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Climatological Features of Rainfall over CAZRI, Jodhpur

R.S. Singh, Bhagirath Singh and S. Poonia
Central Arid Zone Research Institute, Jodhpur 342 003, India

Abstract: Based on 40 year (1963-2002) rainfall data of CR Farm, CAZRI, Jodhpur, the daily normal, monthly, seasonal and annual rainfall have been analyzed. Diurnal variation of rainfall during monsoon showed maximum rainfall intensity in the afternoon and evening. Rainfall received during February has got significant positive correlation with rainfall of July and monsoon season during the same year. By applying Weibulls' formula the return period of 24 hour peak rainfall for Jodhpur is found to be 50 years. M-K rank statistics value and Spearman rank statistics indicated no significant change in seasonal and annual rainfall. Quasi biennial oscillation and half/fractional sun spot cycles are found in some seasonal and monthly rainfall.

Key words: Normal rainfall, diurnal variation, extreme values, return period, periodic oscillations.

Rapid urbanization and changes in land use pattern have adversely affected the environment, including availability of water for drinking and agricultural use. A recent survey has shown that water withdrawal has increased more than double the rate of population growth. This has necessitated well-planned management of exiting water resources in arid regions. Since rainfall is the primary and only source of fresh water, a strong understanding of rainfall pattern of a place is essential. Earlier researchers have made a critical study of rainfall of various cities located in humid, sub-humid and semi-arid regions of India (Ramakrishnan, 1953; Saxena and Agarwal, 1989; Suresh *et al.*, 1998; Bhadram and Narayanaswamy, 2000).

In this paper, an attempt has been made to study rainfall pattern over CAZRI, Jodhpur (26.18°N; 73.01°E) located in arid plains of NW India at a height of 224 m above mean sea level. This study is based on the precipitation data recorded at agrometeorological observatory in CAZRI, Jodhpur, from 1963 to 2002.

Methodology

Data on daily rainfall, and intensity and duration of rainfall at agrometeorological observatory at Central Research Farm of CAZRI, Jodhpur, recorded using automatic raingauge during 1989-2002 were analyzed for mean hourly and diurnal variation. Monthly and seasonal normal values of rainfall were also worked out. Annual time series for maximum rainfall values worked out for one, two, three, four and five days wet spell period is used to calculate the probable maximum precipitation (PMP) adopting methodology and equation developed by Singh *et al.* (1992) and return period (T) adopting Weibull's formula (Chow, 1964).

Mann-Kendall rank statistic test at 95% level of confidence (WMO, 1966) was used

to find the rainfall trend. Relative values of all terms in the rainfall series under analysis were arranged by their ranks such that each term is assigned a number ranging from 1 to N.

$$S = \sum_{i=1}^{N-1} n_i$$

where,

n_i = number of later terms whose value exceeds n_i (the element) of k_i (the rank); then

$$r = \frac{4S}{N(N-1)} - 1$$

If the value of 'r' is +1, there is a perfect systematic upward trend, and if 'r' is –1, there is a systematic downward trend. The value of 'r' will be very near to zero when no significant trend is seen.

The value of 'r' thus can be used as the basis of a significant test by comparing it with

$$r(t) = \pm\ t_g \sqrt{\frac{4N + 10}{9N(N-1)}}$$

where,

t_g is the desired probability point of the Gaussian normal distribution. In the present study, t_g = 1.96 at 5% probability point has been taken for comparison (Srivastava *et al.*, 1998).

Another similar alternate method of trend test known as the spearman rank statistics (r_S) has also been applied to find out presence of any significant increase or decrease (trend) in the rainfall series.

To determine the periodicities in the fluctuations of rainfall series, the series have been subjected to power spectrum analysis as suggested by Blackman and Tukey, as described in WMO (1966) and simplified by Singh and Singh (1988). Maximum lags were taken 24% of the total number of years of rainfall data to get optimum resolution and stability in power spectrum. Spectral estimate peaks, which exceed or equaled 95% confidence limit, were considered to represent real oscillations or periodicities (T) in the rainfall time series of Jodhpur. Periodicity (P) is worked out according to following relation as also used by Singh and Singh (1987) and Singh *et al.* (1990).

$$P = \frac{2\,m.\,\Delta t}{L}$$

where,

m is the maximum lag, L is significant lag (L = 0, 1, 2, --- m) and Δt being the interval between successive observations which is one year in the present computations.

Results and Discussion

Daily normal rainfall

The daily mean rainfall of Jodhpur from January to April and November to December was found to be very low and hence the rainfall for the period May to October is presented in Fig. 1. There is progressive increase in daily rainfall after 28 June, marking the arrival of southwest monsoon normally around 5 July over Jodhpur. The highest daily mean rainfall of 9.4 mm falls around 18 July followed by a decreased spell in the last week of July. Second peak of daily mean rainfall (8.9 mm) falls around 5 August, and thereafter gradually decreased

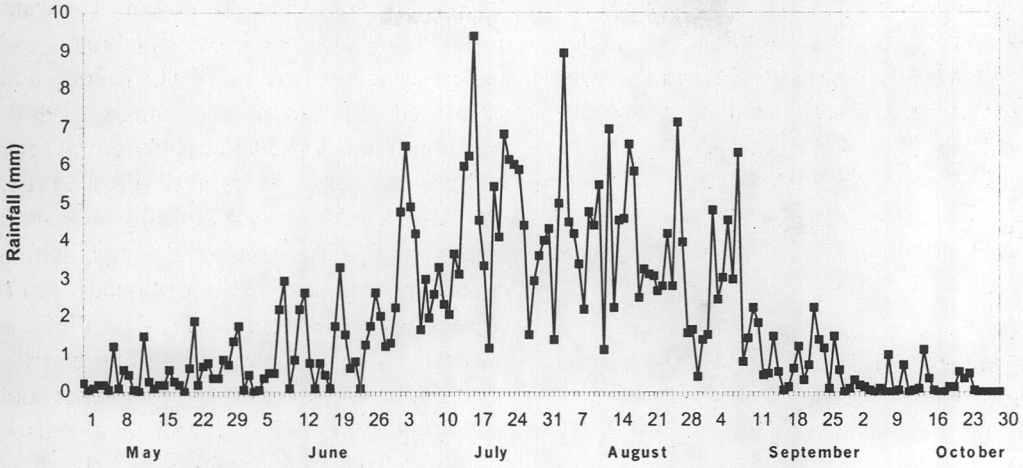

Fig. 1. Daily normal rainfall over CR Farm, CAZRI, Jodhpur from May to October.

till first week of September. A sharp fall in rainfall is observed after 10 September indicating the retreat of monsoon from the area. The decreased spell of rain between last week of July and in first week of August is mainly due to break conditions in monsoon when the monsoon trough shifts to foothills of Himalayas leading to striking decrease of rainfall over main land of the country.

Diurnal variation of rainfall

The time of occurrence of maximum rainfall during the 24 hour period, for any place, is much sought information for planning. The diurnal variations reveal maximum rainfall occurs between 16:00 and 18:00 hours (Fig. 2). In the month of June the diurnal variation of rainfall is not significant. In July and August, there are two peaks 09:00-11:00 hours and 16:00-18:00 hours, while in September, the maximum rainfall is noticed between 17:00-19:00 hours. In general, rainfall is most intense from 17:00 to 18:00 hours, from July to September.

Mean and extreme monthly rainfall

Since zero was the lowest total for certain months in many years, the number of such year alone is given in Table 1. December had no rain in 34 years, out of 40 year of study period. July and August are the rainiest months followed by September and June. It is interesting to note the maximum rain is received in July, but in July 2002 no rainfall was received. Lowest rainfall recorded in the month of August was 4.1 mm during 1993. The highest rainfall recorded in the month of July (516.0 mm) was in 1990, followed by August (374.2 mm) in 1970 and September (241.2 mm) in 1975. These very heavy rainfall events were mainly in association with a deep depression, which formed over Central Bay of Bengal and moved toward the main land in northwesterly direction and arrived over this part of NW India.

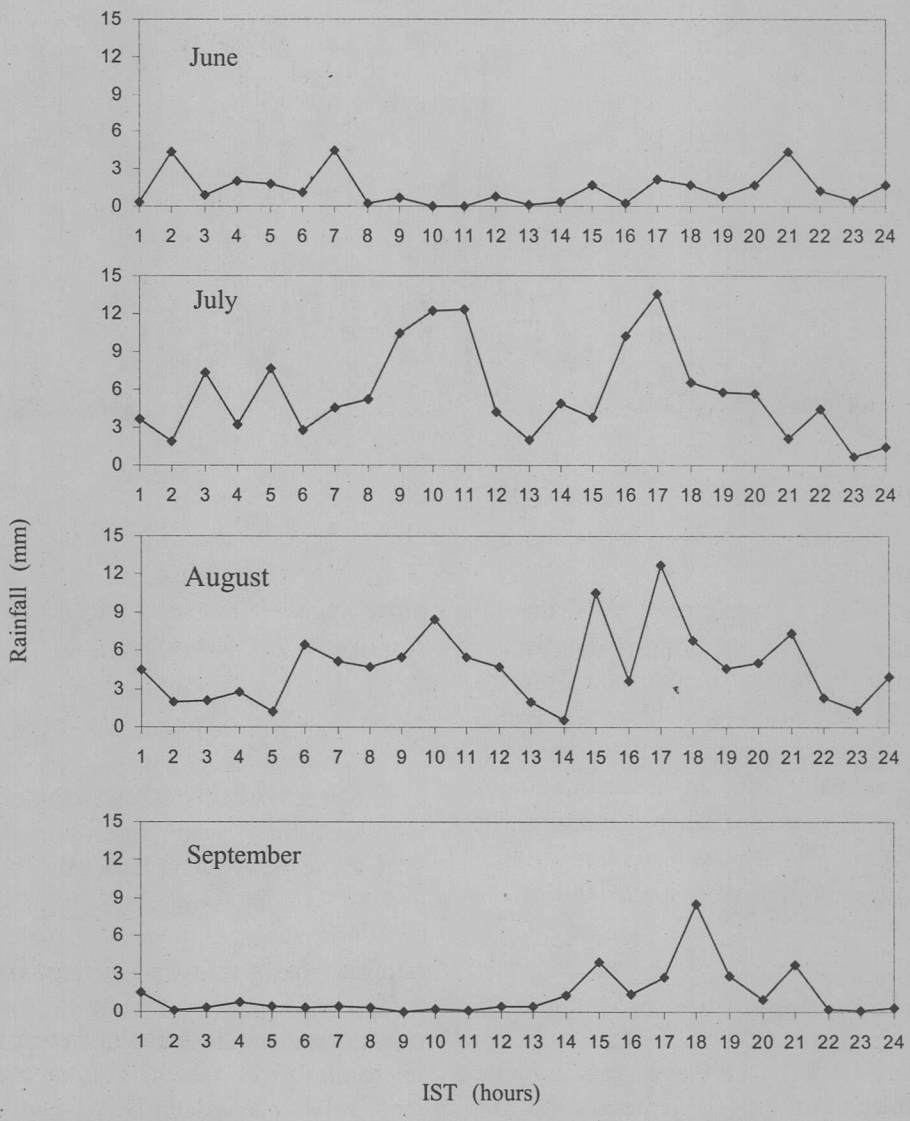

Fig. 2. Diurnal variation of rainfall recorded at CR Farm, CAZRI, Jodhpur from June to September.

Seasonal and annual rainfall

The seasonal and annual rainfall of Jodhpur from 1963 to 2002 is presented shown in Fig. 3. The annual normal rainfall is 375.6 mm and that of southwest monsoon (June to September) season is 331.3 mm, implying that 88.2% of the annual rainfall occurs during the monsoon season. Study revealed that February rainfall has significant positive correlation with the rainfall subsequently received in July and the season (June-September). The

Table 1. Monthly, seasonal and annual rainfall (mm) characteristics at CR Farm CAZRI, Jodhpur (1963-2002)

Month/Season	Normal rainfall (mm)	Frequency of rainy days	CV of rainfall (%)	Highest rainfall (mm)	Year	Lowest rainfall (mm)	Years
January	2.9	0.3	200	26.6	1992	0	23
February	3.5	0.5	195	35.5	1990	0	14
March	3.5	0.4	359	79.9	1967	0	27
April	8.3	0.6	269	130.0	1982	0	21
May	15.2	1.0	118	58.7	1982	0	13
June	34.9	2.1	115	164.0	1996	0	2
July	126.8	5.6	84	516.0	1990	0	1
August	123.0	5.8	77	374.2	1970	4.1	1
September	46.6	2.8	125	241.2	1975	0	3
October	6.7	0.6	185	47.7	1997	0	20
November	3.2	0.2	327	55.1	1976	0	31
December	1.0	0.1	357	14.6	1980	0	34
Annual	375.6	20.1	47.8	844.0	1990	50.0	1
Winter (Jan.-Feb.)	6.4	0.8	142.7	39.4	1992	0	8
Pre-monsoon (March-May)	26.9	2.0	133.0	197.8	1982	0	3
Monsoon (June-September)	331.3	16.3	50.4	776.6	1990	32.5	1
Post monsoon (October-December)	10.9	0.9	148.9	57.5	1997	0	15

correlation coefficients are found 0.6103 and 0.5694, respectively and also significant at 1% level.

During the period under study, the highest annual rainfall was 844.0 mm in 1990, while the lowest 50.0 mm was received in 2002. However, the highest monsoon seasonal rainfall of 776.6 mm was recorded in 1990 and lowest seasonal rainfall of 32.5 mm was in 2002. Incidentally, these extreme rainfall events of Jodhpur are in agreement with all India monsoon rainfall of +7% (Normal) in 1990 and -31% (Deficient) in 2002, respectively.

Peak rainfall and return period

Rainfall with different return periods were computed based on extreme values of rainfall for 1-day, 2-day, 3-day, 4-day and 5-day spells, revealed that rainfall may received in 5 years of return period during one, two, three, four and five days spells are 102, 143, 179, 206 and 238 mm respectively, over CR Farm, Jodhpur (Table 2). Similarly rainfall with 100 years return period are worked out to be 193, 287, 382, 441 and 519 mm for above duration of wet spell. These findings are comparable with the earlier report on return period

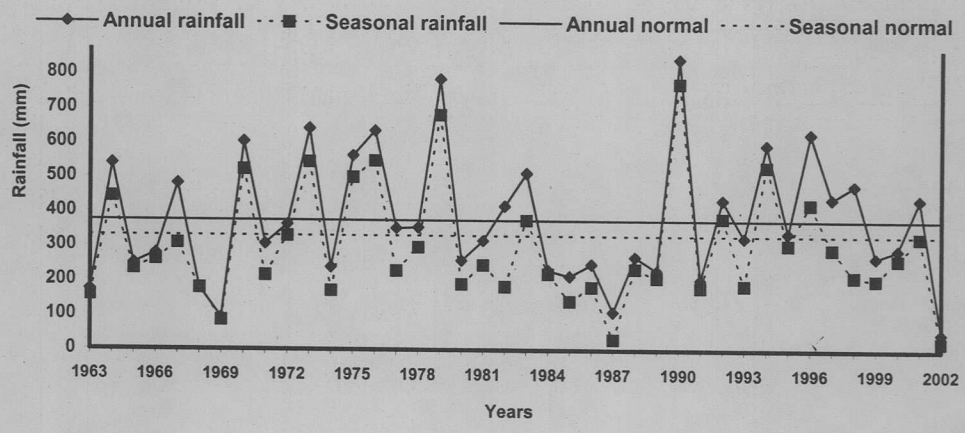

Fig. 3. Annual and seasonal (June-September) rainfall over CR Farm, CAZRI, Jodhpur (1963-2002).

of rainfall in Indian desert (Singh *et al.*, 1992). The return period of 24 hour peak rainfall (170 mm) recorded over CAZRI, Jodhpur during 1996 is 50 year, whereas the return period for highest rainfall (516 mm) recorded during 5-day spell in 1990 is found 100 year (Table 3).

The study also revealed that one-day PMP value is 253 mm whereas for 5 days PMP value is 705 mm. It is difficult to say how realistic these values are, but undoubedtly these values are estimated upper limits to the likely rainfall. This is useful for planning in construction works like making of drainage, road, bridge, dam and building railway tracks.

Trends and periodic oscillations in rainfall

Both, the Mann-kendall statistics as well as the Spearman rank statistics do not reveal any significant trend in seasonal and annual rainfall over Jodhpur during the period. However, the above analysis indicated that within, the monsoon season, rainfall during June and July is apparently increasing at a linear rate of 1 to 1.2 mm year^{-1} whereas during August and September it is apparently decreasing at a linear rate of 0.4 to 0.9 mm year^{-1}. Both the methods identified significant increasing trend in rainfall during the month of April only. For all other months, no significant change has been identified by any of the statistical methods. Other characteristics including skewness and kurtosis values with respect to monthly/seasonal rainfall time series are also carried out. The skewness, which is a measure of asymmetric in a frequency distribution around mean is indicating distribution of rainfall is more or less asymmetric to the right of the mean over the station during most of the season. Kurtosis is also worked out, which is a statistic describing the peaked ness of a symmetrical frequency distribution.

A plot of spectral estimate (density) vis-à-vis lags in respect of some monthly, seasonal and annual rainfall of CAZRI Jodhpur is shown in Fig. 4. Periods of 2.0 to 2.6 years found in pre-monsoon and

Table 2. Return period (T) of rainfall (mm) during different durations of wet spell over CAZRI, Jodhpur

Return period T (years)	Duration of wet spell				
	One-day	Two-day	Three-day	Four-day	Five-day
5	102	143	179	206	238
10	124	177	228	263	306
20	145	211	275	317	371
50	172	254	336	388	456
100	193	287	382	441	519
150	205	306	409	471	556
200	213	319	428	493	582
500	240	362	488	563	665
1000	260	394	533	615	728
10000	328	502	685	790	938

post-monsoon, seasonal/monthly rainfall are presented in Table 4. It also lists the spectrum analysis results for all the months and season. Here, it can be seen that Quasi Bi-ennial Oscillations (QBO) is seen in some seasonal and monthly rainfall confirms the earlier finding by Mooley and Parthasarathy (1984). The QBO was also observed by Alvi and Koteswaram (1985) Indian rainfall. However, other cycles of periodicities 6 and 9 years resembling by (Vines, 1986) for all India rainfall fluctuations. Studies by Bhalme (1975) showed that an increase sunspot activity is associated with decrease of rainfall and vice-versa. Rao *et al.* (1973) also showed presence of solar cycle in palmer drought indices at certain subdivisions of the country. Hence the QBO and solar cycle (sun spot cycle) are also found in some seasonal and monthly rainfall over Jodhpur. However, there is no significant periodic

Table 3. Probable maximum precipitation (PMP) and return period (T) of peak rainfall

Duration of wet spell (in days)	Peak rainfall received	Year of recording	Return period (in years)	Probable maximum precipitation (PMP)	
				First	Second
One	170.0	1996	50	253	236
Two	296.3	1990	100	382	336
Three	415.2	1979	150	516	415
Four	473.3	1990	150	596	486
Five	516.0	1990	100	705	541

half/fractional sun spot cycles were noticed, particularly in winter season and February rainfall series which supports earlier finding oscillation noticed in monsoon and annual rainfall over Jodhpur during the same period.

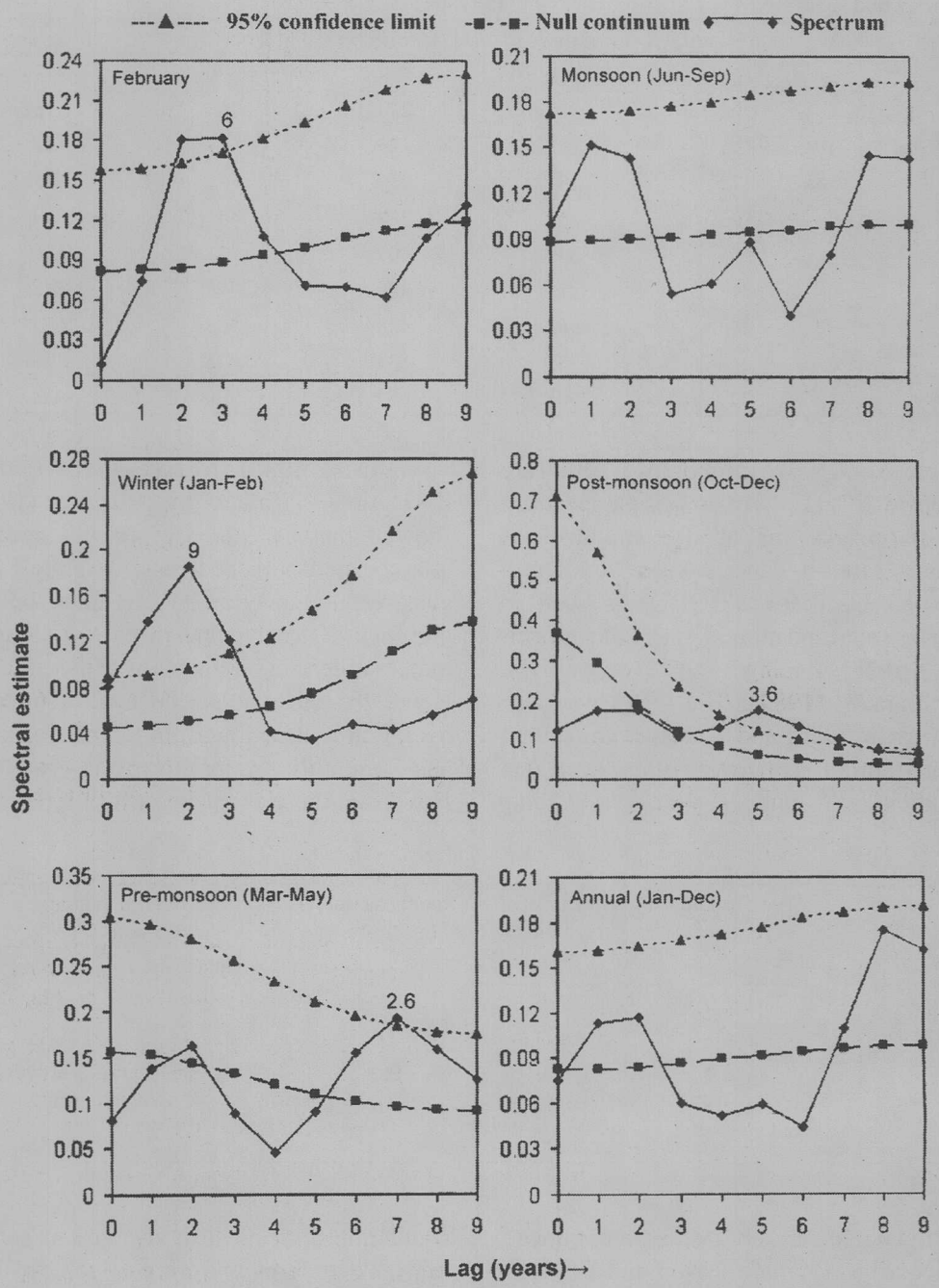

Fig. 4. Power spectrum of rainfall over CR Farm, CAZRI, Jodhpur.

Table 4. Results of power spectrum analysis, trend analysis and other statistical properties of monthly, seasonal and annual rainfall recorded at CR Farm, Jodhpur

Months/Season	M-K statistics value	Spearman rank statistics	Linear trend rate (mm/year)	Skewness	Kurtosis	Periodicity/ significant cycles (years)
January	0.1721	2.0628*	0.14	2.82	8.09	18
February	-0.0242	-0.2055	-0.09	2.93	9.93	6, 9
March	0.0156	0.9177	0.21	5.60	33.01	3-18
April	0.2304*	2.6646*	0.34	4.58	23.90	2-9
May	-0.0213	-0.1545	-0.09	1.09	0.24	2.6
June	0.1052	1.0206	1.00	1.92	3.92	–
July	0.0427	0.3119	1.18	2.16	5.76	–
August	-0.0185	-0.2596	-0.86	1.00	0.24	–
September	-0.0654	-0.5332	-0.42	1.89	3.32	–
October	0.1437	1.7412	0.33	2.36	5.28	2-6
November	0.0228	1.5326	0.07	4.02	16.48	3-18
December	-0.0740	1.4680	-0.02	4.30	19.82	–
Annual	0.0640	0.5904	1.42	0.72	-0.08	–
Winter (Jan.-Feb.)	0.1294	1.0118	0.22	1.77	3.02	6, 9, 18
Pre-Monsoon (March-May)	0.0797	0.9362	0.04	3.17	13.21	2.6
Monsoon season (June-September)	0.1351	0.6491	0.90	0.83	0.15	–
Post-Monsoon (October-December)	0.0925	1.1484	0.26	1.90	2.78	2.6-3.6

Note: * Significant at 5% level; 2. Mann-kendall statistics test value for 5% level of significance for the study period = ±0.2218; 3. Spearman rank statistic test value for 5% level of significance for the study period = ±2.03.

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