Acta Geophysica (2021) 69:353–364
https://doi.org/10.1007/s11600-020-00520-2

RESEARCH ARTICLE - ATMOSPHERIC & SPACE SCIENCES

Temporal and spatial trend analysis of rainfall on Bhogavo River watersheds in Sabarmati lower basin of Gujarat, India

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Received: 11 June 2020 / Accepted: 21 November 2020 / Published online: 3 January 2021

Abstract

Global warming is a biggest issue around the world. In this research paper, the temporal and spatial trend analysis of seasonal and annual rainfall on Bhogavo River watersheds in Sabarmati lower basin of Gujarat state of India has been analysed using the data of 11 rain gauge stations installed in Bhogavo watershed. Linear regression, Mann–Kendall Test, Sen's slope test and innovative trend analysis methods are used to carry out monthly and annual rainfall trend analysis. In addition to the rainfall analysis, a number of rainy days change in magnitude as a percentage of mean rainfall have also been analysed using linear regression and Sen's slope method, respectively. The IDW method is used to develop a spatial distribution of annual and seasonal rainfall trend over the study area. From the results, it is concluded that annual rainfall shown increasing (positive) trend at nine stations out of 11 stations. The highest value of change in magnitude of trend as a percentage of mean monthly rainfall has been obtained in the month of July, attributing increasing trend at Sayla station and lowest value magnitude of trend as a percentage of mean rainfall in the monthly rainfall has been obtained in the month of August, attributing decreasing trend at Bavla station.

Keywords Bhogavo River watersheds · Climate change · Innovative trend analysis · Mann–kendall test · Rainfall trend · Temporal and spatial trend

Introduction

Temperature and precipitation are the key parameters of climate. Variations in the pattern of these parameters can affect human health, economic growth and development. An increase or decrease in precipitation can result in the increase in the frequency of floods, instances of droughts and impact on water quality. Patle and Libang (2014) investigated that the annual rainfall trend shown decreasing trend in the post monsoon season with Sen's slope magnitude is 3.01 mm/year, 3.32 mm/year and 3.95 mm/year in east siang, upper siang and lower dibang valley districts which are located in N–E region of India. According to Chandole et al. (2019) determined that the annual rainfall has been increasing at the rate of 2.19 mm/year, 4.18 mm/year and 5.50 mm/year for the period of 1928–2013, 1955–2013 and 1970–2013, respectively, in lower Tapi River basin of Gujarat State, India. Pingale et al. (2014) found that monsoon rainfall shows decreasing slope of − 8.56 mm/hydrologic year for Tonk and percentage change of − 88.16% in Jodhpur, India, during 1971–2005, and also, significant increasing trend was observed in non-monsoon rainfall at Hanumangarh (1.70 mm/hydrologic year). Sayemuzzaman et al. (2014) emphasized on the range of magnitude of annual precipitation in North Carolina, USA, during 1950–2009. Annual precipitation trend varies from − 5.50 to + 9 mm/year. Zarenistanak et al. (2014) studied the winter and summer season precipitation trend for the period of 1950 to 2007

Communicated by Theodore Karacostas, Prof. (CO-EDITOR-IN-CHIEF).

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11600-020-00520-2) contains supplementary material, which is available to authorized users.

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in southwest Iran. Gajbhiye et al. (2016) discussed that most of the stations of the Sindh River basin from 1901 to 2002 showed an increasing trend except Guna and Vidisha (2016) which reported to have a decreasing trend (*Z*-value). Sindh River basin showed an increasing trend of precipitation during monsoon seasons. Chandniha et al. (2017) addressed annual and seasonal precipitation trends for 1901–1949 and 1950–2011 period in Jharkhand State of India. Annual and winter precipitation decreased in Jharkhand State during 1901–2011, while increasing trend in precipitation during period 1950–2011 observed. Zhang et al. (2015) observed increasing trends in annual and seasonal precipitation, except for the summer season, over 1961–2012 in the Southeast of Tibetan Plateau. Cui et al. (2018) addressed monitoring and sustainable management of land surface ecosystems. Dayal et al. (2018) examined long-term changes in aridity index (AI) and precipitation for the period of 1901–2013 at 21 stations over Betwa River basin which is part of Madhya Pradesh and Uttar Pradesh states of India, and correlation between aridity index and precipitation was developed. In the study, the modified Mann–Kendall test is applied for detecting the trend. Narsinghpu and Banda exhibited a decreasing trend of aridity index with slope of -2.74×10^{-3} and -2.45×10^{-3}, respectively, because of increase in potential evapo-transpiration, no significant trend was observed in precipitation, during post-monsoon season. Farhangi et al. (2016) analysed average monthly and annual rainfall time series and any trends investigated during the period of 26–45 years. Ten sub-basins in western region of Iran were chosen for the analysis. Analysis of time series of control stations revealed that 49% experienced increasing trends, while 51% of time series have decreasing trends. Six out of ten studied sub-basins had a decreasing trend of annual rainfall time series of all over the basin. Among the rainiest months in the country (November–May), in November 68% of the stations had an increasing trend, while in March 92% of the stations had a decreasing trend. Basistha et al. (2009) emphasized on rainfall patterns in Himalaya regions of India from 1902 to 1980 of data from 30 rain gauge laid by the India Meteorological Department (IMD). Possible shift and rainfall trends were found using Pettitt–Mann–Whitney (PMW) test and modified Mann–Kendall test (MMK), respectively. Up to year 1964, trend was increasing, followed by a decreasing trend from 1965 to 1980. Joshi and Shah (2019) analysed annual and monthly rainfall trends for the rain gauges installed in a river basin of Orsang. They also have focused on the importance of concentrated annual precipitation for the safe operation of hydraulic structures. Finally, it was concluded that annual rainfall magnitude is increasing and shifting of the monsoon season to start and finish late. Kumar et al. (2010) studied seasonal, annual and monthly trends from 1871 to 2005 of rainfall considering 135 years data series for 30 subdivisions in India. Fifty per cent of the subdivisions showed increasing trend in annual rainfall, which is not significant at 5%. The subdivisions showed increasing rainfall in the months of June and July. In August, the number of subdivisions showing an increasing trend exceeded those showing a decreasing trend, whereas the condition is opposite in September. Post-monsoon, pre-monsoon and winter rainfall increased at the national scale. Rainfall from June, July and September decreased while in august it results increased. Kaur et al. (2017) addressed long-term seasonal and annual rainfall trend of India for the period of 1901–2013 using gridded ($0.25°\times0.25°$) rainfall data, Mann–Kendall test, Theil-Sen's nonparametric test and linear regression have been used for the analysis. It was observed that 10% of the numbers of districts are showing a significant increasing trend and 13% significantly decreasing (mainly in Uttar Pradesh) trend. It was also demonstrated that the rainfall of the country is not indicating any trend. Liang and Ding (2016) analysed extreme heavy precipitation in Shanghai on temporal and spatial scales. Pakalidou and Karacosta (2017) determined the rainfall regime trends of long precipitation time series of 1892–2015 in Thessaloniki using monthly and annual rainfall data. Also statistical analysis of the standard deviation, the root mean square difference and correlation coefficient is carried out. Gocic and Trajkovic (2014) analysed monthly precipitation across Serbia for 29 stations for the time series of 1946–2012 using multivariate statistical analysis methods. Camuffo et al. (2020) developed the relationship between return periods, selected percentiles and the concepts of extreme and rare events in hydrological and climate series.

Study area

Sabarmati River is one of the longest rivers in Gujarat. Sabarmati River basin of Gujarat has been divided into two sub-basins, the upper basin and the lower basin. In the lower basin, the major river is Bhogavo. (https://indiawris.gov.in/wris/#/. Bhogavo River watershed covers 6493 km^2 area in Ahmadabad and Surendranagar districts of Gujarat State.

Figure1 shows Bhogavo River watershed. Locations of 11 rain gauge stations are shown in Fig.2. Limdi Bhogavo and Wadhwan Bhogavo are two major tributaries of Bhogavo River. Limdi Bhogavo tributary originates from Reshamiya village of Surendranagar District and spreads into the Bhal region near Panashina village of Limbdi taluka. Wadhwan Bhogavo tributary originates from Bhimgadh village of Surendranagar District.

Rainfall trend analysis has been carried out using data of 11 rain gauge stations established on Bhogavo River watershed. The area covered by each rain gauge is 590 km^2 per rain gauge.

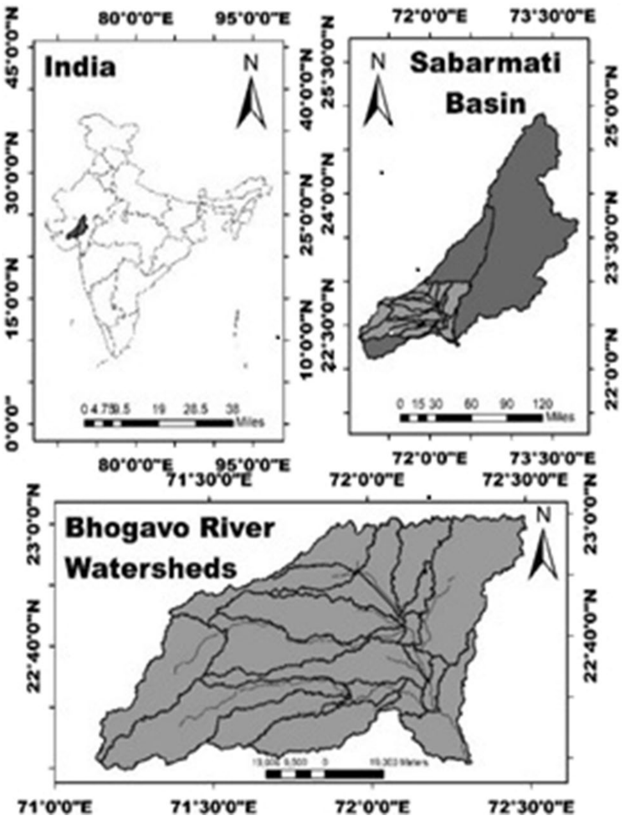

Fig. 1 Map of Bhogavo River watershed

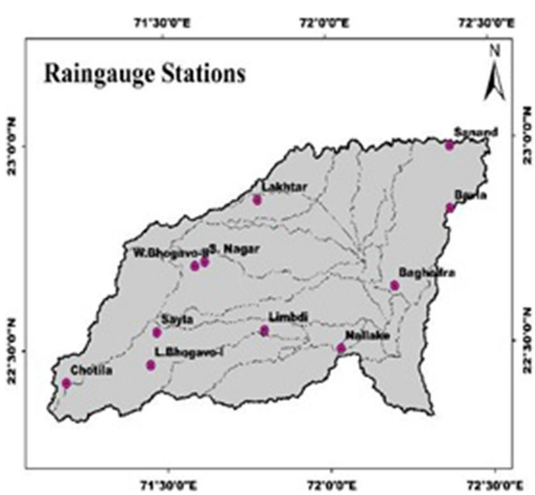

Fig. 2 Location of rain gauge stations on Bhogavo River watershed

Material and methods

Data collection

From the State Water Data Centre (SWDC) of Gujarat, Data series of 1969–2016 from 11 rain gauge stations (Chotila, L.Bhogavo-I, W.Bhogavo-II, Limdi, Lakhtar, Sayla, Surendranagar, Baghodra, Bavla, Nallake and Sanand) laid on Bhogavo River watershed stations have been used. The mean annual rainfall of the whole area is 524.2 mm/year. As given in Table1, Chotila rain gauge station is located at the highest elevation of 187 m and Nallake rain gauge station is located at the lowest elevation of 11 m. Station-wise data span is given in Table1. Digital elevation map of Bhogavo Watershed is shown in Fig.3.

Methodology

The trend analysis methods such as linear regression, Mann–Kendall, Sen's slope estimator and innovative trend analysis are used to detect the seasonal and annual rainfall trend. Also, the inverse distance weighting (IDW) method has been used for spatial distribution of annual and seasonal rainfall trend.

Sen's slope

Sen's slope test is a nonparametric procedure for estimating the slope of trend, and it is widely used in hydro-meteorological time series (Gocic and Trajkovic 2013). Sen's slope approach was used to establish slope of data set (Suryavanshi et al. 2013) in Betwa Basin, India. If the trend of present time series is linear, then it is required to find out slope of trend by using Sen's slope test which can be found out by (Gajbhiye, Meshram et al. 2016)

$$\beta = \text{Median}\left(\frac{yi - yj}{i - j}\right) \quad \text{for all } j < i \tag{1}$$

y_i and y_j are data value at the time of i and j, respectively. If the number of value (N) is odd, then Sen's slope estimator is computed by ßmed = ß$_{(N+1)}$/2 and if N value is even, then Sen's slope is computed by ßmed = [ß$_N$ + ß$_{(N+1)}$]/2. Here N is the number of pairs of time series elements.

The percentage change in magnitude of trend can be estimated by using Sen's slope median value and that mean by using linear trend in the time series.

$$C = \frac{\beta \times \text{length of year}}{\text{mean}} \times 100 \tag{2}$$

Here C indicates the magnitude of trend as % of mean rainfall (defined as the variation of trend from the mean rainfall) and ß indicates Sen's slope value.

Innovative trend analysis (ITA)

This method was proposed by Sen (2012). In this method, the subsection time series plot considered on a Cartesian coordinate system. If any decreasing or increasing trend

Table 1 Bhogavo River watershed rain gauge station details

Rank	Station name	Latitude	Longitude	Elevation (m)	Data from	Data to
1	Chotila	22.42	71.19	187	1968	2016
2	L.Bhogavo-I	22.46	71.45	113	1971	2010
3	W.Bhogavo-II	22.70	71.59	72	1971	2011
4	Limdi	22.54	71.80	45	1968	2016
5	Lakhtar	22.85	71.78	38	1968	2016
6	Sayla	22.54	71.47	124	1968	2016
7	Surendranagar	22.71	71.62	70	1968	2016
8	Baghodra	22.64	72.20	13	1969	2004
9	Bavla	22.82	72.37	27	1980	2014
10	Nallake	22.49	72.03	11	1970	2010
11	Sanand	22.98	72.38	38	1967	2010

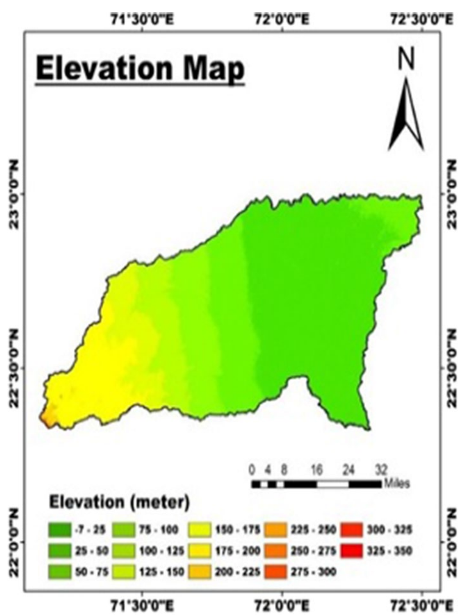

Fig. 3 Elevation map of Bhogavo River watershed

exists by finding lower and upper triangle with respect to the 45° trend-free line. The trend is monotonic, if the 1:1-line plots appear along a straight line parallel to 1:1 line, otherwise it is a combination of various trend-free portions or trends (Sonali and Kumar 2013). Sen (2012) found the applicability of an innovative trend analysis by considering the 1:1 (45°) straight line on the Cartesian coordinate system. The approach is working on the basis of the fact that the plot against each other will be scatter of points along 1:1 (45°) line on the Cartesian coordinate system if two time series are identical to each other. Sen developed the innovative trend analysis method to analyse hydro-meteorological variables trend. According to ITA (Innovative Trend Analysis), time series data should be split into two separate sub-series and the data of each sub-series should be sorted in the ascending order. Then, the second and first half of the time series should be placed on Y- and X-axis, respectively. If the data are accumulated on the 45° line, then it can be said that the given time series has no trend. For the data that are on the upper region of triangular, it can be said that the time series has an increasing trend (Sanikhani et al. 2018). The main advantage of this method is that it does not depend on any restrictive parameter such as serial correlation, non-normality, etc. As per Wu and Qian 2016 trend indicator is given by,

$$D = \frac{1}{n}\sum_{i=1}^{n}\frac{10\left(y_i - y_j\right)}{\bar{x}} \quad (3)$$

In this method, the detection and evaluation parameter D is used as an indicator. When it is positive, then it shown increasing trend and when it is negative, it results in decreasing trend. In this study, innovative trend indicators have been evaluated for seasonal and annual rainfall data.

Mann–kendall test

Mann–Kendall test is a statistical method formulated by Mann (1945) as nonparametric test for trend detection and the test statistic distribution had been given by Kendall (1975) (Makhasana and Joshi 2019)**.** Mann–Kendall test (Kendall 1975) is a statistical and effective method, the nonparametric method. It is also applicable in the research area of climate change, mainly aimed to identify the significance of trend of precipitation, discharge and temperature (Li et al. 2019). In hydrology, time series research is usually carried out under the assumption of stationary, independence and homogeneity of time series (Jeneiova et al. 2014). It is the nonparametric test method to identify trends in climatological and hydrological time series. Mann–Kendall Test is also called Kendall's tau test. It is commonly used to detect hydrological trend (Yue et al. 2002). Mann–Kendall test is also known as Kendall's s statistic, and it is a rank-based procedure, with resistance to the importance of extreme values (Partal and Kucuk 2006). Mann–Kendall test has been an excellent tool to detect a trend, and many researchers are using it to know the trend of hydro-climatic time series data such as stream flow, temperature and precipitation. The test statics equals (Jain 2012) follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(y_i - y_j) \tag{4}$$

where n = length of time series.

This test can be applied to the time series y_i rank from $i = 1, 2...., n-1$ and y_j rank from j = n + 1, $n + 2.... n$. In (5), $sgn\left(y_i - y_j\right)$ is sign function defined as,

$$\operatorname{sgn}\left(y_i - y_j\right) = \begin{cases} +1 \text{ if } \left(y_i - y_j\right) > 1 \\ 0 \quad \text{if } \left(y_i - y_j\right) = 0 \\ -1 \text{ if } \left(y_i - y_j\right) < 1 \end{cases} \tag{5}$$

Here, y_i and y_j are the value of the data.

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{p-1}^{m} t_k\left(t_p - 1\right)\left(2t_p + 5\right)}{18} \tag{6}$$

In case of $n > 10$, the standard normal test statistics is calculated by using (7),

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \text{ if } S > 0 \\ 0 \qquad \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} \text{ if } S < 0 \end{cases} \tag{7}$$

Here Z value indicates whether the trend value is positive or negative. Negative sign indicates decreasing trend and positive sign indicates increasing trend. Sometimes no trend can be identified by the level of significance (α). Generally, most of the researchers (Joshi and Makhasana (2020) and Chandole et al (2019)) take values of level of significance 1% or 5%.

Linear regression method

Linear regression analysis is used to analyse trends in the time series. Negative slope value indicates decreasing trends. Positive slope value indicates increasing trends (Tabari et al. 2011). Zhao et al. (2014) identified human activity as main driving factors of run-off using regression analysis. The linear regression method is the most useful parametric method. Slope sign plays an important role in deciding the variable's trend. Trend is increasing if slope sign is positive, whereas it is decreasing if sign is negative (Motiee and McBean 2009). The linear regression is given in (8). Linear regression used for long-term trend analysis and to define any correlation between dependent variable (Y) and independent variable (x).

$$Y = mx + B \tag{8}$$

where Y could be the amount of rainfall and independent variable is time in year. Slope m is a trend indicator.

Spatial distribution using inverse distance weighting (IDW) method

This method is used to interpolate spatially varied hydrological data such as rainfall, temperature, run-off and humidity. Spatial distribution of annual rainfall will be helpful for water management, hydrological and agricultural purposes. This method was developed in 1972 by the US National Weather Services. The inverse distance weighting (IDW) method is based on the first law of Tobler's or the law of geography. This method is defined as 'everything is related to everything else, but near things are more related than distant things' (Feug and Chen 2012). In this method, the weighted factor is calculated by using (9) (Feug and Chen 2012).

$$Q_i = \frac{H_i^{-x}}{\sum_{i=1}^{n} H_i^{-x}} \tag{9}$$

Here Q_i is the weighing of each rainfall station, H_i means the distance from each rainfall station to the unknown point, and x is the control parameter. This weight based on power of 10 and the effect of the points are reduced when increasing the power. Spatial distribution of annual and seasonal rainfall trend over the study area have been developed using the IDW method in Arc GIS 10.3.

Parameter used in this study for development of the spatial distribution using Sen's slope value (ß) in mm/year.

Result and discussion

Spatial and temporal trends of rainfall on annual and seasonal basis

The spatial distribution of mean annual rainfall and annual rainfall trend is shown in Fig. 4. The spatial distribution of seasonal rainfall and seasonal rainfall trend developed in this study for Bhogavo watershed is shown in Fig. 5. The highest value of mean annual rainfall is 666.7 mm/year at Sanand station, and the lowest value of mean annual rainfall is 405.5 mm/year at Limidi Bhogavo-I stations. The highest values of mean annual rainfall from June to September months obtained are 111.4 mm/year, 263.5 mm/year, 226.5 mm/year and 107.46 mm/year at Chotila, Bavla, Sanand and Limdi stations, respectively. On the

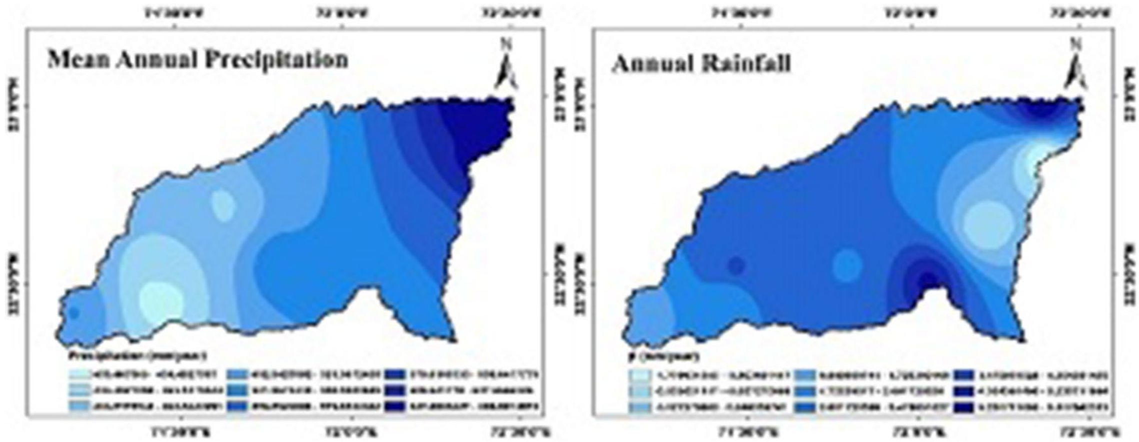

Fig. 4 Spatial distribution of mean annual rainfall *(Left)* and annual rainfall trend *(Right)*

other side, the lowest values are 85.9 mm/year at Nallake and 133.5 mm/year, 109.3 mm/year and 58.1 mm/year at Limidi Bhogavo-I stations, respectively.

Result of innovative trend analysis method

Annual rainfall trend analysis at the 11 rain gauge stations installed in Bhogavo watershed has been carried out using the innovative trend analysis method. The relevant plots are presented in Fig.6. It is observed that mean annual rainfall follows an upward trend in the time series of 1969–2016 at Chotila station up to 500 mm, from 500 to 900 mm shows no trend but trend becomes negative beyond 900 mm. At stations Baghodra and Balva, the annual rainfall trends are decreasing (negative), and at station L. Bhogavo station, the annual rainfall do not show any trend, whereas at all other stations annual rainfall trends are increasing (positive).

As per Fig. 6, most of the points lying above the 45° line indicate increasing trend at Chotila, W. Bhogavo-II, Limbdi, Lakhtar, Sayla, Surendranagar, Nallake and Sanand stations and most of the points laid below the 45° line indicate decreasing trend at Baghodra and Bavla stations. Monsoon season (June to September) rainfall trend analysis for time series 1969–2016 has been also carried out using the innovative trend analysis method. Out of all 11 rain gauge stations, the results are presented for only Chotila station shown in Fig.7. It is observed that for June, there is no trend up to 200 mm, but from 200 to 400 mm trend is increasing. For July rainfall, trend is increasing up to about 400 mm but after 400 mm there is no trend. In August, all points are laid on lower triangle so it results in decreasing trend and in September, all points are laid on upper triangle so it results in increasing trend.

Summary of annual rainfall trend analysis

Annual rainfall trend analysis has been carried out using linear regression, Sen's slope test, Mann–Kendall test and innovative trend analysis at the 11 stations. Percentage change in magnitude of trend and results obtained from various methods are shown in Table2. No sign indicates increasing or upward trend and negative sign indicates decreasing or downward trend. 'I' and 'D' given in Table2 represents an increasing and decreasing trend, respectively. Baghodra and Bavla stations show a decreasing trend, whereas Chotila, L.Bhogavo-I, W.Bhogavo-II, Limdi, Lakhtar, Sayla, Surendranagar, Nallake and Sanand show a significant increasing trend. Linear regression analysis shows the highest magnitude of increasing trend (7.33) at Sanand station and the lowest magnitude of decreasing trend (−1.32) at Baghodra station. Mann–Kendall test shows the highest '*Z*' statistics value of increasing trend (1.69) at Sanand station and the lowest '*Z*' statistics value of decreasing trend (−0.31) at Bavla station.

Innovative trends analysis shows the highest 'D' indicator value of increasing trend (3.03) at Wadhwan Bhogavo-II station and the lowest 'D' indicator value of decreasing trend (−1.07) at Baghodra station. Sen's slope method shows the highest value trend of annual rainfall (6.11) at Sanand and the lowest value (−1.781) at Bavla station. The highest positive magnitude of trend as % of mean rainfall (40.74) at Nallake station and the lowest negative (−9.37) at Bavla station.

Summary of monsoon rainfall trend analysis

The summary of rainfall trend during the monsoon period is presented in Table3. For June, the highest value of magnitude of increasing trend in terms of regression slope is 1.83, Sen's slope value is 0.477, and *Z* statistics value is 0.57

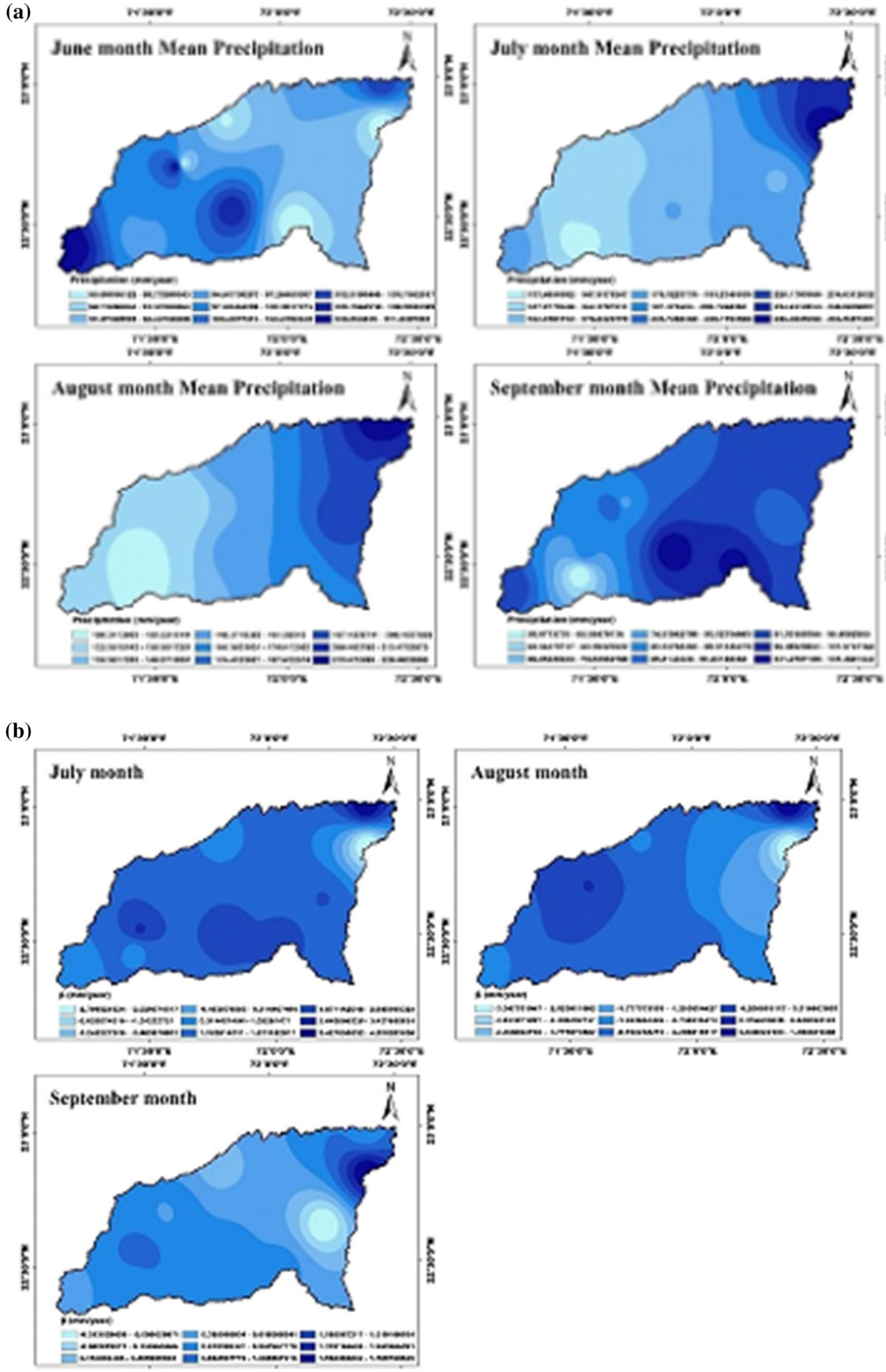

Fig. 5 Spatial distribution of **a** mean seasonal rainfall and **b** seasonal rainfall trend

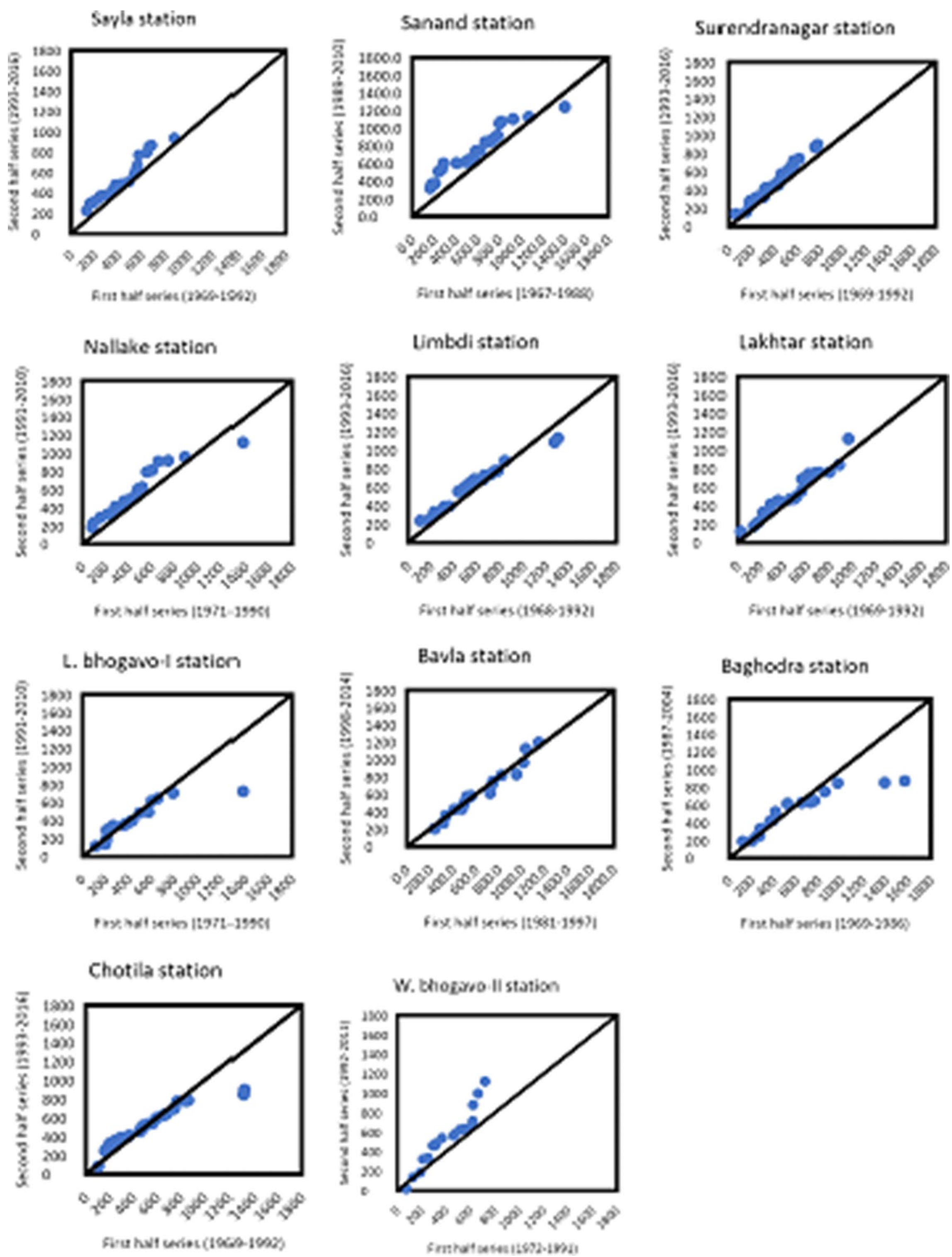

Fig. 6 Results of ITA method for annual rainfall trend analysis for the 11 stations of the study

are established at Nallake station and D indicator value is 4.31 for Sayla station, whereas highest values of magnitude of decreasing trend in terms of regression slope is -0.15, Sen's slope value is -0.50, Z statistics value is -0.72, and D indicator value is -2.66 are established at Limdi station, Wadhwan Bhogavo-II station, Surendranagar station and Baghodra Station, respectively. The highest magnitude of trend as % of mean rainfall shows positive value (22.77%)

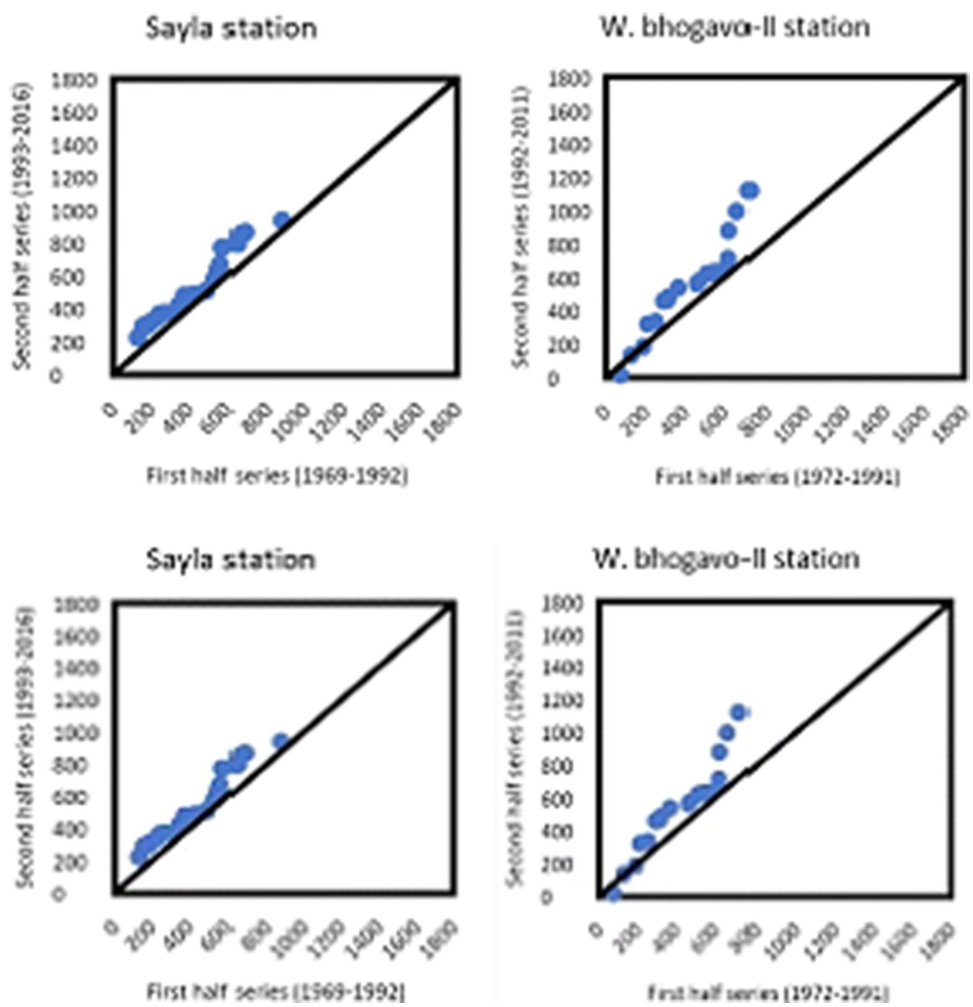

Fig. 7 Results of ITA method for Chotila station from June to September

Table 2 Summary of annual rainfall trend analysis

Rank	Station	Linear regression slope (m)	Sen's slope (ß)	Mann–Kendall statistic (Z)	ITA (D indicator)	Result of trend	Magnitude of trend as a % of mean rainfall
1	Chotila	0.1669	1.015	0.35	0.299	I	9.52
2	Limdi Bhogavo–I	0.2084	2.059	0.76	0.894	I	20.31
3	Wadhwan Bhogavo–II	3.6414	3.187	1.29	3.030	I	26.88
4	Limbdi	1.3799	2.503	1.13	0.949	I	22.34
5	Lakhtar	3.3805	2.747	0.94	1.355	I	26.84
6	Sayla	3.6317	3.637	1.67	2.552	I	38.88
7	Surendranagar	2.9087	3.250	1.37	2.115	I	35.78
8	Baghodra	−1.3161	−0.893	−0.18	−1.076	D	−5.82
9	Nallake	5.5015	5.445	1.42	2.410	I	40.74
10	Sanand	7.3296	6.108	1.69	2.612	I	40.31
11	Bavla	−0.3689	−1.781	−0.31	−0.127	D	−9.37

Table 3 Summary of monsoon rainfall trend analysis

Sr.no	Station	Month	Linear regression slope (*m*)	Sen's slope (ß)	Mann–Kendall statistic (*Z*)	ITA (D indicator)	Result of trend	Magnitude of trend as a % of mean rainfall
1	Chotila	June	−0.1231	−0.150	−0.19	−0.119	D	−6.60
		July	0.6724	0.455	0.34	1.063	I	12.03
		August	−2.7909	−0.930	−1.27	−5.234	D	−34.93
		September	1.4751	0.536	0.92	4.265	I	27.62
2	Limdi Bhogavo–I	June	−0.0685	−0.359	−0.38	−1.155	D	−15.17
		July	0.3794	0.720	0.57	0.979	I	21.58
		August	−1.5732	−0.236	−0.26	−4.665	D	−8.64
		September	1.4216	0.676	1.12	7.658	I	46.56
3	Wadhwan Bhogavo–II	June	−0.1149	−0.500	−0.62	−0.946	D	−12.38
		July	1.401	1.634	1.26	3.863	I	64.71
		August	0.7221	0.473	0.55	1.177	I	−22.56
		September	1.3358	0.533	0.57	6.173	I	−41.87
4	Limbdi	June	−0.1533	−0.500	−0.66	−2.153	D	−22.59
		July	2.2832	2.203	1.78	3.855	I	60.79
		August	−1.6446	−0.537	−0.61	−3.412	D	−16.94
		September	1.1388	0.718	1.17	3.754	I	32.74
5	Lakhtar	June	0.4831	0.000	−0.03	3.761	I	0.00
		July	1.4254	0.754	0.66	3.204	I	22.25
		August	−0.3383	−0.785	−0.84	−2.880	D	−24.46
		September	2.241	0.210	0.77	6.309	I	11.46
6	Sayla	June	0.4043	0.000	0.19	4.319	I	0.00
		July	2.9189	2.793	2.41	5.052	I	85.26
		August	−1.0665	−0.150	−0.16	−3.024	D	−6.28
		September	1.4967	1.081	1.53	4.449	I	63.80
7	Surendranagar	June	−0.068	−0.232	−0.72	−1.073	D	−6.03
		July	1.1106	1.539	1.31	2.620	I	47.69
		August	−0.07	−0.127	−0.16	−1.738	D	−5.08
		September	1.8384	0.781	1.08	4.424	I	49.62
8	Baghodra	June	−0.1403	−0.498	−0.60	−2.663	D	−19.21
		July	2.1135	1.910	0.99	2.833	I	39.40
		August	−1.520	−1.716	−0.75	−2.436	D	−31.42
		September	−2.182	−0.314	−0.48	−2.313	D	−12.90
9	Nallake	June	1.8325	0.477	0.57	1.19	I	22.77
		July	2.3007	2.042	1.20	4.588	I	47.09
		August	−0.1017	−0.579	−0.20	−2.742	D	−14.23
		September	1.9416	0.726	0.69	4.597	I	28.62
10	Sanand	June	−0.1186	−0.487	−0.47	−0.335	D	−20.29
		July	4.2335	4.207	2.26	6.233	I	77.37
		August	2.4358	1.364	0.64	1.239	I	26.50
		September	0.9338	0.684	0.74	3.441	I	31.57
11	Bavla	June	1.734	0.250	0.33	3.721	I	9.82
		July	−0.0434	−2.800	−0.76	−1.041	D	−36.12
		August	−2.098	−3.348	−1.26	−1.532	D	−57.00
		September	1.4703	1.786	1.38	1.342	I	63.04

at Nallake station and negative value (−22.59%) at Limbdi station.

For the month of June, Sen's slope value is zero because of the reason that in most of the stations there were no rain fall in the month of June.

For July, the highest value of magnitude of increasing trend in terms of regression slope is 4.23, Sen's slope value is 2.79, Z statistics value is 2.41 and D indicator value is 6.23 at Sanand station, Sayla station, Sayla station and Sanand station, respectively, whereas highest values of magnitude of decreasing trend in the form of regression slope is −0.04, Sen's slope value is −2.80, Z statistics value is −0.76 and D indicator value is −1.04 are established at Bavla station. The highest magnitude of trend as % of mean rainfall shows the positive value (85.26%) at Sayla station, but a negative value (−36.12%) at Bavla station.

For August, the highest value of magnitude of increasing trend for regression slope is 2.44, Sen's slope value is 1.36, *Z* statistics value is 0.64 and *D* indicator value is 1.24 at Sanand station, whereas decreasing trend for regression slope is -2.79, Sen's slope value is −3.35, *Z*- statistics value is −1.27 and D indicator value is −5.23 are established at Chotila station, Bavla station, Chotila stations, Chotila station, respectively. The highest magnitude of trend as % of mean rainfall shows positive value (26.5%) at Sanand station and the negative value (−57%) at Bavla station. For September, the highest value of magnitude of increasing trend for regression slope is 2.24, Sen's slope value is 1.78, *Z* statistics value is 1.53 and *D* indicator value is 7.65 at Lakhtar station, Bavla station, Sayla station and Limdi Bhogavo-l, respectively, whereas the highest value of magnitude of decreasing trend for regression slope is −2.18, Sen's slope value is −1.72, *Z*- statistics value is −0.48 and *D* indicator value is −2.31 at Baghodra station. The highest magnitude of trend as % of mean rainfall shows positive value (63.8%) at Sayla station and the negative trend value is (−41.9%) at Wadhwan Bhogavo-II.

Conclusion

Annual rainfall trend analysis and monsoon rainfall trend analysis were carried out using data obtained from 11 rain gauge stations in Bhogavo. From the results of linear regression analysis, Mann–Kendall test, Sen's slope test and innovative trend analysis methods, it is concluded that annual rainfall trend is increasing (positive) at Chotila, Limdi Bhogavo-I, Wadhwan Bhogavo-II, Limdi, Lakhtar, Sayla, Surendranagar, Nallake and Sanand stations, whereas at Baghodra and Bavla stations annual rainfall trend is decreasing (negative).

The maximum percentage change in magnitude of annual rainfall trend is in increasing trend at Nallake station and in decreasing trend at Bavla station. The highest percentage of positive change in magnitude of trend of monthly rainfall is in July at Sayla station and the lowest percentage of highest negative change in magnitude of rainfall trend in August at Bavla station.

In the June, rainfall trend is increasing at Lakhtar, Sayla, Bavla and Nallake stations whereas rainfall trend is decreasing at Chotila, Limdi Bhogavo-I, Wadhwan Bhogavo-II, Limdi, Surendranagar, Baghodra and Sanand stations. In the July, rainfall trend is increasing at Chotila, Limdi Bhogavo-I, Wadhwan Bhogavo-II, Limdi, Lakhtar, Sayla, Surendranagar, Nallake, Sanand and Baghodra stations, whereas it is decreasing at Bavla. In August, rainfall trend is increasing at Wadhwan Bhogavo-II and at Sayla stations, whereas at Chotila, Limdi Bhogavo-I, Limdi, Lakhtar, Surendranagar, Nallake, Sanand, Baghodra and at Bavla stations rainfall trend is decreasing.

In the month of September, rainfall trend is increasing at Chotila, Limdi Bhogavo-I, Wadhwan Bhogavo-II, Limdi, Lakhtar, Sayla, Surendranagar, Nallake, Bavla and Sanand stations, whereas it is decreasing trend at Baghodra. It is also concluded that the results obtained with this research can help Bhogavo River basin water management. Rainfall trend analysis will be helpful for the planning of water resources schemes in the Bhogavo watershed of Gujarat state of India.

Acknowledgements Thanks to State Water Data Centre (SWDC) of Gujarat for providing the necessary data related to the study area. Also, thanks to the water resources and Kalpasar department, Gujarat, for providing the basic information about the study area.

Authors' contribution Pratik Patel contributed to writing—original draft preparation, software and data analysis; Geeta S. Joshi and Shilpesh Rana contributed to writing—review and editing, supervision and validation; Geeta S. Joshi contributed to conceptualization and methodology; Geeta S. Joshi, Shilpesh Rana and Pratik Patel contributed to formal analysis and investigation. All authors have read and agreed to the published version of the manuscript.

References

Basistha A, Arya D, Goel N (2009) Analysis of historical changes in rainfall in the Indian Himalayas. Int J of Climatol 29:555–572

Camuffo D, Becherini F, Della Valle A (2020) Relationship between selected percentiles and return periods of extreme events. Acta Geophys. https://doi.org/10.1007/s11600-020-00452-x

Chandniha S, Meshram S, Adamowski J, Mesharam C (2017) Trend analysis of precipitation in Jharkhand state, India investigating precipitation variability in Jharkhand state. J Theor Appl Climatol 130:261–274. https://doi.org/10.1007/s00704-016-1875-x

Chandole V, Joshi GS, Rana SC (2019) Spatio-temporal trend detection of hydro -meteorological parameters for climate change assessment in lower Tapi river basin of Gujarat state, India. J Atmos Solar-Terrestrial Phys 195:105–130. https://doi.org/10.1016/j.jastp.2019.105130

Cui L, Wang L, Singh R et al (2018) Association analysis between spatiotemporal variation of vegetation greenness and precipitation

/ temperature in the Yangtze river basin (China). J Environ Sci Pollut Res 25:21867–21878. https://doi.org/10.1007/s11356-018-2340-4
Dayal D, Pandey A, Himanshu S, Palmate S (2018) Long term historic changes of precipitation and aridity index over an Indian river basin. World Environ Water Res Congr 2018 262:262–272. https://doi.org/10.1061/9780784481417.026
Farhangi M, Kholghi M, Chavoshian S (2013) Rainfall trend analysis of hydrological sub basins in western Iran. J Irrig Drain Eng 144:1–11. https://doi.org/10.1061/(ASCE)IR.1943-4774.0001271
Feng W, Chen L (2012) Estimation of the spatial rainfall distribution using inverse distance weighting (IDW) in the middle of Taiwan. J Paddy Water Environ 10:209–222. https://doi.org/10.1007/s10333-012-0319-1
Gajbhiye S, Meshram C, Mirabbasi R, Sharma S (2016) Precipitation trend analysis of Sindh river basin, India, from 102-year record (1901–2002). J of Atmos Sci 77:71–77. https://doi.org/10.1002/asl.602
Gocic M, Trajkovic S (2013) Analysis of changes in meteorological variables using Mann-Kendall and Sen' s slope estimator statistical tests in Serbia. J Glob Planet Change 100:172–182. https://doi.org/10.1016/j.gloplacha.2012.10.014
Gocic M, Trajkovic S (2014) Spatio-temporal patterns of precipitation in Serbia. Theoret Appl Climatol 117(3–4):419–431. https://doi.org/10.1007/s00704-013-1017-7
Jain S, Kumar V, Saharia M (2012) Analysis of rainfall and temperature trends in northeast India. Int J Climatol. https://doi.org/10.1002/joc.3483
Jeneiova K, Kohnova S, Sabo M (2014) Detecting trends in the annual maximum discharges in the Vah river basin, Slovakia. J Silvatica et Lignaria Hungarica 10:133–144. https://doi.org/10.2478/aslh-2014-0010
Joshi GS, Makhasana P (2020) Assessment of seasonal climate transference and regional influential linkages to land cover—investigation in a river basin. J Atmos Solar-Terrestrial Phys 199:105–290. https://doi.org/10.1016/j.jastp.2020.105209
Joshi GS, Shah S (2019) Analysis of climate change impacts on rainfall trends in the Orsang river basin, India. World Environ Water Res Congr (ASCE). https://doi.org/10.1061/9780784482346.033
Kaur S, Diwakar S, Das A (2017) Long term rainfall trend over meteorological sub divisions and districts of long-term rainfall trend over meteorological sub divisions and districts of India. Mausam 68:439–450. https://doi.org/10.13140/RG.2.1.3908.4409
Kendall (1975) Rank correlation methods. 4th Edition, Charles Griffin, London, pp 34–37
Kumar V, Jain S, Singh Y (2010) Analysis of long-term rainfall trends in India. J Hydrol Sci 55(4):484–497. https://doi.org/10.1080/02626667.2010.481373
Li H, Liu L, Shan B et al (2019) Spatiotemporal variation of drought and associated multi-scale response to climate change over the Yarlung Zangbo river basin of Qinghai—Tibet. J Remote Sens 11:1596–1617. https://doi.org/10.3390/rs11131596
Liang P, Ding YH (2017) The long-term variation of extreme heavy precipitation and its link to urbanization effects in Shanghai during 1916–2014. Adv Atmos Sci 34(3):321–334. https://doi.org/10.1007/s00376-016-6120-0
Makhasana P, Joshi G (2019) Assessment of climate change impact using hydro-meteorological indicators-rainfall, temperature and runoff in Mazam river. Int Conf Clim Change 3:1–17. https://doi.org/10.17501/2513258X.2019.3101
Mann HB (1945) Non-parametric tests against trend. Econometrica 13:245–259
Motiee H, McBean E (2009) An assessment of long-term trends in hydrologic components and implications for water levels in Lake superior. J Hydrol Res 40:564–579. https://doi.org/10.2166/nh.2009.061
Pakalidou N, Karacosta P (2017) Statistical analysis of a 124-year period of precipitation data in Thessaloniki. In: Karacostas T, Bais A, Nastos PT (eds) Perspectives on atmospheric sciences. Springer, Cham, pp 537–543. https://doi.org/10.1007/978-3-319-35095-0_77
Partal T, Kucuk M (2006) Long-term trend analysis using discrete wavelet components of annual precipitations measurements in Marmara region (Turkey). J Phys Chem Earth 31:1189–1200. https://doi.org/10.1016/j.pce.2006.04.043
Patle G, Libang A (2014) Trend analysis of annual and seasonal rainfall to climate variability in North-East region of India. J Appl Nat Sci 6:480–483. https://doi.org/10.31018/jans.v6i2.486
Pingale S, Khare D, Jat M, Adamowski J (2014) Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centres of the arid and semi-arid state of Rajasthan, India. J Atmos Res 138:73–90. https://doi.org/10.1016/j.atmosres.2013.10.024
Sanikhani H, Kisi O, Mirabbasi R, Meshram S (2018) Trend analysis of rainfall pattern over the Central India during 1901–2010. Arab J Geosci 11:437–451. https://doi.org/10.1007/s12517-018-3800-3
Sayemuzzaman M, Jha M (2014) Seasonal and annual precipitation time series trend analysis in. J Atmos Res 137:183–194. https://doi.org/10.1016/j.atmosres.2013.10.012
Sen Z (2012) Innovative trend analysis methodology. J Hydrol Eng 17:1042–1046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000556
Sonali P, Kumar N (2013) Review of trend detection methods and their application to detect temperature changes in India. J Hydrol 476:212–227. https://doi.org/10.1016/j.jhydrol.2012.10.034
Suryavanshi S, Pandey A, Chaube U, Joshi N (2013) Long-term historic changes in climatic variables of Betwa. J Theor Appl Climatol 117:403–418. https://doi.org/10.1007/s00704-013-1013-y
Tabari H, Marofi S, Aeini A, Talaee P, Mohammadi K (2011) Agricultural and forest meteorology trend analysis of reference evapotranspiration in the western half of Iran. J Agric For Meteorol 151:128–136. https://doi.org/10.1016/j.agrformet.2010.09.009
Wu H, Qian H (2016) Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the 1950s. Int J Climatol 37:5282–5292. https://doi.org/10.1002/joc.4866
Yue S, Pilon P, Phinney B, Cavadias G (2002) The influence of autocorrelation on the ability to detect trend in hydrological series. 1829(October 2000). J Hydrol Proc 16:1807–1829. https://doi.org/10.1002/hyp.1095
Zarenistanak M, Dhorde A, Kripalani R (2014) Trend analysis and change point detection of annual and seasonal precipitation and temperature series over southwest Iran. J Indian Acad Sci 2:281–295. https://doi.org/10.1007/s12040-013-0395-7
Zhang X, Wang S et al (2015) Temporal and spatial variability in precipitation trends in the southeast Tibetan plateau during 1961–2012. J Clim Past Discuss. https://doi.org/10.5194/cpd-11-447-2015
Zhao J, Huang Q et al (2015) Analysis of temporal and spatial trends of hydro-climatic variables in the Wei river basin. J Environ Res 139:55–64. https://doi.org/10.1016/j.envres.2014.12.028