Original Research Article

Trends Analysis of rainfall and temperature over Nagwan watershed, Hazaribagh district, Jharkhand

ABSTRACT

Trend analysis is performed to find the pattern that prevails in Nagwan watershed area located in Hazaribagh district of Jharkhand (India) having very high average annual rainfall in the range of 1146 mm. The study aims to investigated the impacts of global warming by examine precipitation and temperature change over a period. Non-parametric MK test and Sen's Slope estimator were used to assess the trend in long-term rainfall and temperature time series (1981-2019). The analysis has been carried out on monthly, seasonal and annual scale to identify meso-scale climate change effect on hydrological regime. The precipitation in the summer showed an increasing trend (Z value +1.67) and there was increasing trend in the seasonal rainfall which influences the total water availability in the watershed. The annual average maximum temperature in the watershed showed a decreasing trend (Z value -1.26). During winter season, the significant decreasing trend may lead to decrease in crop productivity and alter the soil moisture condition required for healthy crop growth. There was increase in minimum temperature during summer season which shows the impact of global warming and may results in increasing the duration of the summer season. The annual average minimum temperature in the watershed showed an increasing trend (Z value +2.08) at 0.05 level of significance indicated hot nights in the summer. Fluctuation and change in trend of rainfall and temperature possess potential risk hence it is important to understand and identify the pattern of rainfall and temperature for assessing impact of climate change and it is necessary to adopt appropriate steps for agriculture crop planning and improving farmer's capability to cope with challenging situations due to environmental and climate changes.

Keywords: Climate change, Non-parametric Mann-Kendell, Sen's Slope, Temperature

INTRODUCTION

Availability of water resources is a major concern for any future planning and development including flood control, flood protection, drought mitigation and sustainable watershed management. The hydrological cycle which play a significant role in sustaining river system through rain are affected which resulted in inadequate water supply to fulfil the different demand mainly for agriculture, hydropower water supply, industry, etc. Uneven distribution of rainfall and unavailability of water influences the agriculture sector, food security and energy sector. Global climate changes affect the long-term rainfall pattern causes inadequate availability of water and resulted into a serious of drought and flood. Different methods were adopted to assess the trend of long-term rainfall pattern. Mann-Kendall test (Mann, 1945 and Kendall, 1975) is one of the best methods amongst them, which is preferred by various researchers (Douglas et al., 2000; Yue et al., 2003). Trend analysis of rainfall time series includes determination of increasing and decreasing trend by using non-parametric Mann-Kendell test and magnitude of trend using Sen's slope method (Jain and Kumar, 2012).

The parametric tests are based on the assumption of the population distribution while, nonparametric tests do not contemplate any such assumptions and commonly used in the climatic study. Some of the examples of application different tests include t-test (e.g., Staudt et al., 2007; Marengo & Camargo, 2008), Mann-Whitney and Pettitt test (e.g., Mauget, 2003; Fealy & Sweeney, 2005; Li et al., 2005; Yu et al., 2006), linear and piecewise linear regression test (e.g., Tomé & Miranda, 2004; Portnyagin et al., 2006; Su et al., 2006), cumulative sum analysis test (e.g., Fealy & Sweeney, 2005; Levin, 2011), hierarchical Bayesian change point analysis test (e.g., Tu et al., 2009); Markov chain Monte Carlo method (e.g., Elsner et al., 2004; Zhao & Chu, 2006), reversible jump Markov chain Monte Carlo algorithm (Zhao & Chu, 2010) and nonparametric regression test (Bates et al., 2010).

"Mann-Kendall test does not require datasets to follow normal distribution and show homogeneity in variance; (Duhan and Pandey, 2013). Sen's slope estimation method gives the magnitude of trend. It assumes that trend line is a linear function in the time series. Sen's slope method shows the rise and fall of the variable through slope value (Jain and Kumar, 2012). Another advantage of using Sen's slope is that it is not affected when outliers and single data errors are present in the dataset (Salmi et al., 2002; Thesis, 2015). The Mann Kendall's test is a statistical test recommended by the World Meteorological Organization for public application (Mitchell et al., 1996) and widely used for the analysis of trend in climatologic and hydrologic time series (Hirsch et al., 1982; Burn & Elnur, 2002; Yue et al., 2003; Yue & Pilon, 2004; Kahya & Kalayci, 2004; Yue & Wang, 2004; Marvomatis & Stathis, 2011). There are two advantages of using this test; first, this test does not require data to be normally distributed; second, this test has low sensitivity to abrupt breaks due to inhomogeneous time series (Taberi, 2011).

Fu et al. (2007) studied the impact of climatic variability on temperature, precipitation and stream flows in the Yellow river basin of China and found that trend in climatic parameters had a significant impact on stream-flow, since it was sensitive to both precipitation and temperature. Modarres & Da Silva (2007) investigated annual rainfall and monthly rainy days of twenty rain gauge stations in Iran for assessing the impact of climate change using Mann Kendall's test and found no significant climate change impacts on precipitation regime. Jaiswal et al. (2008) analyzed evaporation and rainfall data of 58 stations distributed uniformly in India for the period of 30 years from 1971 to 2000 where annual, summer (March to May), winter (December to February), monsoon (June to September) and post-monsoon (October, November) periods at 95% level of confidence were computed. It has been observed that the evaporation in the country has significantly decreased in all seasons while there is no significant trend in rainfall. Out of 58 stations, 45 stations in annual, 30 in winter, 42 in summer and 35 in monsoon and post-monsoon season indicated the significant decreasing trend for evaporation.

Gao *et al.* (2009) analysed annual stream-flow and sediment discharge in the Wuding River and observed a significant decreasing trend. Kumar *et al.* (2010) conducted trend assessment on rainfall for 30 sub-divisions in India and found that Chhattisgarh sub-division exhibited a significant downward trend out of 15 sub-divisions showing a decreasing trend in annual rainfall series. Looking in the well acceptability of Man-Kendall test and Sen's slope for identification of trend in climatological series, the present study has been taken to analyze temporal changes using non-parametric Mann–Kendall test and its magnitude of change were determined using Sen's slope methods.

MATERIALS AND METHODS

STUDY AREA:

The Nagwan watershed is situated at the Upper Damodar Valley, Hazaribagh district, Jharkhand. It has an area of 92.32 km^2 and lies between $85^0 16' 41''$ and $85^0 23' 50''$ E longitudes and $23^0 59'33''$ and $24^0 5'37''$ N latitudes. The area experiences sub-humid sub-tropical monsoon type of climate, characterized by hot summers (40°C) and mild winters (4°C). The watershed receives an average annual rainfall of 1272.5 mm, out of which more than 80% is received during monsoon season (June–October). The daily mean relative humidity varies from a minimum of 40% in the month of April to a maximum of 85% in the month of July. The soil which prevails in that region is mainly silty loam, loamy sand, and sandy loam. Figure 1 show the location of study area.

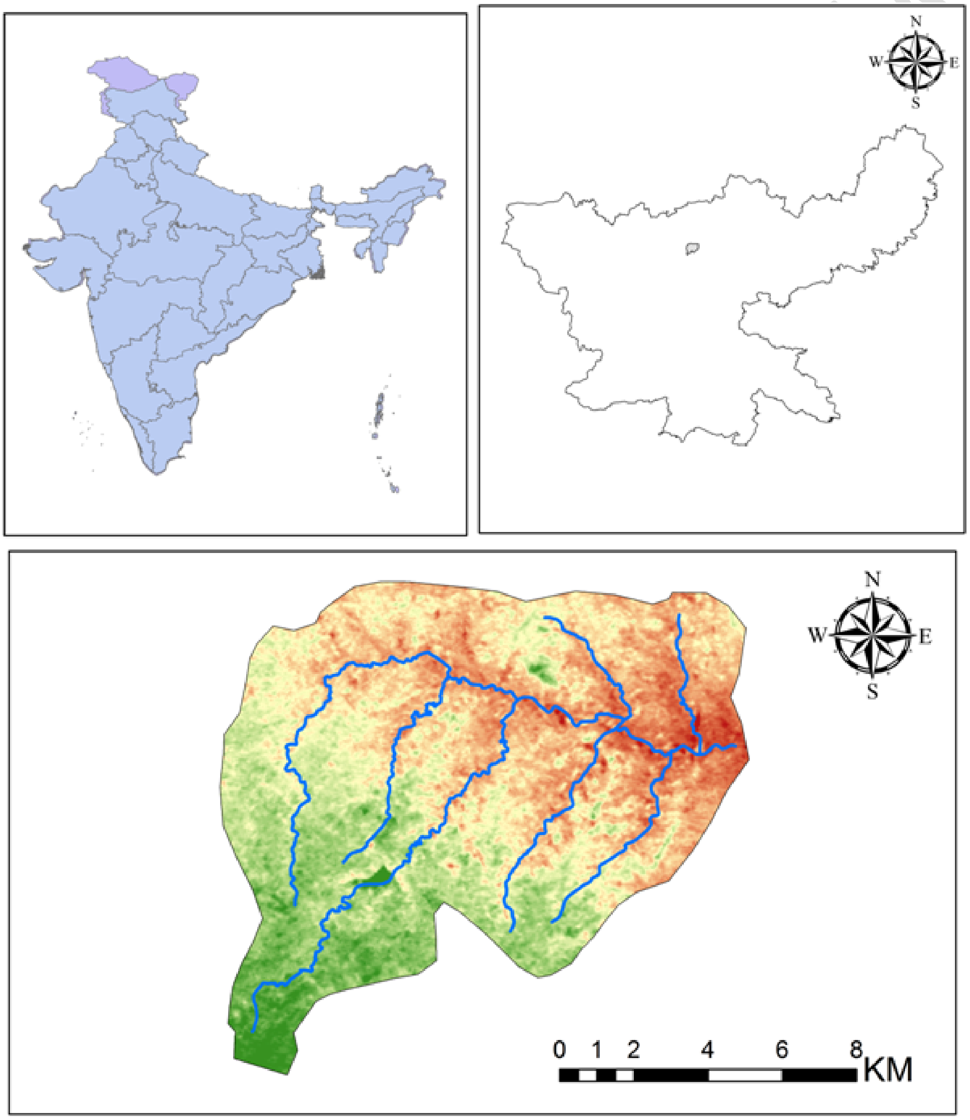


Fig.1. location of study area

DATA USED

In order to assess impact of climate change, the historical precipitation and temperature data for 1981-2019 (i.e. 39 years) were employed to accomplish the research and had been collected from the Damodar Valley Corporation, Jharkhand. MK Test and Sen's Slope test had been adopted for trend assessment and are briefly discussed below.

Mann-Kendall (MK) Test

Mann presented a non-parametric test for randomness against time, which constitutes a particular application of Kendall's test for correlation commonly known as the 'Mann- Kendall' or the 'Kendall *t* test'. Mann- Kendall test is a statistical test widely used for the analysis of trend in climatology and in hydrologic time series (Jaiswal, Lohani, & Tiwari, 2015; Kocsis, Kovács-Székely, & Anda, 2020) There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Secondly, the test has low sensitivity to abrupt breaks due to inhomogeneous time series.

The Mann-Kendall test statistic S is calculated using the formula (Milanovic, 2015).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_i - x_j)$$

Where x_i and x_j are the annual values in years i and j, respectively, ($i > j$) and n is the number of data points. The value of sign(x_i - x_j) is computed as follows:

$$sign(x_i - x_j) = \begin{cases} 1 & \text{if } x_i - x_j > 0 \\ 0 & \text{if } x_i - x_j = 0 \\ -1 & \text{if } x_i - x_j < 0 \end{cases}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered(Jain, Kumar, & Saharia, 2013; Pandit, 2016).
For sample size $n > 10$, the mean and variance are given by:

$$\sigma^2(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18}$$

Where m is the number of tied groups and t_i is the number of ties of extent i (Afouda, 2017; Panda et al., 2020; Yu et al., 2017).

If there are no ties between the observations, the variance is computed as:

$$\sigma^2(S) = \frac{n(n-1)(2n+5)}{18}$$

The standard normal test statistic Z is computed as:

$$Z = \frac{S-1}{\sqrt{Var(S)}} \qquad \text{if } S > 0$$

$$Z = 0 \qquad \text{if } S = 0$$

$$Z = \frac{S+1}{\sqrt{Var(S)}} \qquad \text{if } S < 0$$

The presence of a statistically significant trend is evaluated using the Z value (Dodamani, 2020). A positive value of Z indicates an upward trend and its negative value a downward trend (Thomas et al.2015). The Z values were tested at 0.05 level of significance.

Sen's Slope Estimator:

The Sen's nonparametric method is used to estimate the true slope of an existing trend. The slope N of all data pairs is computed as (Sen, 1968)

$$N = \frac{x_j - x_i}{j - i}$$

Where *xj* and *xi* are considered as data values at time *j* and *i* (*j*>*i*) correspondingly.

The median of these n values of Q is represented as Sen's estimator of slope

$$Q = T_{\frac{N+1}{2}} \quad \text{If } N \text{ is odd}$$

$$Q = \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+1}{2}}\right) \qquad \text{If N is even}$$

Sen’s slop estimator is computed as Q=T (N+1)/2 if N appears odd, and it is considered as Q=[T(N/2)+T(N+2)/2]/2 if N appears even. At the end, Q is computed by a two sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q indicates an upward or increasing trend and a negative value of Q gives a downward or decreasing trend in the time series.

RESULTS AND DISCUSSIONS

Statistical analysis

The preliminary data analysis was carried out to find the statistical parameters (mean, standard deviation, and coefficient of variation) of average annual rainfall for the period 1981-2019. Annual precipitation in the watershed varies between 749.85 mm (1983) to 1459.9 mm (1994) with a standard deviation of 189.58 mm. Annual average precipitation is 1146.39mm. Coefficient of variation (CV) was found to be 16.54%. All the statistical parameters computed for annual and seasonal basis are given in Table 1.

Table 1: computed statistical parameter for annual and seasonal rainfall

S.No.	**Mean**	**Maximum(Year)**	**Minimum(Year)**	**SD**	**CV(%)**
Annual	1146.39	1459.99(1994)	749.85(1983)	189.58	16.54
Seasonal rainfall	963.135	1287.97(2011)	619.62(1983)	179.59	18.65
Winter Season	32.6647	134.973(1995)	1.00(2013)	28.763	88.06
Summer Season	74.3838	118.44(2005)	17.69(1996)	27.618	37.13

The rainfall variability in the region was high indicating climatic risk, which causes fluctuations in reservoir storage and crop yield from year to year. Agriculturally it is the more crucial parameter based on which suitable farming practices need be adopted, so as to render the impact of inter-annual variability which existed in the region.

Trend assessment of monthly, seasonal and annual rainfall

Trends in annual and seasonal rainfall series are commonly assessed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen Slope method. The results of MK test and Sen’s slope estimator are presented in Table 2. Figure 2 showing the variation of the Mann- Kendall’s test statistics (Z value) and Sen’s slope (Q value) of the trend analysis.

Table 2. represent the value for Mk test statistics and Sen slope for rainfall data

Time series	MK Test statistics (Z)	Sen Slope(Q)	Significance
January	-0.76	-0.06	-
February	-1.33	-0.21	-
March	0.60	0.09	-
April	0.36	0.06	-
May	1.65	0.64	+
June	-0.70	-0.46	-
July	0.46	0.80	-
August	0.85	1.01	-
September	0.97	0.94	-
October	1.14	0.52	-
November	-1.48	-0.07	-
December	-0.33	0.00	-
Annual	1.11	3.80	-
Seasonal	0.87	2.38	-
Winter	-1.33	-0.50	-
Summer	1.67	0.68	+

Note: + if trend at $\alpha = 0.1$ level of significance, - trend at $\alpha > 0.1$ level of significance

The results shown in Table 2 indicated a falling trend in month of January, February, June, November and December at a significance level greater than 0.1 whereas significant rising trends showed in the months of May at 0.1 level of significance. The precipitation in the summer showed an increasing trend (Z value +1.67). There is an increasing trend in the seasonal rainfall which influences the total water availability in the watershed however; inadequate rainfall during winter may help to reduce post-harvest crop losses. A decreasing winter precipitation (Z value -1.33) will result in less water availability to winter crops.

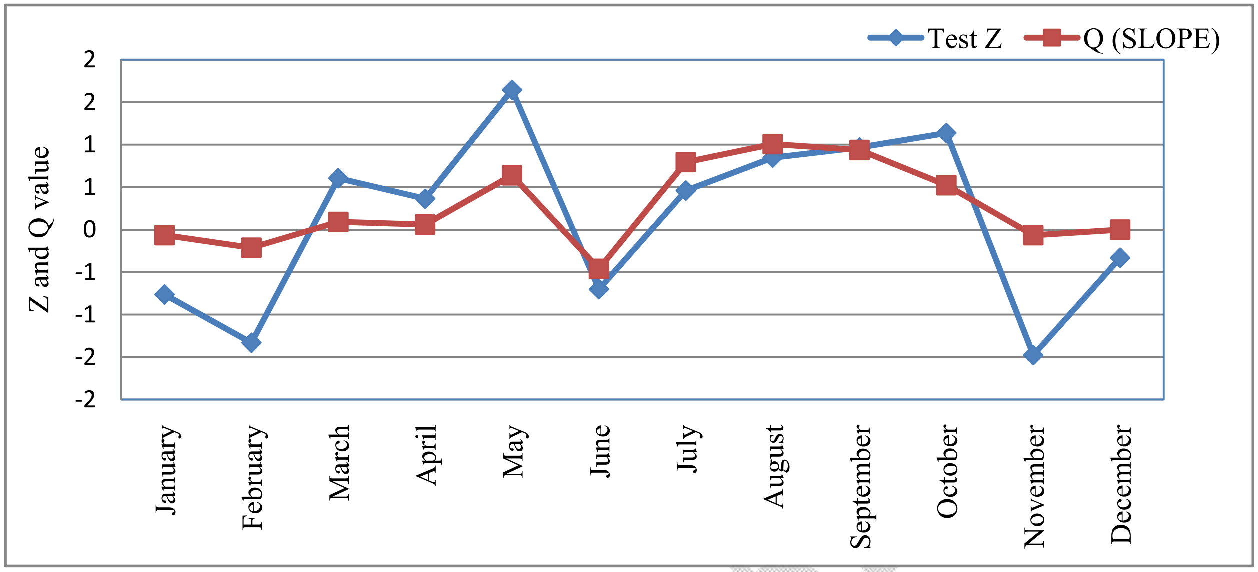
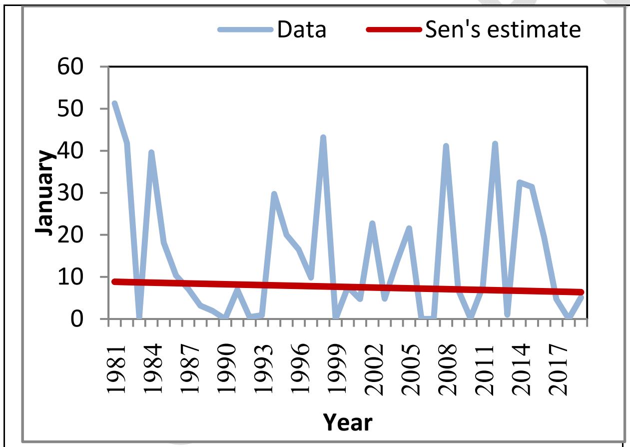
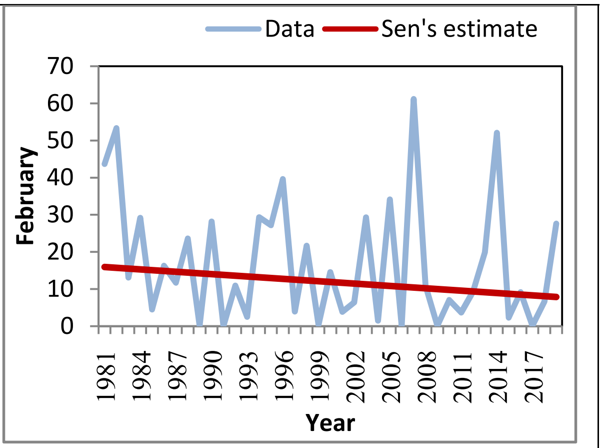
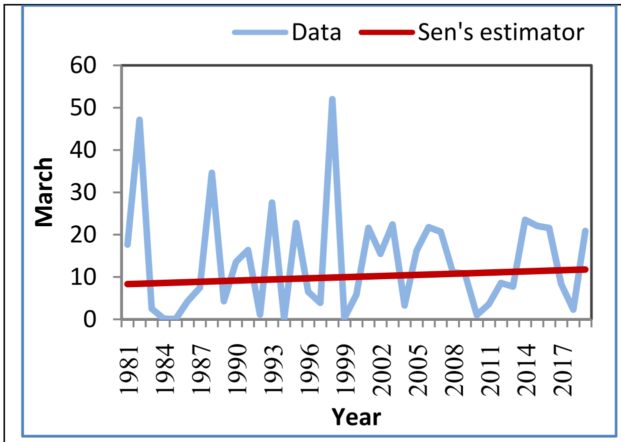


Fig.2. plot showing MK statistics (Z value) and Sen's slope (Q value) for rainfall trend analysis.

Figure 3 depicts the precipitation variability during the period 1981-2019 for different months, seasons and annual rainfall.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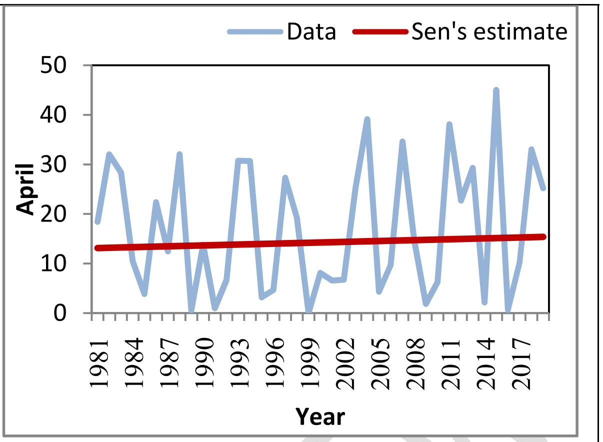
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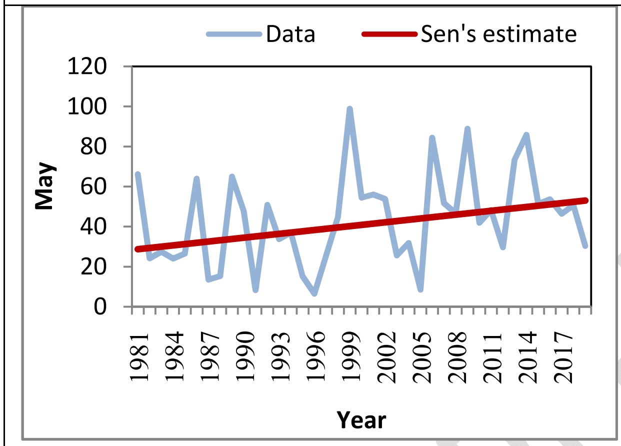
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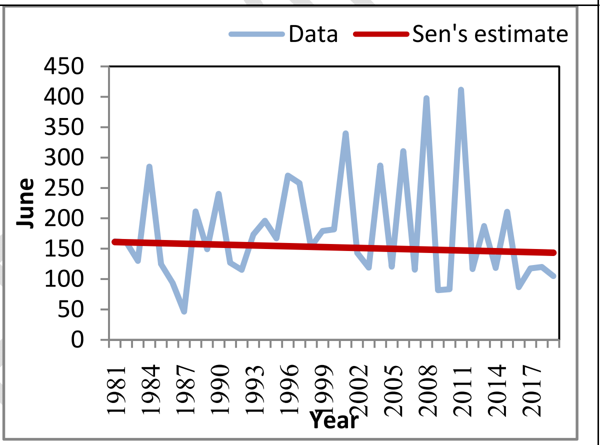
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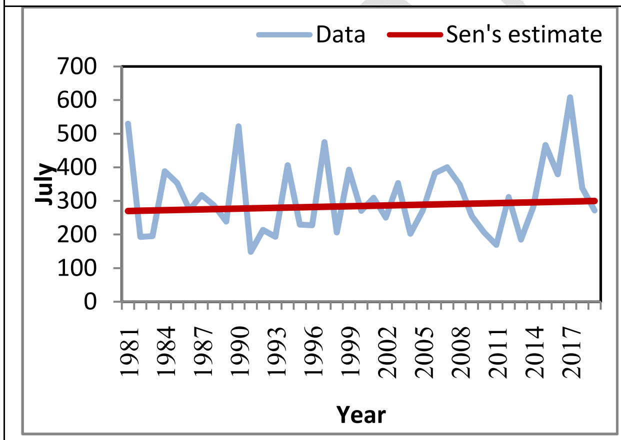
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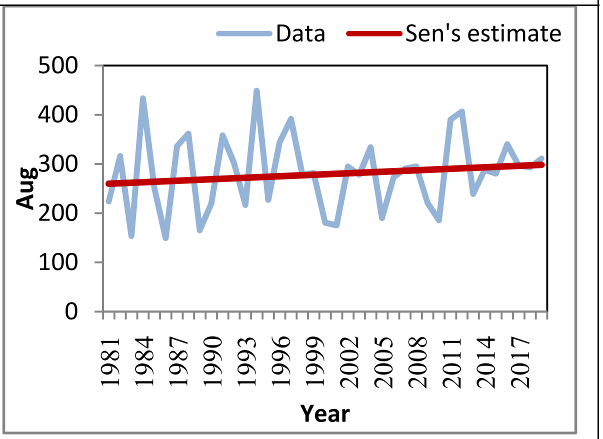
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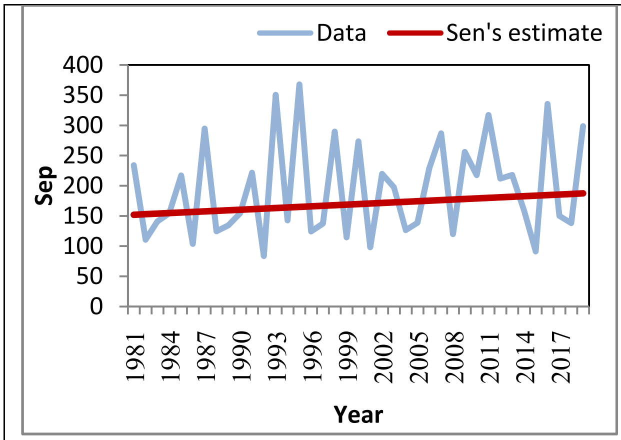
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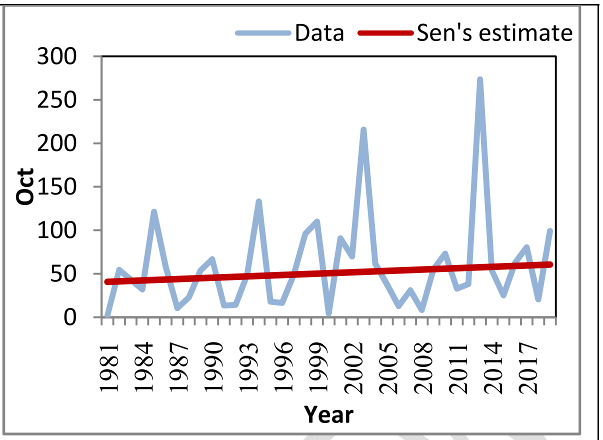
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Sen's estimate
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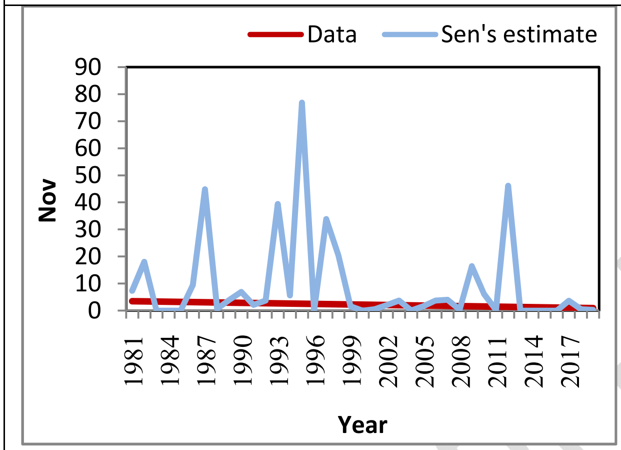
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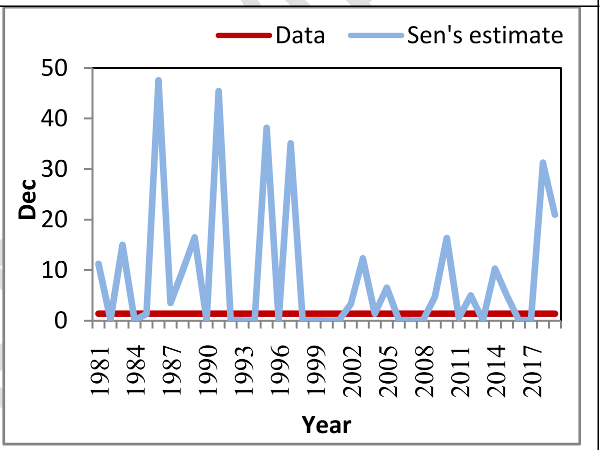
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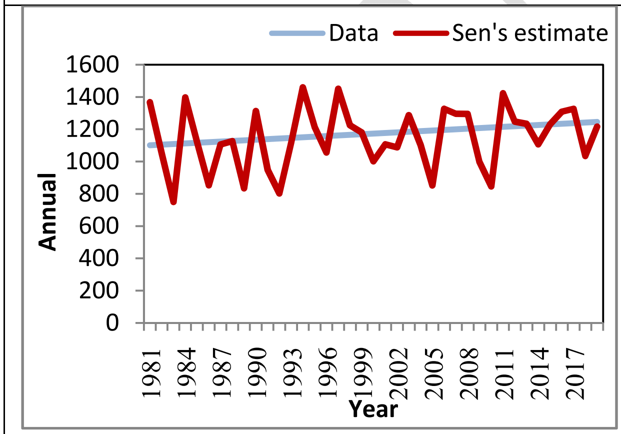
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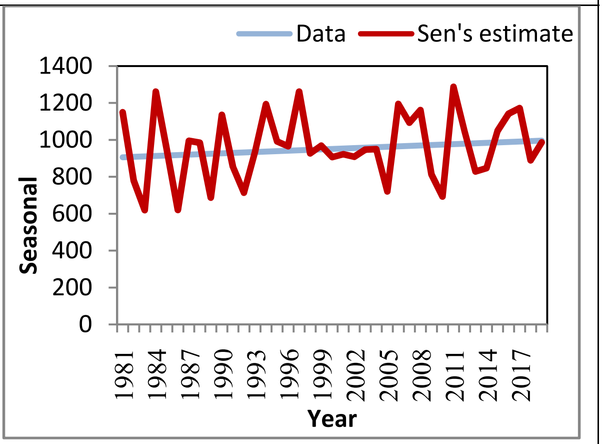
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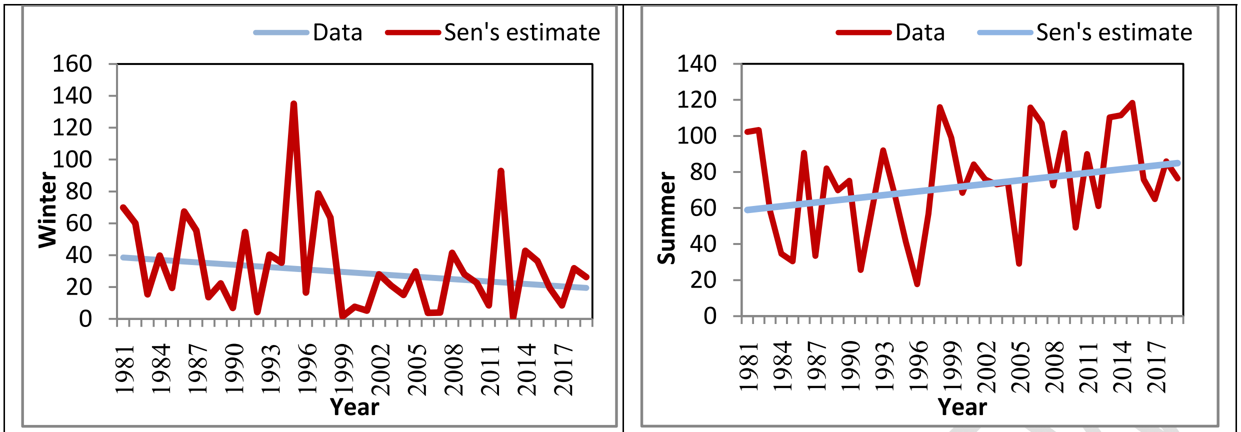


Fig.3. variability in rainfall pattern in different months, seasons and annual rainfall

Trend analysis of Temperature

Maximum Temperature

The statistical analysis was carried out to find out mean, standard deviation and coefficient of variance for annual maximum temperature for the period 1981-2019. Maximum annual temperature in the watershed varies between 29.9°C (2008) to 32.3 (2010) where mean annual maximum temperature is 31.01^0C with standard deviation 0.59^0C. All the statistical parameters for annual and seasonal basis are shown in Table 3.

Table 3. Statistical parameter for annual and seasonal maximum temperature

S.No.	Mean	Maximum(Year)	Minimum(Year)	SD	CV(%)
Annual	31.01	32.3(2010)	29.90(2008)	0.59	1.90
Seasonal rainfall	32.19	33.9(1983)	30.47(2008)	0.88	2.75
Winter Season	48.59	51.97(1990)	44.87(2012)	1.89	3.88
Summer Season	37.85	39.83(2010)	35.97(1982)	0.94	2.48

Trend assessment of monthly, seasonal and annual maximum temperature

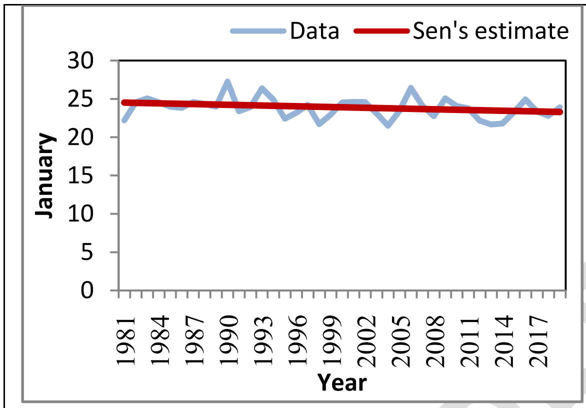
Trends in annual and seasonal maximum temperature series are computed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen’s Slope method. The results of MK test and Sen’s slope estimator are presented in Table 4.

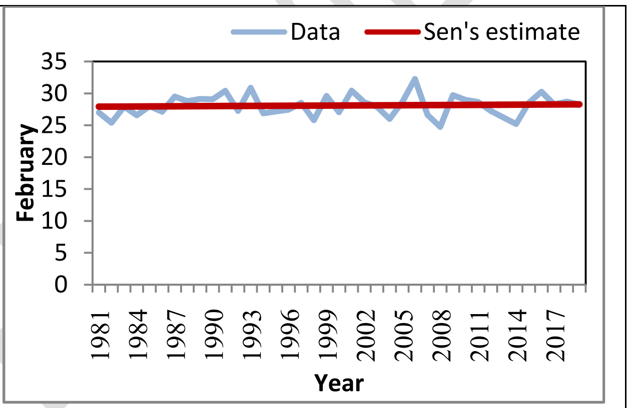
Table 4. represent the value for Mk test statistics and Sen slope for maximum rainfall data

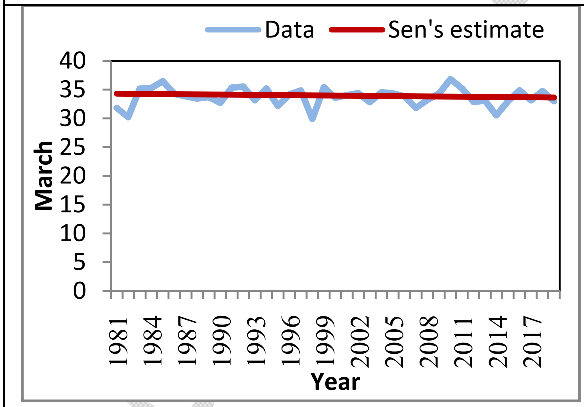
Time series	MK Test statistics (Z)	Sen Slope(Q)	Significance
January	-1.81	-0.032	+
February	0.44	0.009	-
March	-0.70	-0.018	-
April	-0.75	-0.020	-
May	-0.51	-0.006	-
June	0.22	0.008	-
July	0.12	0.002	-
August	-0.82	-0.007	-
September	0.27	0.002	-
October	-0.36	-0.007	-
November	-0.46	-0.007	-
December	-2.01	-0.039	*
Annual	-1.26	-0.013	-
Seasonal	-0.51	-0.006	-
Winter	-2.15	-0.065	*
Summer	-0.73	-0.012	-

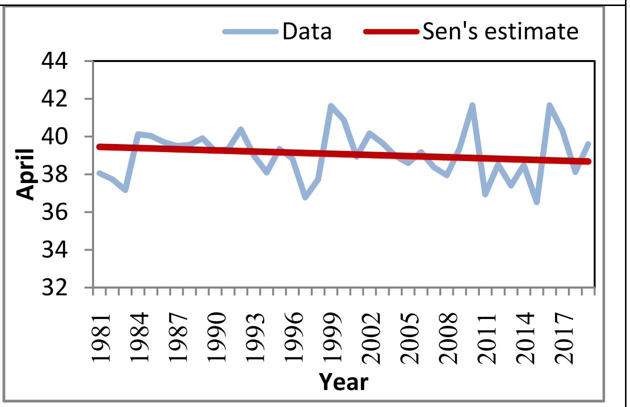
Note: *if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance, - trend at α > 0.1 level of significance

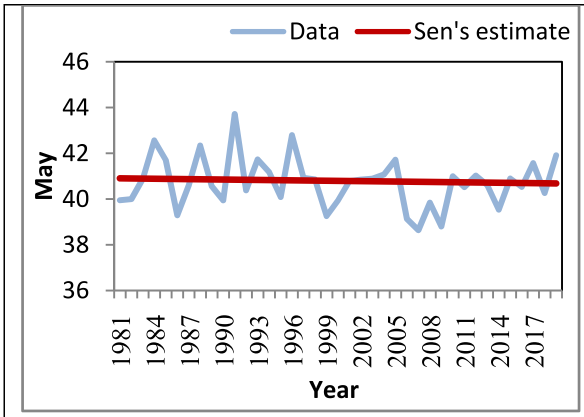
The results shown in Table 4 indicated a falling trend in month of December at 0.05 level of significance and in the month of January at 0.1 level of significance, and in rest of the month there is decreasing trend with significant at 0.1 level of significance except in February, June, July, and September which has increasing trend at level of significance greater than 0.1. The annual average maximum temperature in the watershed showed a decreasing trend (Z value -1.26) and will affect the hydrological cycle which maintains the water level in that region. A significant decreasing trend (Z value -2.15) at 0.05 level of significance, during winter consequently decreases the crop productivity and may alter the soil moisture condition required for healthy crop growth. A decreasing seasonal maximum temperature will result in less evaporation loss causing to rise in the ground water table. Figure 4 depict the maximum temperature variability during the period 1981-2019.







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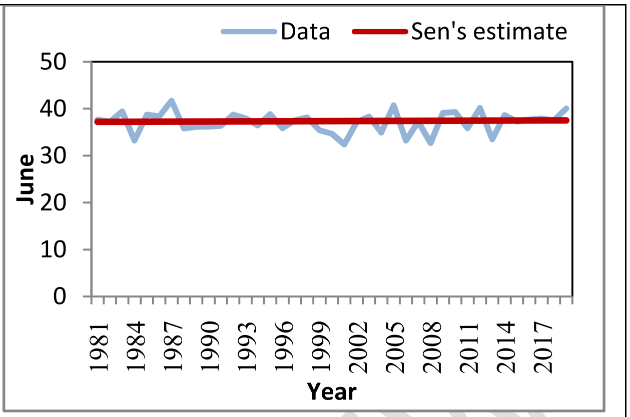
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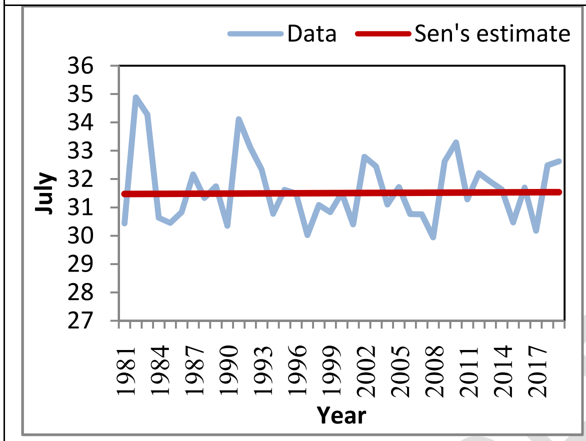
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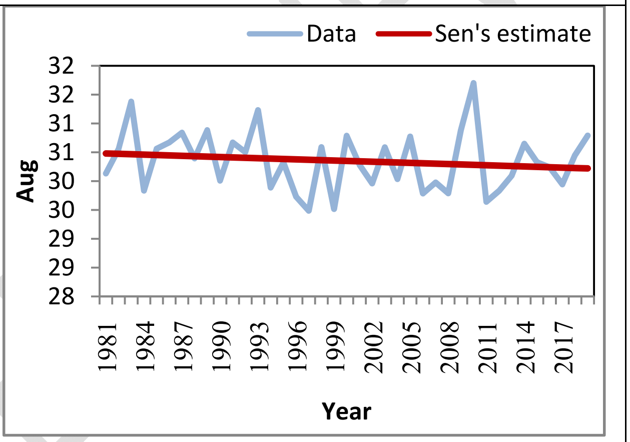
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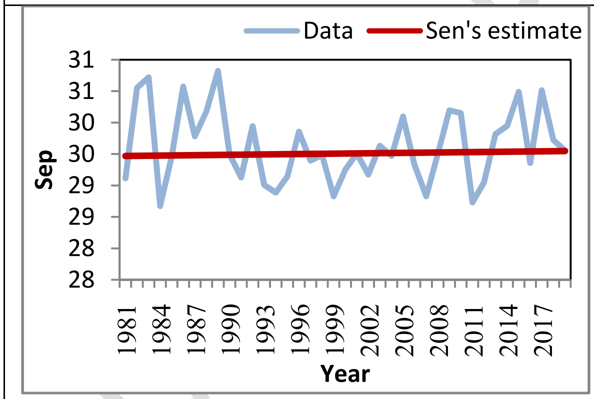
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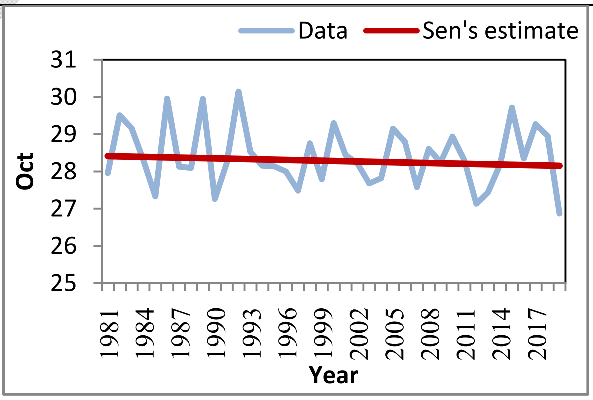
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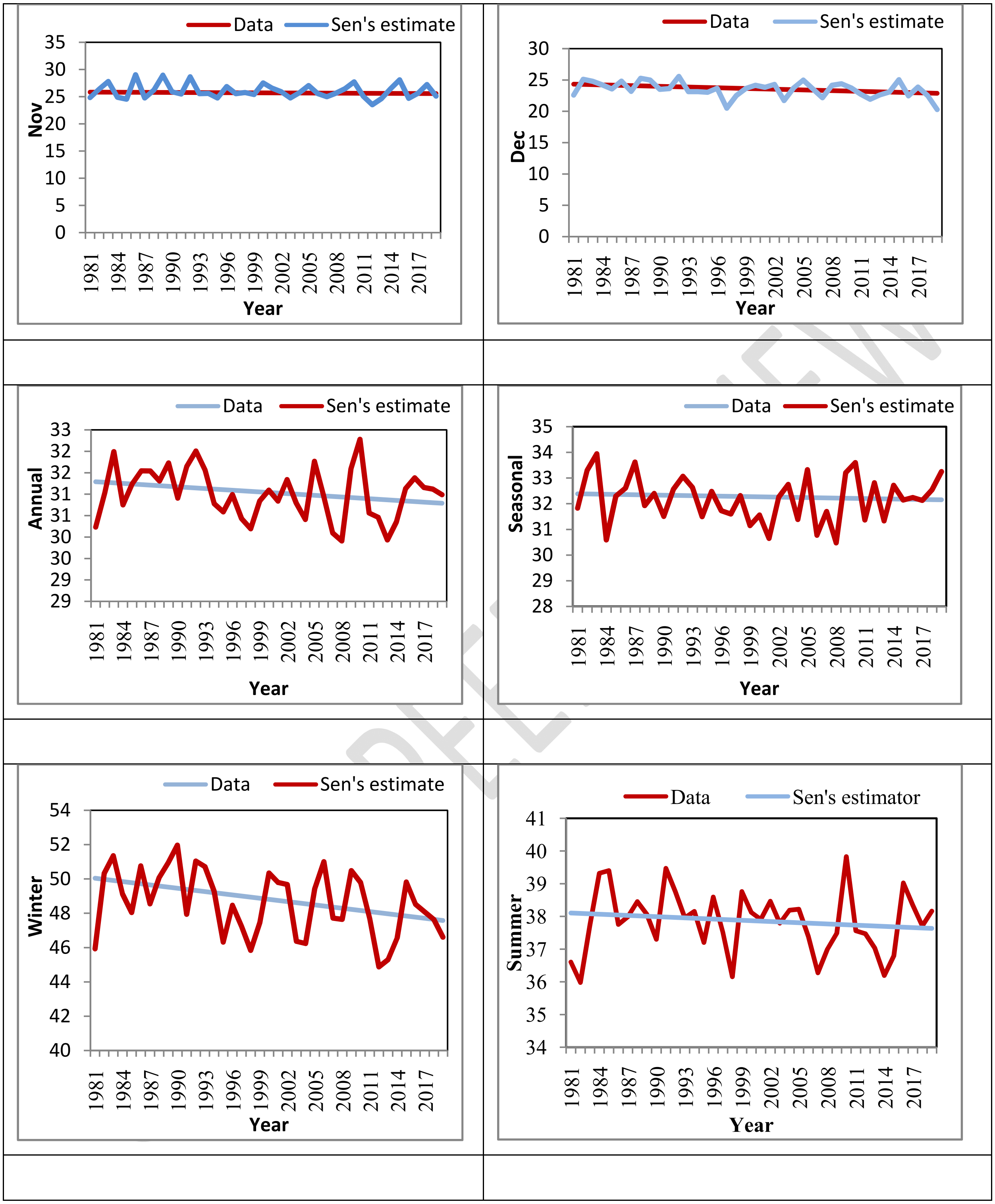


Fig.4. maximum temperature variability during the period 1981-2019 for different months, season and annual rainfall

Minimum Temperature

For annual minimum temperature the statistical analysis was carried out to find out mean, standard deviation and coefficient of variance for the period of 1981-2019. Minimum annual temperature in the watershed varies between 18.47^{o}C (1981) to 20.13 (2010) whereas mean annual minimum temperature is 19.13^{0}C with standard deviation 0.34^{0}C. All the statistical parameters for annual and seasonal basis are shown in Table 5.

Table 5. Statistical parameter for annual and seasonal minimum temperature

S.No.	**Mean**	**Maximum(Year)**	**Minimum(Year)**	**SD**	**CV(%)**
Annual	19.13	20.13(2010)	18.47(1981)	0.34	1.78
Seasonal rainfall	24.61	25.35(2019)	23.71(1984)	0.39	1.58
Winter Season	21.63	24.04(2009)	18.66(2013)	1.22	5.64
Summer Season	21.82	23.67(2016)	20.43(1998)	0.68	3.12

Trend assessment of monthly, seasonal and annual rainfall

Trends in annual and seasonal maximum temperature are assessed using nonparametric Mann-Kendell test and its magnitude of change is detected using Sen's Slope method. The results of MK test and Sen's slope estimator are presented in Table 6.

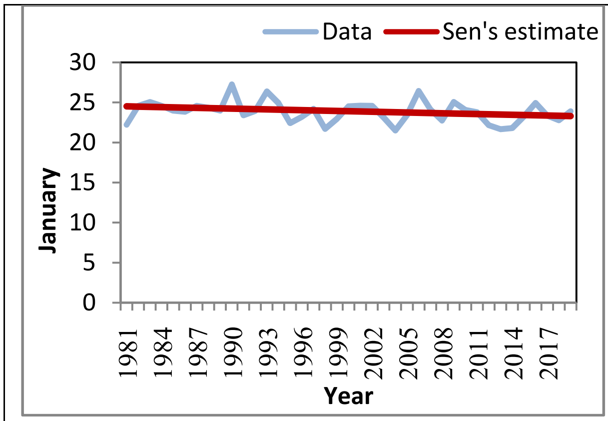
Table 6. represent the value for Mk test statistics and Sen slope for maximum rainfall data

Time series	MK Test statistics (Z)	Sen Slope(Q)	Significance
January	-2.01	-0.031	*
February	1.57	0.038	-
March	1.33	0.024	-
April	2.30	0.028	*
May	2.27	0.020	*

June	1.74	0.028	+
July	0.90	0.008	-
August	1.60	0.005	-
September	1.52	0.010	-
October	1.62	0.020	-
November	0.92	0.014	-
December	-1.16	-0.013	-
Annual	2.08	0.012	*
Seasonal	2.08	0.013	*
Winter	-1.45	-0.021	-
Summer	2.61	0.022	**

Note: **if trend at $\alpha = 0.005$ level of significance, *if trend at $\alpha = 0.05$ level of significance, + if trend at $\alpha = 0.1$ level of significance, - trend at $\alpha > 0.1$ level of significance

The results shown in Table 6 indicated a falling trend in month of January at 0.05 level of significance and in December at 0.1 level of significance, and in rest of the month there is increasing trend with significant at 0.1 level of significance except April and May which are significant at 0.05 level of significance. Increase in minimum temperature during summer season shows the impact of global warming which resulted in increasing summer temperature and thus influence growth of plants. The annual average minimum temperature in the watershed showed an increasing trend (Z value +2.08) at 0.05 level of significance. There is a decreasing trend in winter season (Z value -1.45) at significance level greater than 0.1. Figure 5 to depict the minimum temperature variability during the period 1981-2019.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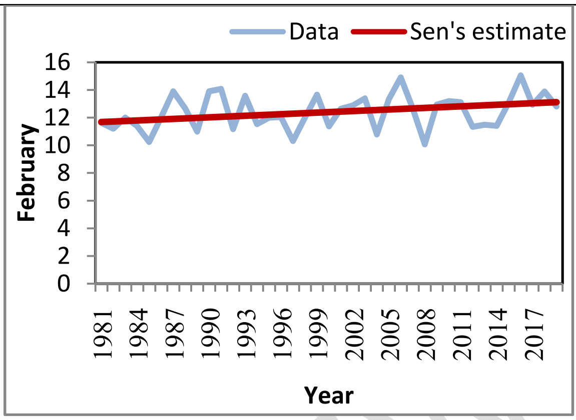
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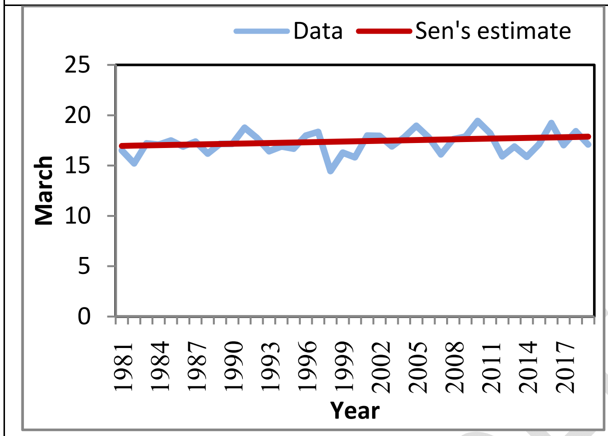
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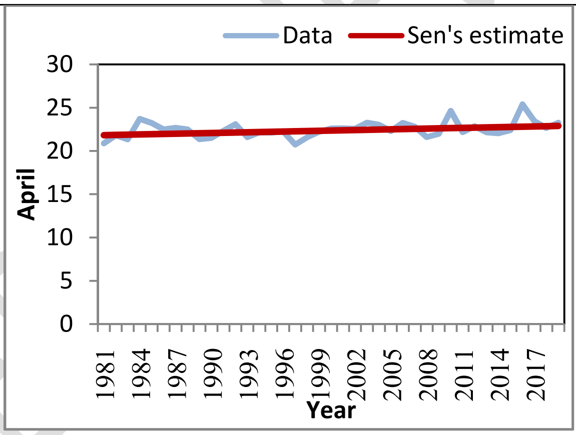
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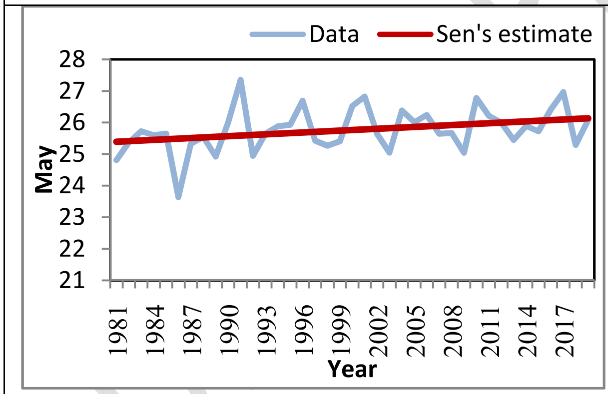
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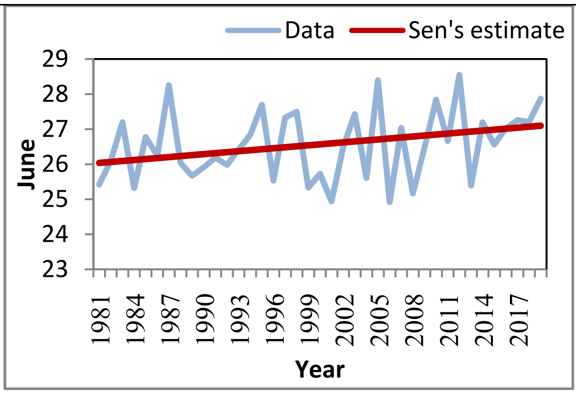
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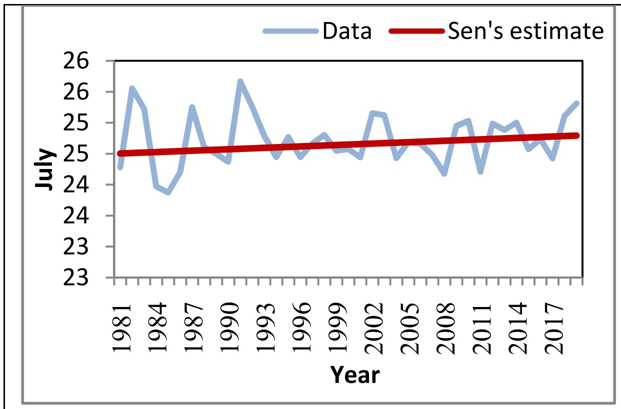
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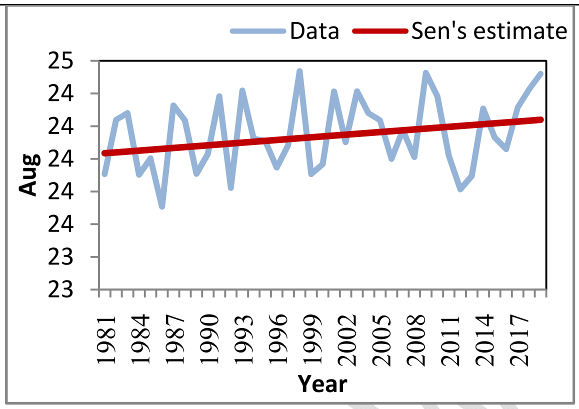
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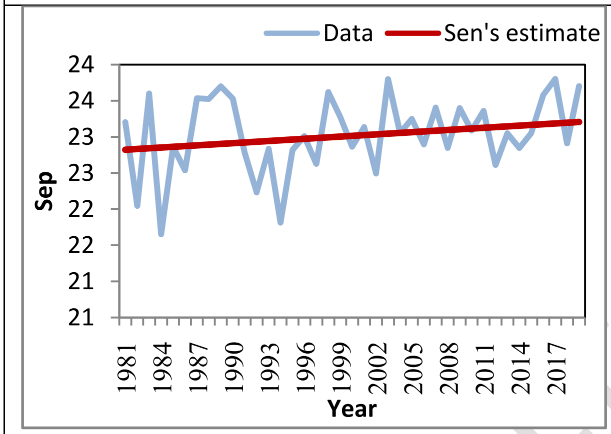
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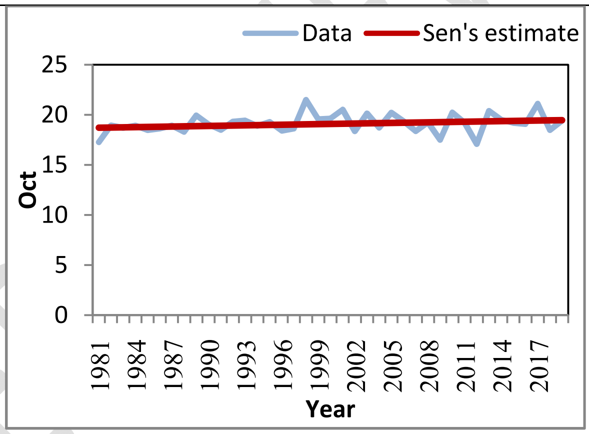
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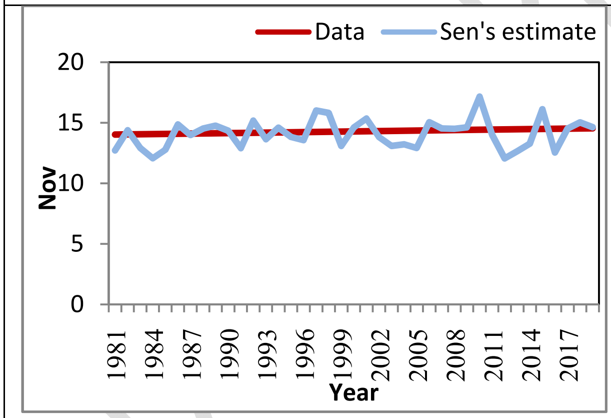
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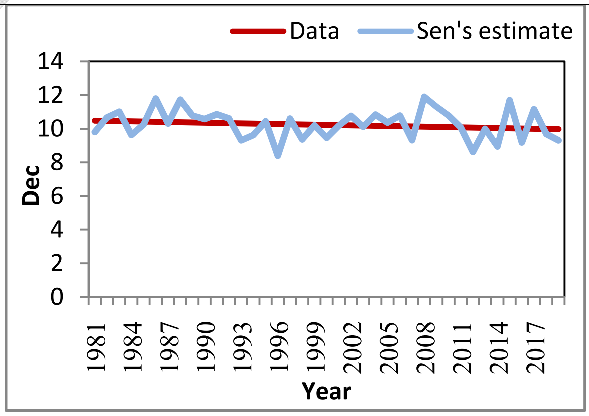
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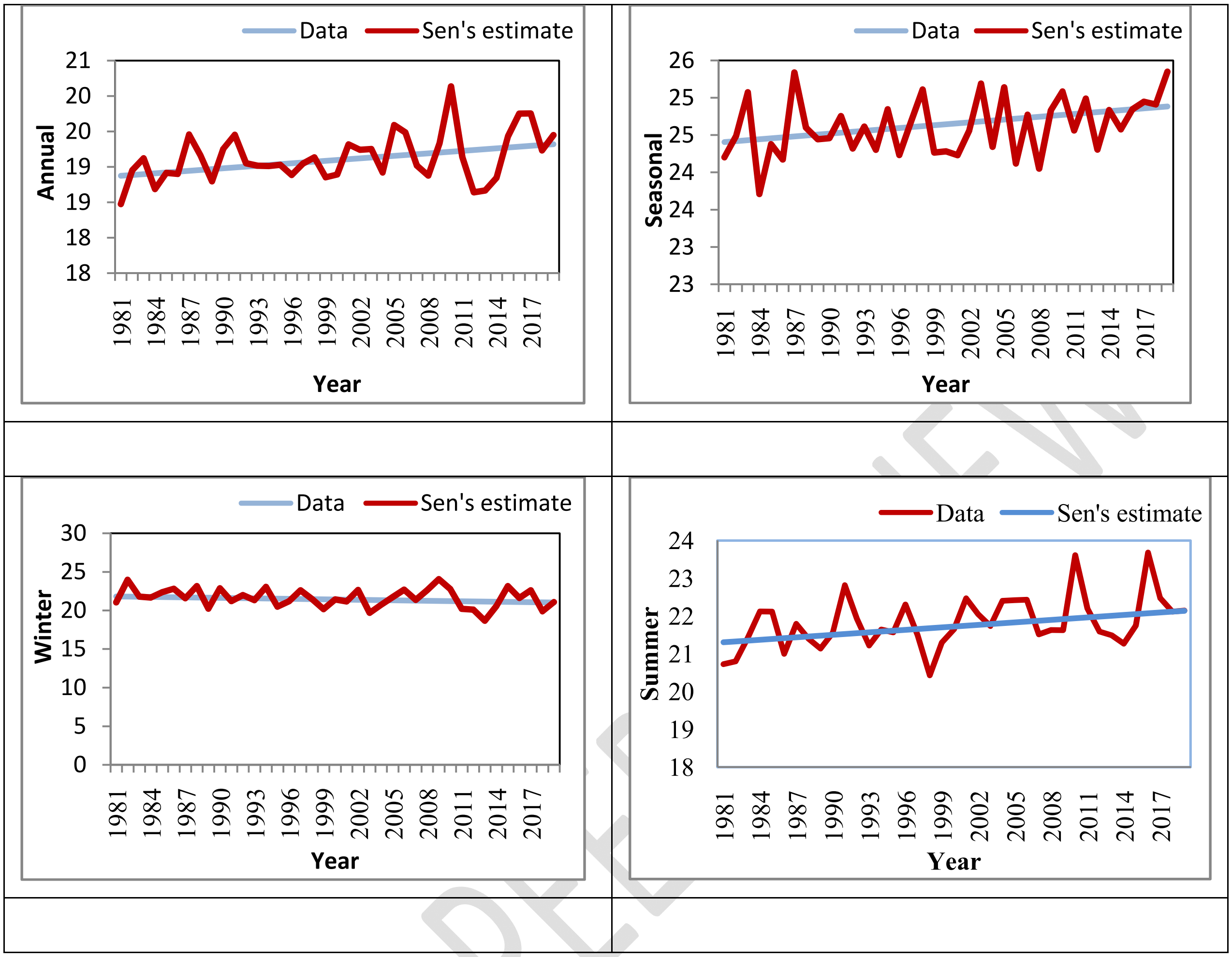

Fig.5. minimum temperature variability during the period 1981-2019 for different months, season and annual rainfall

CONCLUSION

The global average surface temperature has increased by 0.6 ± 0.2°C over the last century (IPCC, 2001) and it is expected that, by 2100, the increase in temperature could be 1.4–5.8°C. The change in temperature is not uniform globally, but varied from regions to regions. In order to assess base line trend in climate in Nagwan watershed trend analysis on rainfall, maximum and minimum temperatures on annual and seasonal data of 39 years. Non-parametric Mann Kendall test was applied to identify the trend and Sen's slope estimator to determine the magnitude of change. From rainfall trend assessment it may be concluded that in summer, an increasing trend prevails and an increasing trend in seasonal rainfall as well which influences the total water availability in the watershed. Maximum temperature data indicated a falling trend in month of December and January which affect the Rabi season crop. The annual average maximum temperature in the watershed showed a decreasing trend and thus affects the hydrological cycle. A decreasing trend during winter consequently decreases the crop productivity and may alter the soil moisture condition required for healthy crop growth. The minimum temperature showed falling trend in January and December and increasing trend in rest of the month. Increase in minimum temperature during summer season shows the impact of global warming resulted in increasing summer temperature and thus influence growth of plants. The watershed showed impact of climate change due to global warming which mainly influence Rabi season (December and January). Due to variability in rainfall and temperature there is decline in yield of crop and therefore different strategies need to be adopted to render the impact of climate change through planning and suitable water resources management.

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