation at six taluka places followed by SPI at five taluka places. From the above results of correlation between different rainfed crops yield data and drought years severity obtained by different indices, it can be concluded that the performance of decile index and SPI can be considered as better in identification of drought over EDI.

The study concludes that SPI was found to be superior over that of decile index and EDI because it describes all the major droughts occurred in Amravati district, more consistency with historical drought events, easily adapted to the local climate, can be computed at almost any time scale, has no theoretical upper or lower bounds and it fulfills the criteria of data requirement and availability for its assessment.

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