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Trend Analysis of Temperature and Rainfall using Mann Kendall Test and Sen's Slope Estimator in Bhaderwah Tehsil of Doda District

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A B S T R A C T

The present study is mainly concerned with the detection of temperature and rainfall trend in Bhaderwah tehsil, located in Middle Himalayas which is highly vulnerable to climate change. This climate change led to changes in land use land cover pattern thereby affecting the livelihood of people. Therefore, examination of the trend of climatic variables like temperature and rainfall is essential. Month wise data of temperature and rainfall have been collected for 37 years (1982-2017) and non-parametric Mann-Kendall and Sen's slope estimator test were used to determine the trend with their statistical significance. The study revealed increasing trend of temperature and rainfall in some months and decreasing trend in other months in case of mean monthly rainfall and mean monthly maximum temperature while in case of mean minimum monthly temperature only positive trend was found. Significant trend was found only in two months in case of mean monthly rainfall (March and May) and mean monthly maximum temperature (June and August) while in case of mean minimum monthly temperature except for December all the 11 months showed significant trend.

***Key words*:** Climatic variables, Precipitation, Temperature, Mann-Kendall test, Sen Slope estimator

Climate change is one of the heated debates in the entire world. Climate change is defined as the change in the average global climate that existed for decades or for longer period. Climate change occurs at a global scale; however, the scale of variation differs from region to region [1]. The change in climate can't easily be accessed. Exploring historical change in the climate anomalies has been one of the necessities of research [2]. Climate change is studied by analyzing the trends in the records of hydro-meteorological variables viz, relative humidity, rainfall, and air temperature [3]. The most widely used non-parametric test Man-Kendall test and Spearman's rho is quite helpful in ascertaining the variability and trend in climate parameters. Since they are free from outliers [4]. The importance of exploring long-term trends and variability of hydro-meteorological variables is quite helpful for water resource management and proper planning of water utilization in water deficit regions [5].

Temperature and precipitation are the two important variables of climate. A little variation in these parameters affects human health, economic growth, development, human adaptability etc. An increase or decrease in these parameters lead to increase in the frequency of floods, instances of drought, famine, and water shortage [6]. India being predominantly an agrarian economy depends mainly on summer monsoon. Agriculture and related sectors such as food production and energy consumption of India are highly dependent on timely availability of adequate amount of water [7]. Hence, it is the need of the hour to examine and analyze the pattern of variability and trends in precipitation and temperature to minimize the risks and losses.

The climate of Jammu and Kashmir is unique due to diversified terrain and latitudinal extent. Jammu region is subtropical with abundant sunshine and hot temperature while Kashmir region has a moderate climate. The union territory of J&K comes under the Himalayan belt which is one of the susceptible regions to climate change. The ramifications of climate change will be upon agriculture, horticulture, tourism, species diversity, habitat, forests, and livelihood of people [8]. Limited studies have been done on climate variability and its impact on day-to-day life. Study on climate variability in the entire region is urgently needed due to its diversity in terrain and climate. However, this paper primarily focuses on the study of climatic variability in Bhaderwah tehsil of Doda district of the union territory of Jammu and Kashmir. In the present paper focus has been given to the analysis and discussion of the trend of temperature and rainfall. Non parametric Mann Kendall test has been used to study the nature of trends of climatic variables while magnitude of trend

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of climatic variables has been calculated by applying Sen's slope estimator method.

MATERIALS AND METHODS

Bhaderwah is a town and tehsil located in the district of Doda of the union territory of Jammu and Kashmir. The latitudinal and longitudinal extent of Bhaderwah tehsil is 32°10' N – 32°39' N and 75°30' E - 76°10' E respectively. Bhaderwah is also known as Mini Kashmir for its lush green grasslands, verdant valleys, glittering rivers, rocky terrains and a rich variety of flora and fauna.

Data collection: Rainfall and temperature data of Bhaderwah meteorological station was collected from IMD Srinagar from 1980 to 2017.The data comprised of daily and monthly rainfall and temperature. Mean monthly rainfall, mean monthly maximum temperature, and mean monthly minimum temperatures were selected as meteorological parameter for statistical and trend analysis.

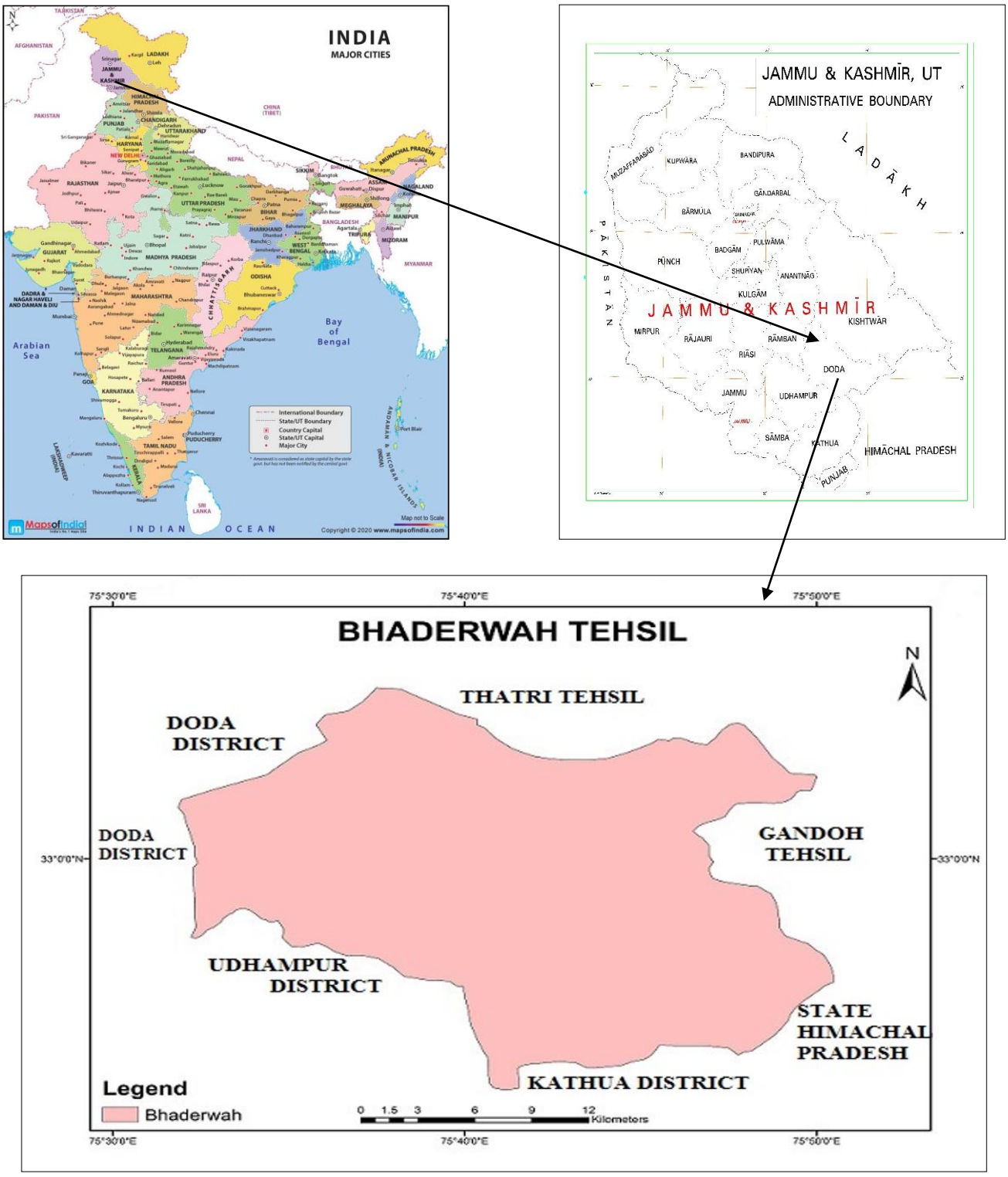

Fig 1 Location map of study area

Statistical analysis: Statistical analysis of Mean monthly rainfall, Mean Monthly Maximum temperature and Mean monthly minimum temperature was performed by using mean and standard deviation.

Trend analysis: In this study non-parametric Mann-Kendall test and Sen's slope estimator test were used for trend analysis of climatic variables. Non parametric test was used in our study because they are very less affected by the presence of outlier and other form of non-normality [9].

Mann-Kendall test: Mann-Kendall test is one of the most widely used method to statistically assess the presence of significance of trend in the series of climatic data [10-12]. This test compares only the relative values of sample data rather than absolute value [13].

In Mann Kendall test the null hypothesis H_o assumes that there is no trend in the data i.e., data is independent and randomly ordered and thesis is tested against alternative hypothesis H_i, which assumes that there is a trend [14].
The Mann-Kendall statistic S is computed as:

$$S = \sum_{j=1}^{n-1} \sum_{k=i+1}^{n} sgn(T_j - T_i)$$

Where n represents the number of data points, T_j and T_k represents the data values in time series j and k such that (k>j), respectively and sign $(T_k - T_j)$ is the sign function as:

$$\text{Sign } (T_k - T_j) = \begin{cases} +1 \ when \ (T_k - T_j) > 0 \\ 0 \ \ when \ (T_k - T_j) = 0 \\ -1 \ when \ (T_k - T_j) < 0 \end{cases}$$

The variance is computed as:

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

Where n represents the number of data set, m is the number of ties group (sample data having the same value) and t_i represents the number of ties to extent i. The standardized test statistic Z_s is computed using following equation:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & if \ S > 0 \\ 0 & if \ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & if \ S < 0 \end{cases}$$

Zs value indicate the nature of trend. Negative value of Zs indicate decreasing trend while positive values indicate increasing trend [11] [15]. Z_s is used to measure the significance of trend. Null hypothesis is tested using the test statistic Z_s values. If $|Z_s| > Z\alpha/2$, where α represent the chosen significance level then the null hypothesis is rejected indicating that the trend is significant [16]. In this study null hypothesis was tested at 5% and 10% significance level.

Sen's slope estimator: Sen's slope estimator which was developed by Sen (1968) [17] is a non-parametric procedure which is used for estimating the magnitude of trend in the sample of N pairs of data.

$$Q_i = \frac{x_k - x_j}{k - j} \text{ for } i = 1 \ldots N,$$

Where x_k and x_j represents the data values at times j and k such that j >k, respectively. The median of N values of Q_i is Sen's estimator of slope which is computed as:

$$Q = \begin{cases} Q_{\frac{N+1}{2}} & N \ is \ Odd, \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & N \ is \ even, \end{cases}$$

Positive value of Q indicates increasing trend while negative value of Q indicates decreasing trend. Q value indicates the steepness of trend. Sen's slope estimator has been widely used for calculating the magnitude of trend in hydro-meteorological time series [10] [15] [18-19].

RESULTS AND DISCUSSION

Statistical analysis of mean monthly rainfall

Mean monthly rainfall in Bhaderwah meteorological station ranges between 35mm to 176mm. Maximum monthly rainfall occurs in the month of February (176.4mm) followed by March (174.1mm) and July (141mm) while minimum monthly rainfall recorded in November (35.3mm) followed by October (36.6mm), December (70.4mm) and June (75.4mm). Bhaderwah receive most of its rainfall in the month of January, February, March, and April through western disturbances and in the month of July, August, and September through monsoon. Standard deviation which shows the dispersion from mean is highest for September (106.6mm) followed by March (105.2mm) and February (88.1mm) while lowest standard deviation is observed in June (35mm) followed by November (39.8mm) and October (40mm).

Trend analysis of mean monthly rainfall

In the Mann-Kendall test Z_s statistic revealed the trend of mean monthly rainfall from 1980-2017 for individual 12 months from January to December which are -0.553, 0.327, -1.748, 0, -1.735, 0.465, -0.830, 0.641, 1.559, -1.157, -1.308 and -0.881. January, March, May, July, October, November, and December showed negative trend while February, June, August, and September showed positive trend. April month did not show any trend. Only March and May month showed significant trend at 0.05 level of significance while for the other month's trend is insignificant.

By applying Sen slope estimator test, it was observed that the magnitude and trend of rainfall is negative for January, March, May, July, October, November, and December while it is positive for February, June, August, and September. Highest positive slope magnitude is observed in September (1.248) followed by February (0.536) while highest negative slope magnitude is observed in March (-2.646) followed by May (-1.307).

Statistical analysis of mean maximum monthly temperature

Mean monthly maximum temperature of Bhaderwah meteorological station is highest for July (30.4°C) followed by June (30.38°C) and August (29.4°C) while lowest mean maximum monthly temperature is showed by January(11.2°C) followed by February(13.5°C) and December(14.7°C). Standard deviation of mean monthly maximum temperature is highest for April (3.989°C) followed by February (2.883°C), March (2.479°C) and January (2.23°C) while standard deviation is lowest for August (1.241) followed by September (1.521), November (1.798°C) and December (1.901°C). Thus, April, February, March, and January month show high

dispersion from mean maximum monthly temperature while it is low for August, September November & December month.

Table 1 Bhaderwah Tehsil- trend of rainfall using Mann-Kendall test and Sen's Estimator-1980-2017

Months	Z_s value	Significance	S value	Sen's Slope	p value	Mean	SD
Jan	-0.553		-45	-0.586	0.580	122.997	78.020
Feb	0.327		27	0.536	0.744	176.471	88.141
Mar	-1.748	**	-140	-2.646	0.081	174.142	105.242
Apr	0.000		1	0.006	1.000	121.495	72.973
May	-1.735	**	-139	-1.307	0.083	91.058	45.762
Jun	0.465		38	0.156	0.642	75.384	35.048
Jul	-0.830		-67	-0.771		141.266	75.872
Aug	0.641		52	0.345	0.521	125.355	73.927
Sep	1.559		125	1.248	0.119	99.068	106.580
Oct	-1.157		-93	-0.400	0.247	36.661	40.084
Nov	-1.308		-105	-0.476	0.191	35.382	39.837
Dec	-0.881		71	-0.629	0.379	70.458	71.051

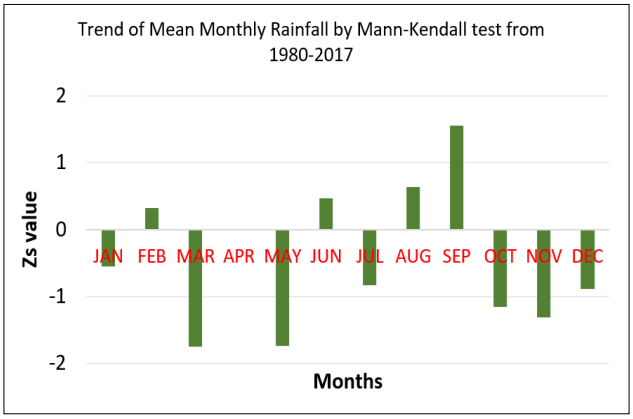

Fig 2 Trend of mean monthly rainfall by Mann-Kendall test from 1980-2017

Trend analysis of mean monthly maximum temperature

On applying the Mann Kendall test on mean monthly maximum temperature data for Bhaderwah meteorological station Z_s statistic value was calculated. These Z_s statistic value reveals the trend of mean monthly maximum temperature from 1980-2017 for individual months from January to December which are -0.243, 0.016, 1.364, -0.130, 0.535, -1.867, -0.138, -2.306, -1.494, -0.325, -1.379, -0.746 respectively. January, April, June, July, August, September, October, November, and December showed negative trend while February, March and May month showed positive trend. However only two months showed significant trend. The month of June showed significant trend at 0.1 level of significance while August showed the trend at 0.5 level of significance.

By applying Sen's slope estimator test, it was observed that the magnitude of mean maximum monthly temperature is negative for January, June, July, October, November, and December while it is positive for March and May. Slope magnitude is 0 for February and April. Highest positive slope magnitude is observed in May (0.035) followed by March while highest negative slope magnitude is observed in June (-0.068) followed by August (-0.056) and September (-0.041).

Table 2 Bhaderwah Tehsil: Trend result of mean maximum monthly temperature using Mann-Kendall test and Sen's slope estimator from 1980-2017

Months	Z_s value	S value	Significance	Sen's slope	p value	Mean	SD
Jan	-0.243	-16.000		-0.012	0.808	11.199	2.230
Feb	0.016	2.000		0.000	0.987	13.489	2.883
Mar	1.364	85.000		0.074	0.173	18.108	2.479
Apr	-0.130	-9.000		0.000	0.897	22.356	3.989
May	0.535	34.000		0.035	0.592	27.351	2.382
Jun	-1.867	-116.000	**	-0.068	0.062	30.389	1.821
Jul	-0.438	-28.000		-0.013	0.661	30.400	1.567
Aug	-2.306	-143.000	*	-0.056	0.021	29.446	1.241
Sep	-1.494	-93.000		-0.041	0.135	27.865	1.521
Oct	-0.325	-21.000		-0.009	0.746	24.347	1.820
Nov	-1.379	-86.000		-0.057	0.168	19.520	1.798
Dec	-0.746	-47.000		-0.025	0.456	14.723	1.901

'**'represent significant trend at 0.1 level of significance while
'*'represent significant trend at 0.05 level of significance

Statistical analysis of mean minimum monthly temperature

Mean monthly minimum temperature of Bhaderwah meteorological station is highest for the month of July (17.3°C) followed by August (16.8°C) and June (14.25°C) while lowest mean minimum monthly temperature is observed in February (0.16°C) followed by January (1.05°C) and March (3.7°C). Standard deviation is highest for May (2.438°C) followed by February (2.147°C) and January (1.732°C) while standard deviation is lowest for December (1.219°C) followed by November (1.281°C) and October (1.492°C). Thus, the months of May, February and January showed highest dispersion from its mean while December, November and October show the lowest dispersion from its mean.

Trend analysis of mean minimum monthly temperature

Z_s statistic value calculated using Mann Kendall test revealed the trend of mean minimum monthly temperature for individual months from January to December which are 2.588, 2.685, 3.148, 2.909, 2.025, 2.433, 2.347, 2.756, 2.228, 3.149, 2.552 and 1.430 respectively. All the months show positive trend of mean monthly minimum temperature. Except December month all the months show significant positive trend of mean monthly minimum temperature at 0.05 level of significance. Slope magnitude for mean minimum monthly temperature is also positive for all the months which show that average mean minimum temperature is increasing in Bhaderwah meteorological station. Highest slope magnitude is shown by March (0.113) followed by February (0.111) and January (0.100) while slope magnitude is lowest for December (0.04) followed by November (0.064) and July (0.081).

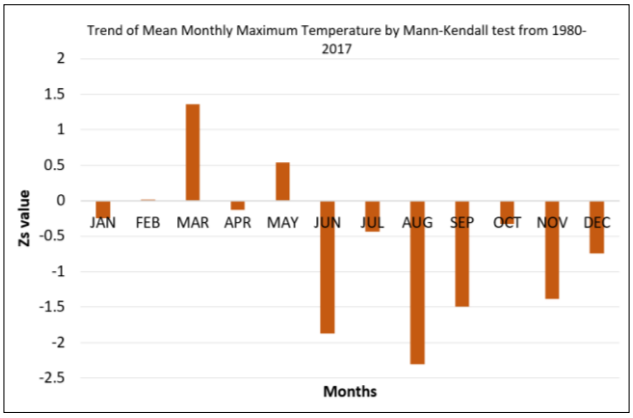

Fig 3 Trend of mean monthly temperature by Mann-Kendall test from 1980-2017

Table 3 Bhaderwah Tehsil-Trend result of mean minimum monthly temperature by Mann-Kendall test and Sen's slope estimator from 1980-2017

Months	Z_s value	S value	Sen's slope	Significance	p value	Mean	SD
Jan	2.588	153.000	0.100	*	0.010	1.052	1.732
Feb	2.685	159.000	0.111	*	0.007	0.163	2.147
Mar	3.148	186.000	0.113	*	0.002	3.747	1.686
Apr	2.909	172.000	0.100	*	0.004	7.377	1.645
May	2.025	120.000	0.106	*	0.043	10.119	2.438
Jun	2.433	144.000	0.089	*	0.015	14.253	1.730
Jul	2.347	139.000	0.081	*	0.019	17.333	1.758
Aug	2.756	163.000	0.100	*	0.006	16.881	1.523
Sep	2.228	132.000	0.085	*	0.026	12.841	1.713
Oct	3.149	186.000	0.091	*	0.002	7.303	1.492
Nov	2.552	151.000	0.064	*	0.011	3.428	1.281
Dec	1.430	85.000	0.040		0.153	0.910	1.219

'**'represent significant trend at 0.1 level of significance while
'*'represent significant trend at 0.05 level of significance

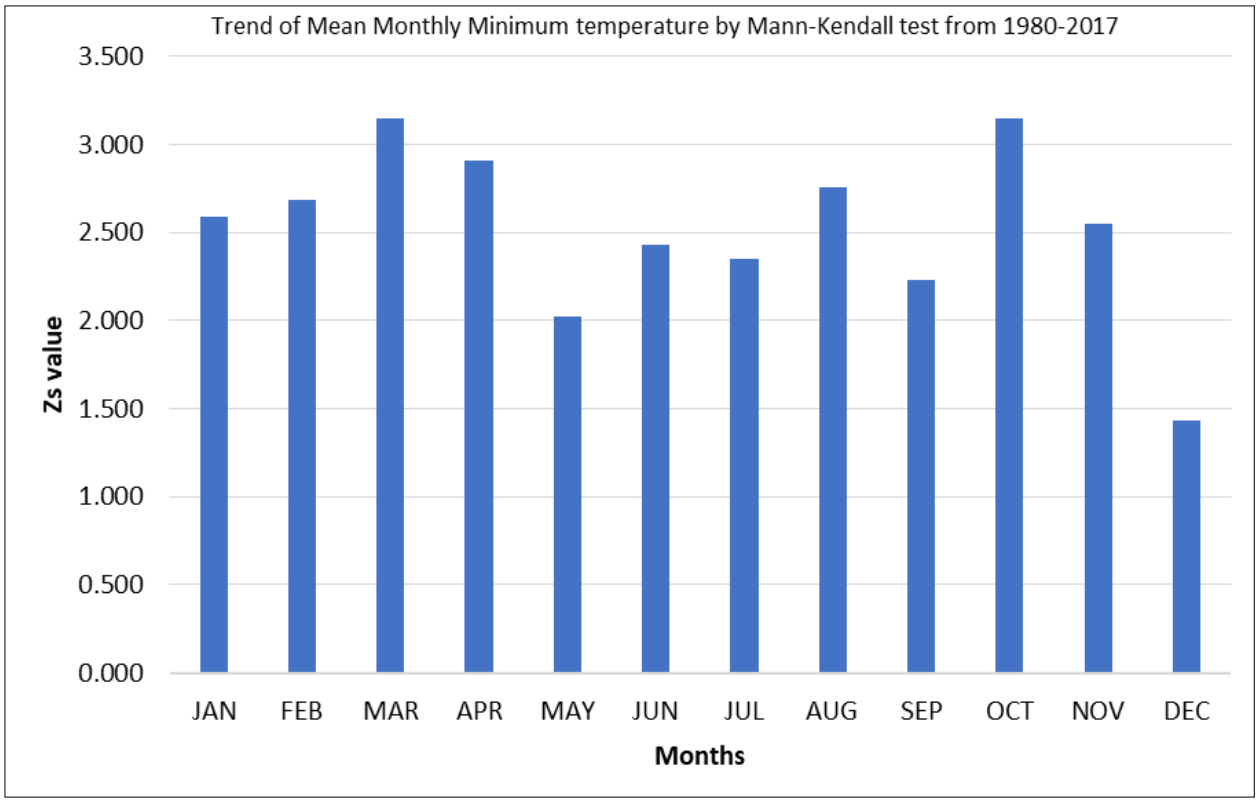

Fig 4 Trend of mean monthly maximum temperature by Mann-Kendall test from 1980-2017

CONCLUSION

In this study an attempt was made to analyse the trend of mean monthly rainfall, mean monthly maximum temperature, and mean minimum monthly temperature for Bhaderwah meteorological station from 1980-2017. Our analysis revealed that mean monthly rainfall showed negative trend for 7 months which are January, March, May, July, October, November, and December while positive trend is observed during the months of February, June, August, and September. Only two months showed significant trend which are March and May. In case of Mean maximum monthly temperature, February and May months recorded positive trend while other 10 months showed negative trend. Only June and August month showed significant trend at 0.1 and 0.05 level of significant level respectively. In case of mean minimum monthly temperature all the months showed positive trend and except for December, all the months showed significant trend at 0.05 level of significance. The slope magnitude calculated through Sen's slope estimator test also showed great significance as the months where Z_s value calculated using Mann Kendall test, which showed negative value, similar negative slope magnitude value was observed for Sen's slope and vice versa.

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