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Meteorological Drought Characterization Using Effective Drought Index (EDI) for Banswara District (Rajasthan), India

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ABSTRACT

The agricultural drought has become a major concern worldwide because of its severe effect on the productivity of rain-fed crops and direct effect on service as well as per capita income. These agricultural droughts occur due to short-term moisture stresses. This work was carried out to analyze droughts in the Banswara region of Rajasthan using Effective Drought Index (EDI). Out of the 11 rain gauge station selected in the study, it was found that according to EDI, a meteorological drought of maximum severity -34.15 occurred for the duration of September 1989 to June 1991 which was of the longest period (22 months) in the study area falling under Sajjangarh rain gauge station. The drought having a maximum intensity of -2.13, occurred in between July 1979 to May 1980, with a severity of -23.46 in the area under Bhungra rain gauge station. The maximum and a minimum number of extreme drought which occurred in Loharia and Arthuna rain gauge station were respectively 10 and 2. A maximum number of 19 severe droughts and 59 moderate droughts occurred in Kushalgarh and Bagidora area respectively and a minimum number of one severe drought and 28 moderate droughts occurred in Banswara and Loharua rain gauge stations respectively. The maximum and a minimum number of 65 and 42 drought events occurred in Kushalgarh and Shergarh rain gauge station respectively. The rising trend of meteorological drought severity was found in the study area.

Keywords

Meteorological
drought, EDI,
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Introduction

Drought is a normal recurring feature of earth's climate, it has a peculiar slow onset and disastrous, long-lasting impacts; it affects more people than any other form of natural disaster. It is characterized in terms of the spatial extension, intensity, and duration (Drought Manual; Govt. of India, 2009). Generally, rainfall deficiencies over a long time period lead to severe droughts events (Wilhite and Knutson, 2008). Mainly four

types of droughts are observed, meteorological (lack of precipitation), agricultural (lack of root zone soil moisture), hydrological (drying of surface water storage), socio-economic drought (lack of water supply for socio-economic purpose) and these drought types are generally interlinked with each other (Sigdel and Ikeda, 2010). Meteorological drought is the situation when there is a considerable decrease from the normal precipitation amount over a particular region during an extended period of time.

Agricultural drought plays a major role in the economy of agrarian countries like India where more than 68% people are dependent upon agriculture. About 16% of India's total area is drought-prone and about 50 million people are annually affected by drought (Dutta *et al.*, 2015). The drought-prone areas of the country are mainly confined to western and peninsular India-mainly arid, semi-arid, and sub-humid regions. The arid tract of the western part of India is under threat of severe droughts due to paucity and abnormality of rainfall and severe climatic characteristics (Jain *et al.*, 2010). The Effective Drought Index (EDI) in daily and monthly time steps, characterizes drought severity superior than any other index (Pandey *et al.*, 2008). Kar *et al.*, (2016) studied the drought severity using EDI for Bundelkhand region and found a gradually increasing severity. Morid *et al.*, (2006) used EDI, which is able to detect the onset and spatiotemporal variation of drought consistently so the EDI was found to be more responsive to the emerging drought and hence preferred. In India, 80% of annual rainfall comes from southwest monsoon, and is very important for the whole country, especially for the low rainfall belts like Rajasthan state. Any kind of deficiency in monsoon, mostly because of climate change causes higher frequencies of droughts in these areas as high as once in every four years (Gupta *et al.*, 2011). In the present research work, the effective drought index is used to characterize and study the meteorological drought scenario of Banswara district for helping the decision makers and planners for efficient management of water resources in the area.

Materials and Methods

Study area

The study has been carried out in Banswara district of Rajasthan; it is situated in the southern-most part, it has an area of 5037 sq.

km., which is 1.47% of a total geographical area and it is surrounded on, the east and southeast by Madhya Pradesh, on the southwest by Gujarat, and on the west by Dungarpur district the north by Udaipur district, on the northeast by Pratapgarh district. Banswara is located at 23.11°N to 23.56°N latitudes and 73.58°E to 74.49°E longitudes. Its elevation above mean sea level is about 302 m. (District Profile data, Banswara, Rajasthan). It lies in the Mahi River basin, the Mahi flows north through the district from its origin in the Vindhya Range of Madhya Pradesh, entering the district from the southeast and flowing north towards the northern end of the district, where it turns southwest to form the boundary between Banswara and Dungarpur districts before entering Gujarat and emptying into the Gulf of Cambay.

Data availability

For carrying out the drought study, the daily rainfall data of 35 years from 1974 to 2008 of eleven rain gauge stations situated around the Banswara district was considered. The rain gauge stations were as follows: Banswara, Garhi, Kushalgarh, Danpur, Shergarh, Arthuna, Loharia, Bhungra, Sajjangarh, and Ghatoland Bagidora. For this purpose, the rainfall data was collected from the Water Resources Department, Government of Rajasthan, which was available online at <http://www.indiawaterportal.org>. Table 1, depicts average rainfall data in mm for eleven rain gauge stations with their corresponding latitude and longitude.

Meteorological drought characteristics evaluation based on effective drought index

In the present study, the Effective Drought Index (EDI) developed by Byun *et al.*, (1999) is used to analyse the drought severity by using the monthly precipitation data. The EDI

is the ratio of the precipitation required for a return to normal (PRN) to the standard deviation of PRN, so it is called as the function of PRN. In monthly analysis, the calculation steps for EDI are discussed as follows:

$$EP_i = \frac{\sum_{n=1}^i \frac{\sum_{m=1}^n P_m}{n}}{n} \quad (1)$$

Where, EP_i is the effective precipitation parameter (mm), P_m is the effective precipitation in (m-1) months before the current month (mm), i represents the duration of the preceding period (months), n is the total number of periods before the current month (months).

The mean of EP for each month (MEP) are calculated and the EP values are converted to deviations from the mean (DEP) by subtracting it from EP values.

$$DEP = EP - MEP \quad (2)$$

EP is effective precipitation and MEP is the mean of each month's EP. Precipitations required for a return to normal (PRN) values were calculated as a function of DEP using the relation:

$$PRN_j = \frac{DEP_j}{\sum_{n=1}^j \frac{1}{n}} \quad (3)$$

j is actual duration over which precipitation deficit is accumulated, The summation term $(1/n)$ is the sum of the reciprocals of all the months.

$$EDI_j = \frac{PRN_j}{std(PR N_j)} \quad (4)$$

Std (PRN_j) is the standard deviation of each month's PRN. The meteorological drought severity classification based on EDI values as per the range given by Byun *et al.*, (2010) is

given in Table 2 is used to identify its severity.

Results and Discussion

Evaluation of meteorological drought characteristics

The Effective Drought Index has been used for evaluating the meteorological drought scenario in the Banswara region. The temporal variation of the drought characteristics at Banswara, Garhi, Kushalgarh, Danpur, Shergarh, Arthuna, Loharia, Bhungra, Sajjangarh, Ghatoland and Bagidora are depicted in Figure 1 to 11. The declining EDI value observed from the analysis signifies an increasing drought severity for the study area. The temporal variation of drought characteristics including its onset, termination, duration as well as its severity has been discussed as follows.

A number of drought events faced at all the eleven rain gauge stations have been analyzed and the results are given in Table 3. It has been observed that extreme drought events occurred at Shergarh, Arthuna Bhungra and Loharia rain gauge station which are 3, 2, 9 and 10 respectively. A maximum number of 19 severe drought events occur in Kushalgarh and lowest at Banswara which is only one. The maximum moderate drought occurs at Bagidora which comes to be 59 and a minimum of 28 at Loharia rain gauge station. The total maximum numbers of 65 drought events occur in Kushalgarh and minimum in 42 at Shergarh rain gauge station.

The meteorological drought characteristics, including onset, termination, duration, severity and intensity based on the EDI have been evaluated for Banswara, Garhi, Kushalgarh, Danpur, Shergarh, Arthuna, Loharia, Bhungra, Sajjangarh, Ghatol and Bagidora rain gauge station and are given in Table 4.

Fig.1 Temporal variation of meteorological drought at Banswara station

Fig.2 Temporal variation of meteorological drought at Garhi station

Fig.3 Temporal variation of meteorological drought at Kushalgarh station

Fig.4 Temporal variation of meteorological drought at Danpur station

Fig.5 Temporal variation of meteorological drought at Shergarh station

Fig.6 Temporal variation of meteorological drought at Arthuna station

Fig.7 Temporal variation of meteorological drought at Loharia station

Fig.8 Temporal variation of meteorological drought at Bhungra station

Fig.9 Temporal variation of meteorological drought at Sajjangarh station

Fig.10 Temporal variation of meteorological drought at Ghatol station

Fig.11 Temporal variation of meteorological drought at Bagidora station

Table.1 Average rainfall data of eleven rain gauge station with latitude and longitude

Rain gauge station	Latitude	Longitude	Average rainfall (mm)
Loharia	23° 46' N	74° 14' E	772.60
Sajjangarh	23° 15' N	74° 15' E	812.08
Garhi	23° 36' N	74° 08' E	852.21
Shergarh	23° 20' N	74° 10' E	825.01
Arthuna	23° 30' N	74° 05' E	860.88
Kushalgarh	23° 12' N	74° 27' E	987.52
Bhungra	23° 41' N	74° 31' E	872.87
Bagidora	23° 27' N	73° 17' E	914.29
Ghatol	23° 45' N	74° 25' E	915.23
Danpur	23° 31' N	74° 43' E	1100.90
Banswara	23° 33' N	74° 27' E	1113.52

Table.2 Meteorological drought severity classification based on EDI values

Drought severity classes	EDI ranges	Drought severity classes	EDI ranges
Extreme drought	≤ -2.00	Moderate drought	-1.00 to -1.49
Severe drought	-1.50 to -1.99	Near normal	-0.99 to 0.99

Table.3 EDI based drought events in Banswara district of Rajasthan

Drought class	Extreme	Severe	Moderate	Total
Banswara	0	1	52	53
Garhi	0	10	35	45
Kushalgarh	0	19	46	65
Danpur	0	15	47	62
Shergarh	3	8	31	42
Arthuna	2	12	44	58
Loharia	10	7	28	45
Bhungra	9	4	36	49
Sajjangarh	0	13	34	47
Ghatol	0	12	33	45
Bagidora	0	5	59	64

Table.4 EDI based meteorological drought characteristics of Banswara district

Rain gauge station	Onset	Termination	Duration	Severity	Intensity
Banswara	July 1985	Sept 1985	3	-3.84	-1.28
	Oct 1989	April 1990	7	-7.40	-1.06
	Nov 1999	April 2000	6	-6.33	-1.06
	Aug 2000	May 2001	10	-13.72	-1.37
	Sept 2001	May 2002	9	-11.27	-1.25
	July 2002	May 2003	11	-13.10	-1.19
	Oct 2008	Dec 2008	3	-3.20	-1.07
Garhi	Aug 1979	Oct 1979	3	-3.88	-1.29
	Jun 1985	Sept 1985	4	-6.62	-1.66
	Nov 1985	Feb 1986	4	-4.4	-1.10
	May 1992	Aug 1992	4	-5.18	-1.30
	July 2002	May 2003	11	-14.89	-1.35
	Oct 2008	Dec 2008	3	-3.37	-1.12
Kushalgarh	Aug 1982	Oct 1982	3	-3.82	-1.27
	Jun 1985	Aug 1985	3	-4.50	-1.50
	Oct 1985	May 1986	8	-9.04	-1.13
	Jun 1992	Aug 1992	3	-3.85	-1.28
	Aug 2000	May 2001	10	-17.34	-1.73
	July 2001	May 2002	11	-16.32	-1.48
	July 2002	May 2003	11	-13.92	-1.27
	July 2008	Dec 2008	6	-7.61	-1.27

Danpur	Jun 1985	Sept 1985	4	-5.67	-1.42
	Nov 1985	Feb 1986	4	-4.19	-1.05
	Oct 1989	April 1990	7	-8.22	-1.17
	Aug 1999	Jun 2000	11	-13.89	-1.26
	Aug 2000	May 2001	10	-16.08	-1.61
	July 2002	May 2003	11	-16.29	-1.48
	Aug 2008	Dec 2008	5	-6.31	-1.26
Shergarh	Jun 1981	April 1982	11	-21.02	-1.91
	July 1985	Sept 1985	3	-3.82	-1.27
	Oct 1989	April 1990	7	-7.38	-1.05
	July 2001	May 2002	11	-12.79	-1.16
Arthuna	Aug 1974	May 1975	10	-15.23	-1.52
	Jun 1985	Sept 1985	4	-6.63	-1.66
	Oct 1989	Dec 1989	3	-3.29	-1.10
	Oct 1999	April 2000	7	-7.89	-1.13
	Aug 2000	May 2001	10	-13.92	-1.39
	Oct 2002	Jan 2003	4	-4.86	-1.21
	July 2008	Dec 2008	6	-7.95	-1.32
Loharia	Jun 1981	Oct 1982	17	-31.48	-1.85
	July 1985	Sept 1985	3	-4.45	-1.48
	Nov 1985	Jun 1986	8	-8.97	-1.12
	Aug 2000	May 2001	10	-14.13	-1.41
Bhungra	July 1979	May 1980	11	-23.46	-2.13
	Jun 1985	Sept 1985	4	-5.26	-1.32
	Aug 2000	May 2001	10	-12.71	-1.27
	Aug 2001	May 2002	10	-13.13	-1.31
Sajjangarh	July 1982	Oct 1982	4	-4.77	-1.19
	Dec 1982	March 1983	4	-4.09	-1.02
	Jun 1985	Sept 1985	4	-5.21	-1.30
	Sept 1989	Jun 1991	22	-34.15	-1.55
	Oct 2000	May 2001	8	-8.35	-1.04
Ghatol	Jun 1985	Sept 1985	4	-5.67	-1.42
	Nov 1999	April 2000	6	-6.56	-1.09
	Aug 2000	May 2001	10	-16.26	-1.63
	Oct 2002	Jan 2003	4	-5.2	-1.30
Bagidora	July 1979	Oct 1979	4	-5.48	-1.37
	Jun 1985	Sept 1985	4	-5.44	-1.36
	Oct 1989	May 1990	8	-10.17	-1.27
	Nov 1999	April 2000	6	-6.76	-1.13
	Oct 2000	May 2001	8	-9.87	-1.23
	Sept 2001	May 2002	9	-11.89	-1.32
	Oct 2002	May 2003	8	-9.18	-1.15
	Aug 2008	Dec 2008	5	-5.62	-1.12

The drought severity assessment based on the EDI indicates that the maximum drought severity of -34.15 occurred between September 1989 to June 1991 and it was for

longest duration (22 months) drought in the area under Sajjangarh rain gauge station. The drought having a maximum intensity of -2.13, occurred from July 1979 to May 1980, with a severity of -23.46 in the area under Bhungra rain gauge station.

The meteorological drought characteristics have been assessed using Effective Drought Index (EDI). According to EDI, a meteorological drought of maximum severity -34.15 occurred for the duration of 22 months from September 1989 to June 1991 which was for longest period in the area falling under Sajjangarh rain gauge station. The drought having a maximum intensity of -2.13, occurred from July 1979 to May 1980, with a severity of -23.46 in the area under Bhungra rain gauge station. The distribution of extreme drought event varies from maximum 10 in numbers to minimum 2 in numbers at Loharia and Arthuna rain gauge station respectively. A maximum number of 19 severe drought events occur in Kushalgarh and lowest of 1 at Banswara. The maximum moderate drought occurs in 59 at Bagidora and minimum in 28 at Loharia rain gauge station.

The total maximum number of 65 drought event occurs in Kushalgarh and minimum in 42 at Shergarh rain gauge station. The trend of meteorological drought severity is found to be rising regularly. The analysis also indicates that there is least occurrence of extreme droughts and frequent occurrence of moderate droughts in the area during the period of study.

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