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TREND ANALYSIS OF RAINFALL AND TEMPERATURE: A CASE STUDY OF BHOGAVO RIVER WATERSHED, GUJARAT

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Abstract: The significance of the trend in rainfall and temperature over Bhogavo River Watershed in Surendranagar district of Gujarat, India has been analysed in the present study. Trend analysis has been carried out on monthly, seasonal and annual basis for the period 1979 to 2019 for rainfall and temperature. Linear trend analysis has been used to assess the variation in rainfall and temperature. The highest trend of total monthly rainfall has been observed in the month of July. The seasonal trend analysis indicates a positive rainfall trend in Pre-Monsoon, Monsoon, and Winter seasons while Post-Monsoon indicates a negative trend. The annual rainfall in the Bhogavo River Watershed indicates a positive trend with slope of regression line 8.1977. The average maximum temperature trend analysis indicates a rising trend in Pre-Monsoon, Post-Monsoon and Winter seasons while a falling trend in monsoon season. The average annual maximum temperature indicates a positive trend with slope of regression line 0.0032. The average minimum temperature trend analysis indicates a rising trend for all months and seasons. The average annual minimum temperature showed a positive trend with slope of regression line 0.029.

Index Terms: Trend Analysis, Climate change, Bhogavo River Watershed, Surendranagar

I. INTRODUCTION:

Water availability is one of the major issues that need attention from the present generation across the whole world to attain sustainability (**Swain S. et.al. 2018**). Precipitation plays an omni-important role in a developing country like India where the lion's share of the economy is dependent on agriculture which in turn is dependent on the rains (**Biswas B. et.al. 2019**). However, with unplanned urbanization and climate change, the precipitation pattern has changed a lot (**Biswas B. et.al. 2019**). Climate Change is a big challenge to the water, food security, and welfare of 1.2 billion people in the 21st century in India (**Goyal M. K. et.al. 2018**). There is uneven spatial distribution of water resources in many regions of India, from the drier northwest, where rainfall is scarce, to the northeast, the highest rainfall-receiving region on the planet (**Goyal M. K. et.al. 2018**). Climate variability, particularly that of the annual air temperature and rainfall, has received a great deal of attention worldwide (**Panda A. et.al. 2019**). The magnitude of the variability or fluctuations of the factors varies according to locations (**Panda A. et.al. 2019**). There are many variables such as temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate (**IPCC 2007, Panda A. et.al. 2019**). Global climate changes may influence long-term rainfall pat-terns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (**Pal et.al. 2017, Panda A. et.al. 2019**). The spatio-temporal variability of climate and climate drivers have caused changes in frequency and intensity of climate extremes such as floods, droughts and tropical cyclones which have significant impact on human life and socio-economic aspects of India (**Jayadas et.al. 2019, Rao G. V. et.al. 2020**). Understanding the spatio-temporal distribution of rainfall characteristics has a major role in assessing the availability of water resources over a catchment (**Rao G. V. et.al. 2020**). Therefore, it is necessary to understand the changes in rainfall characteristics using gridded precipitation data and robust statistical analysis for making decisions (**Rao G. V. et.al. 2020**). Global warming is a biggest issue around the world (**Patel P. S. et.al. 2021**). Detection of past trends, changes, and variability in the time series of hydro-climatic variables is very important in understanding the potential impact of future changes in the region (**Sahoo et.al. 2009, Pingale et.al. 2013**). Statistical analysis could be extended to analyse climatic parameters and their relationships with water resources, land use/cover changes, urbanization etc. (**IPCC 2001**). Trend analysis of the mean (monsoon season, non-monsoon season and annual) and extreme annual daily rainfall and temperature at the spatial and temporal scales has been carried out for all the 33 urban centers of the arid and semi-arid state of Rajasthan, India (**Pingale et.al. 2013**). Rainfall and temperature data for period of 1980–2017 has been analyzed and long-term changes and short-term fluctuations in monsoonal rainfall and temperature over Kalahandi, Bolangir and Koraput (hereafter KBK) districts in the state of Odisha has been examined (**Panda A. et.al. 2019**). The temperature and rainfall trend has been successfully analysed for meteorological data of Labandi station, Raipur district in Chhattisgarh, India by linear trend analysis (**Khavse R. et.al. 2015**). The increasing trend in mean maximum temperature (MMAX) and total mean rainfall (TMRF) is confirmed by Mann-Kendall trend test (**Khavse R. et.al. 2015**).

II. STUDY AREA:

River Bhogavo is originating from hilly regions of Chotila, passing through various areas of Surendranagar District and terminating to plains near Nal-sarovar area of Ahmedabad District (https://gpcb.gujarat.gov.in/uploads/ROVER_ACTION_PLAN_BHOGAVO). Bhogavo River is the major right tributary of Sabarmati River in Gujarat, India. Bhogavo River watershed covers 6493 km^2 area in Ahmedabad and Surendranagar districts of Gujarat State (**Patel P. S. et.al. 2021**). Bhogavo River has two major tributaries namely Limbdi Bhogavo and Wadhwan Bhogavo. Wadhwan Bhogavo river is 107km long with 1570 km^2 catchment area, originates near Muli and passes through sedimentary terrain & meets Arabian sea in Bay of Khambhat (**Srivastava S. et.al. 2020**). Limdi Bhogavo river is 120 km with 1116 km^2 catchment area originates from Chotila ridge & also joins Bay of Khambhat (**Srivastava S. et.al. 2020**). Fig. 1 shows the location map of Bhogavo River Watershed.

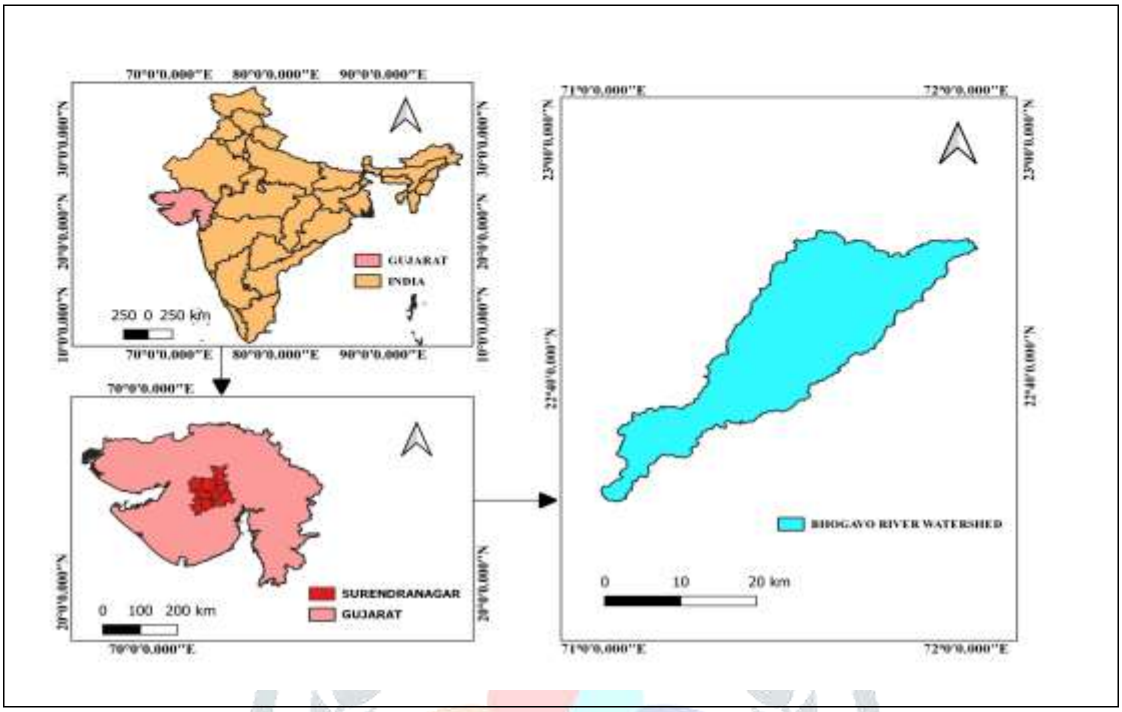


Fig. 1 Location Map of Bhogavo River Watershed

III. RESEARCH METHODOLOGY:

The daily precipitation, maximum and minimum temperature data for the years 1979-2019 was extracted from https://swat.tamu.edu for 22°38′12″N Latitude and 71°33′45″E Longitude.

The 41 years data analysis was carried out and the monthly precipitation, average maximum and average minimum temperature for each year was obtained. From the monthly precipitation; the annual and seasonal precipitation (Winter, Pre-Monsoon, Monsoon, Post-Monsoon) precipitation was found. From the average monthly maximum temperature and average monthly minimum temperature; the average annual maximum temperature and average annual minimum temperature was found.

Trend is defined as the general movement of a series over an extended period of time or it is the long-term change in the dependent variable over a long period of time (**Webber et.al. 1980, Panda A. et.al. 2019**). Linear Regression Method was used for trend analysis to detect the monthly, seasonal and annual rainfall trend monthly and annual temperature trend. The rising trend in rainfall, maximum temperature and minimum temperature was confirmed by performing Mann-Kendall test.

3.1 Linear Regression Method:

Negative slope value indicates decreasing trends and Positive slope value indicates increasing trends (**Tabari et.al. 2011, Patel P. S. et.al. 2021**).

$$y = mx + B \qquad (3.1)$$

where dependent variable (y) could be the amount of rainfall or maximum or minimum temperature and independent variable (x) is the time in year and slope (m) is the trend indicator.

3.2 Mann-Kendall Test:

The Mann-Kendall test is a nonparametric method, used for trend analysis (Mann, 1945; Kendall, 1975). Let X_1, X_2, ………. X_n represents n data points where X_i represents the data point at time j. Mann-Kendall statistic (S) is given by

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(X_i - X_j) \qquad (3.2.1)$$

where n = length of time series, i=1, 2…., n-1 and j=n+1, n+2…. n.

$$sgn\left(X_i - X_j\right) = 1 \text{ if } X_i - X_j > 0$$

$$= 0 \text{ if } X_i - X_j = 0$$

$$= -1 \text{ if } X_i - X_j < 0 \qquad (3.2.2)$$

S is an indicator of trend where very high positive value of S indicates an increasing trend and a very low negative value indicates a decreasing trend. For n > 10, a normal approximation to the Mann-Kendall test may be used. For this, variance of S is given by,

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m}(t_k-1)(2t_k+5)}{18} \qquad (3.2.3)$$

Where, m is the number of tied groups and t_k is the size of the k^{th} tie group
Then standardized test statistics is computed by Z value which is given as follows:

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

$$= 0 \text{ if } S = 0,$$

$$= \frac{S+1}{\sqrt{Var(S)}} \text{ if } S < 0 \qquad (3.2.4)$$

Negative Z value indicates falling trend and Positive Z value indicates increasing trend.

IV. RESULTS AND DISCUSSION:

4.1 Trend analysis of rainfall

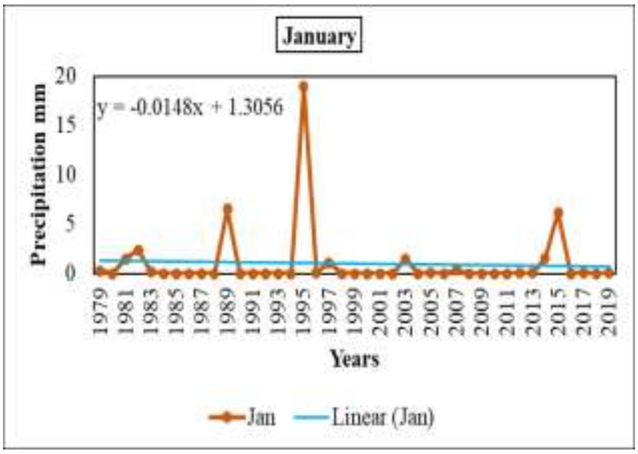
Table1: Statistical Parameters of Monthly, Annual and Seasonal Rainfall Pattern

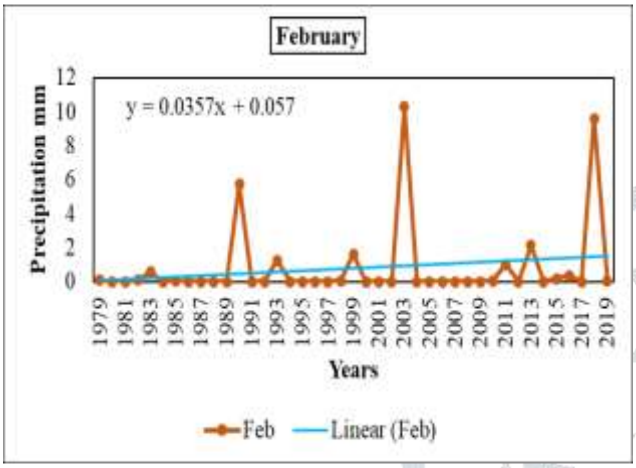
Time series	Mean	Standard Deviation	Coefficient of Variation
Jan	0.94	3.349	356.28
Feb	0.654	1.985	303.28
March	0.472	1.488	315.22
April	0.741	1.431	193.2
May	5.789	11.145	192.52
June	116.684	129.425	110.91
July	259.22	171.34	66.09
August	224.198	139.2	62.08
September	103.63	100.871	97.33
October	29.838	44.711	149.84
November	11.52	30.64	265.96
December	1.605	4.009	249.81
Annual	755.3	330.91	43.81
Pre-Monsoon	7.0014	11.04	157.70
Monsoon	703.74	338.30	48.072
Post- Monsoon	41.35	55.47	134.13
Winter	3.19	7.094	221.75

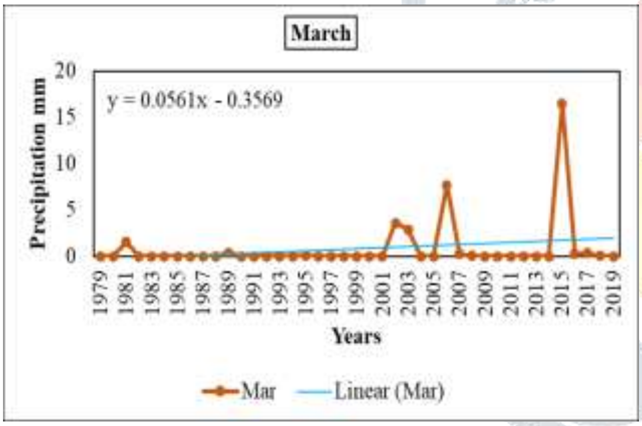
Table 2: Results of Rainfall Trend analysis using Linear Regression Method

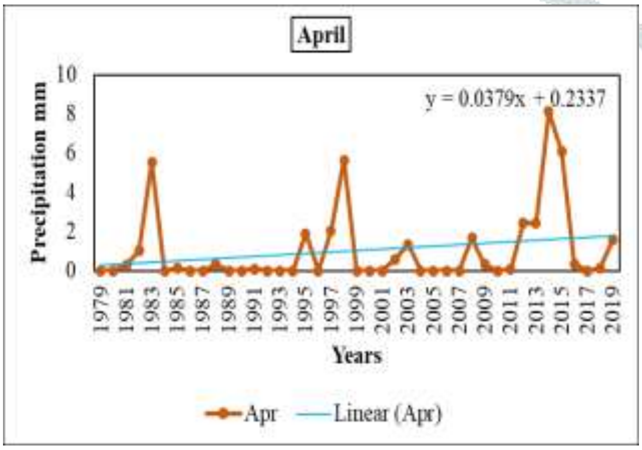
Time Series	Regression Line Slope
Jan	-0.0148
Feb	0.0357
Mar	0.0561
Apr	0.0379
May	-0.0834
June	1.3595
July	3.6976
August	0.9488
Sep	3.0635
Oct	-0.2745
Nov	-0.667
Dec	0.0383
Annual	8.1977
Pre-Monsoon	0.0106
Monsoon	9.0694
Post-Monsoon	-0.9415
Winter	0.0592

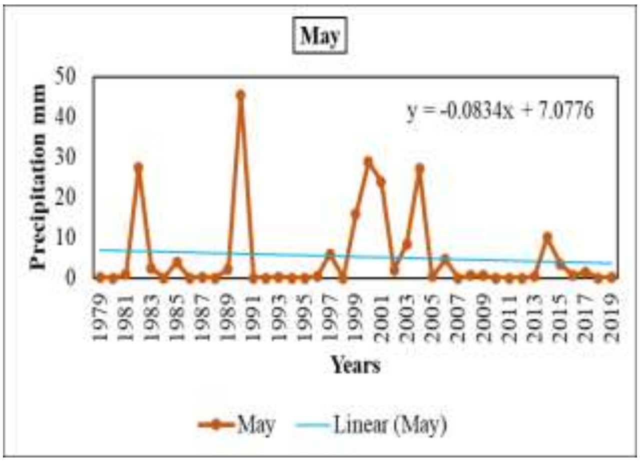
Note: Significance Level is 5%

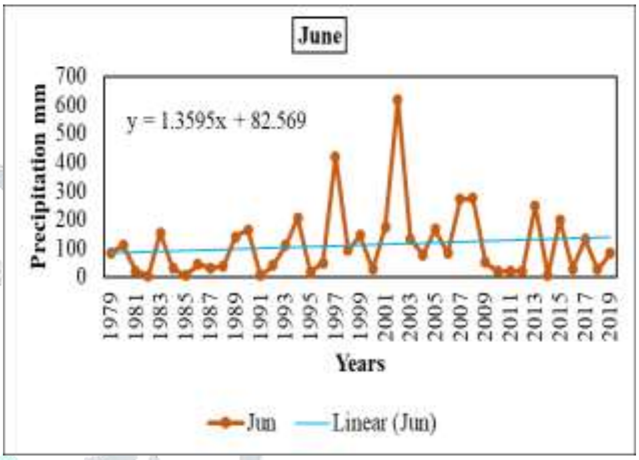

January
y = -0.0148x + 1.3056
Precipitation mm
Years
Jan
Linear (Jan)

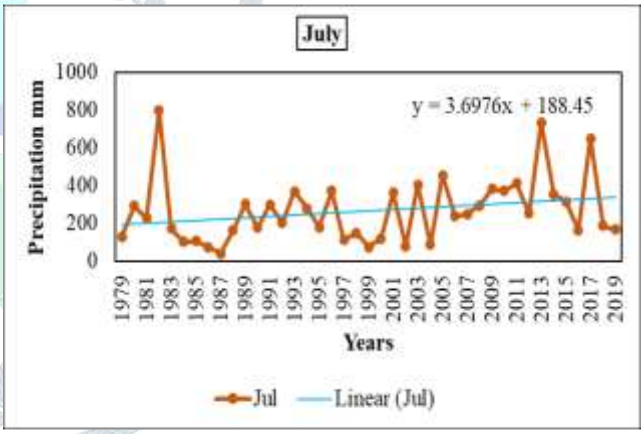

February
y = 0.0357x + 0.057
Precipitation mm
Years
Feb
Linear (Feb)

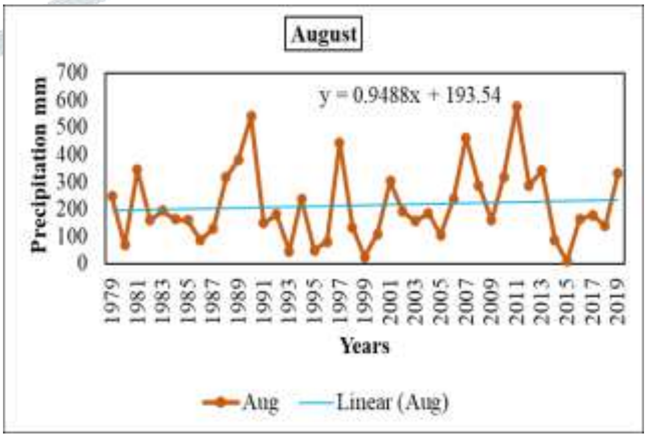

March
y = 0.0561x - 0.3569
Precipitation mm
Years
Mar
Linear (Mar)

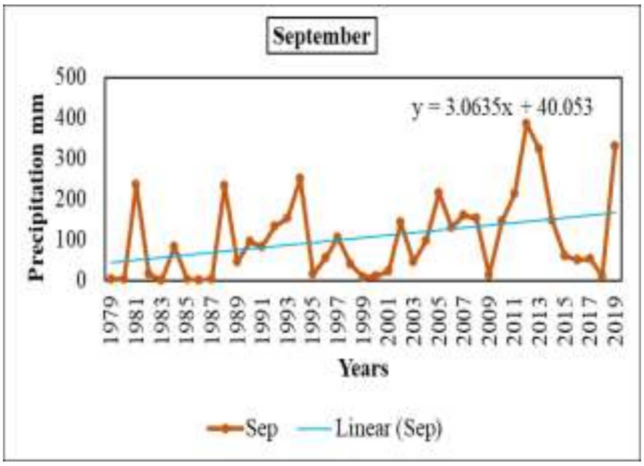

April
y = 0.0379x + 0.2337
Precipitation mm
Years
Apr
Linear (Apr)

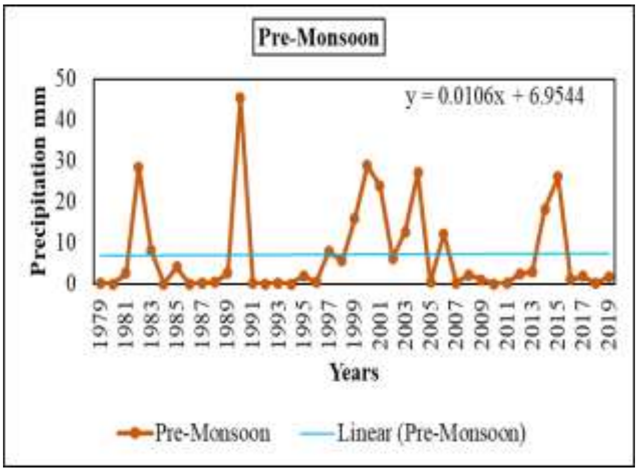

May
y = -0.0834x + 7.0776
Precipitation mm
Years
May
Linear (May)

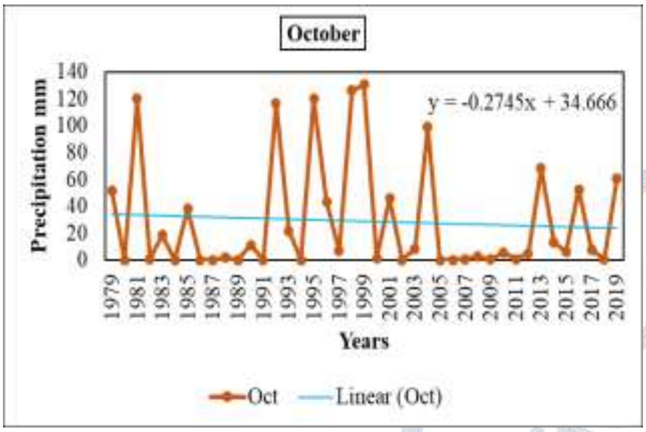

June
y = 1.3595x + 82.569
Precipitation mm
Years
Jun
Linear (Jun)

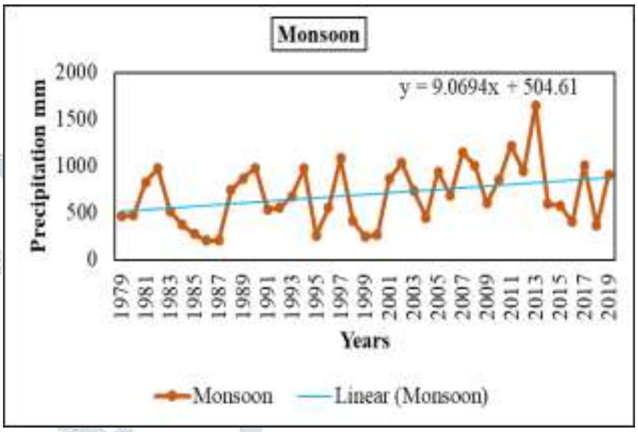

July
y = 3.6976x + 188.45
Precipitation mm
Years
Jul
Linear (Jul)

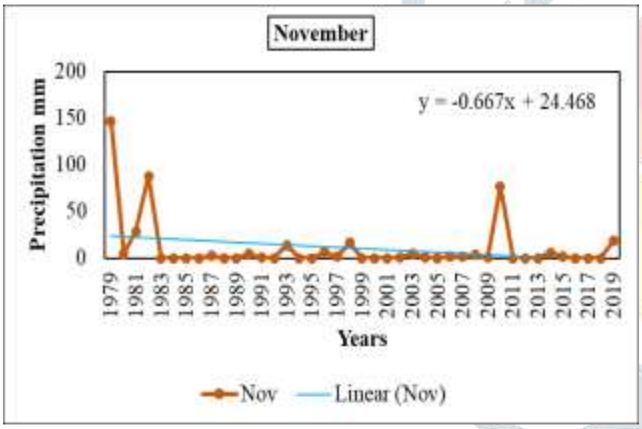

August
y = 0.9488x + 193.54
Precipitation mm
Years
Aug
Linear (Aug)

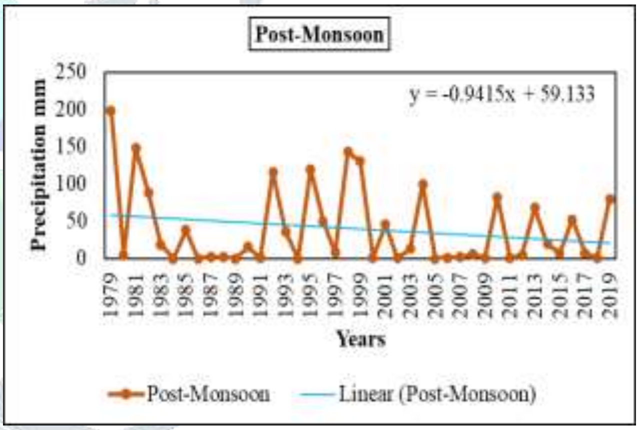

September
y = 3.0635x + 40.053
Precipitation mm
Years
Sep
Linear (Sep)

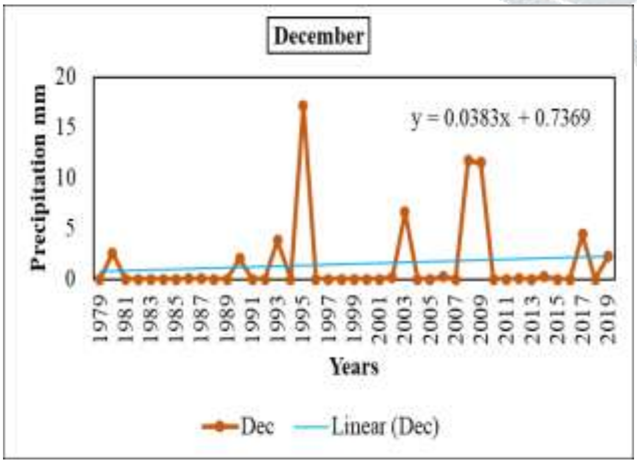

Pre-Monsoon
y = 0.0106x + 6.9544
Precipitation mm
Years
Pre-Monsoon
Linear (Pre-Monsoon)

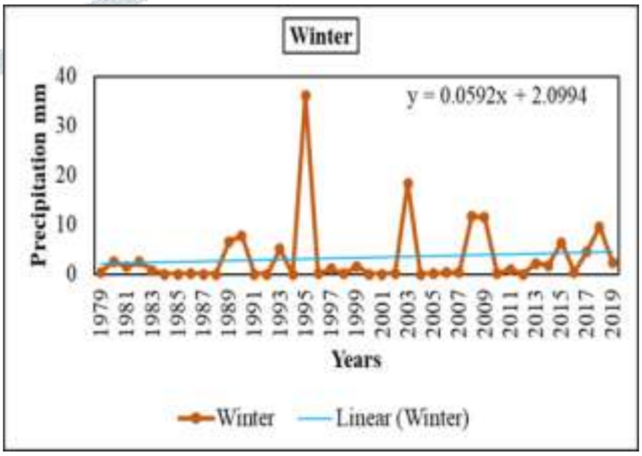

October
y = -0.2745x + 34.666
Precipitation mm
Years
Oct
Linear (Oct)


Monsoon
y = 9.0694x + 504.61
Precipitation mm
Years
Monsoon
Linear (Monsoon)


November
y = -0.667x + 24.468
Precipitation mm
Years
Nov
Linear (Nov)


Post-Monsoon
y = -0.9415x + 59.133
Precipitation mm
Years
Post-Monsoon
Linear (Post-Monsoon)


December
y = 0.0383x + 0.7369
Precipitation mm
Years
Dec
Linear (Dec)


Winter
y = 0.0592x + 2.0994
Precipitation mm
Years
Winter
Linear (Winter)

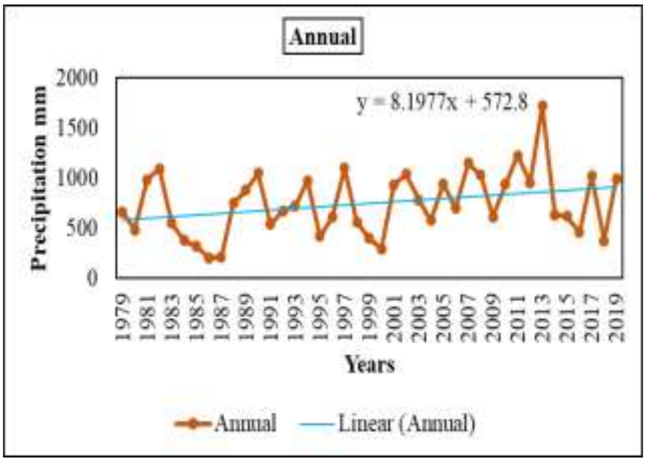


Figure 2 Linear rainfall trends for the period 1979-2019 on monthly, seasonal and annual basis

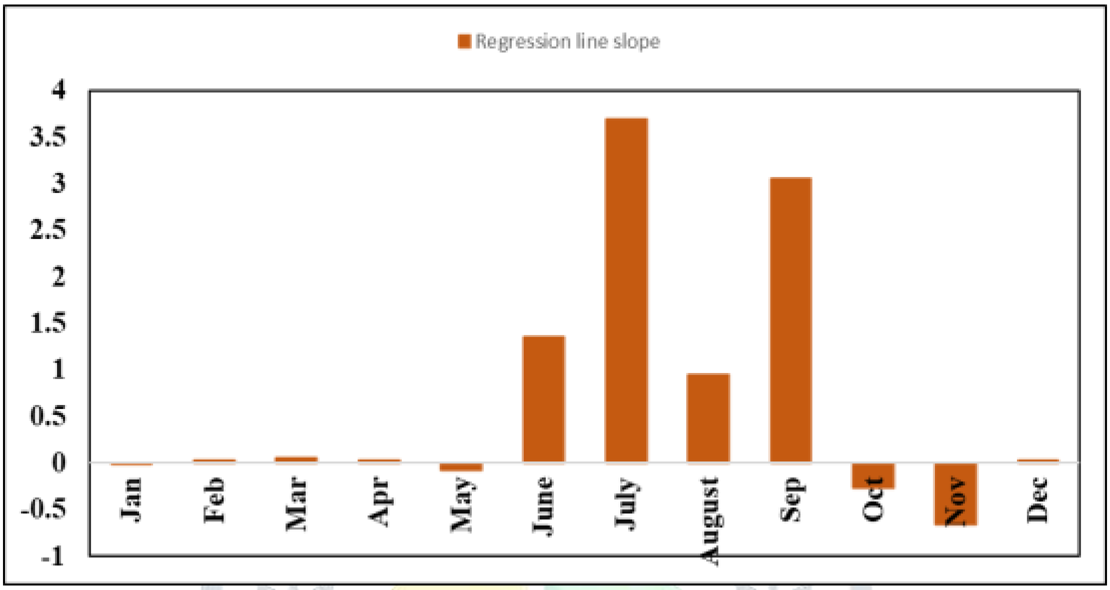


Figure 3 Linear Regression Slope for different months

4.2 Trend analysis of Temperature

4.2.1 Maximum Temperature

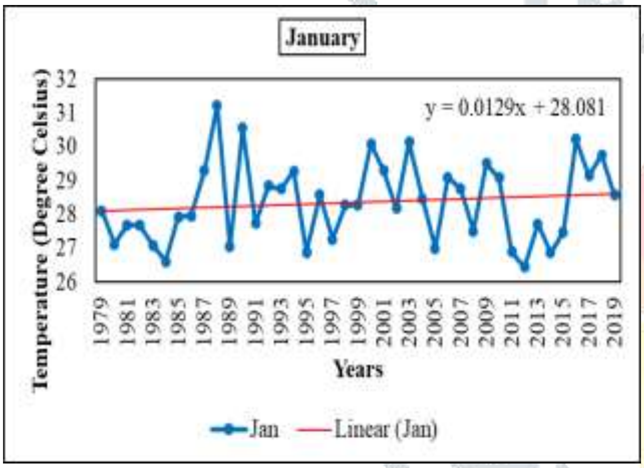
Table 3: Statistical Parameters of Monthly, Annual and Seasonal Maximum Temperature

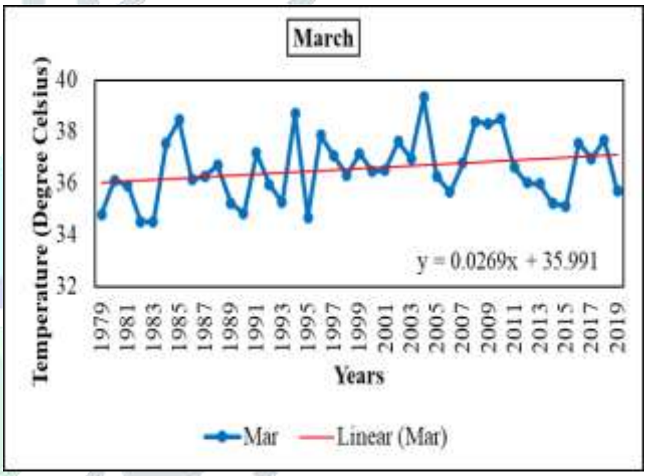
Time Series	Mean	Standard Deviation	Coefficient of Variation
Jan	28.29	1.17	4.13
Feb	31.375	1.308	4.16
March	36.6	1.277	3.49
April	40.709	1.188	2.91
May	42.651	0.792	1.856
June	40.047	1.532	3.824
July	33.80	1.77	5.24
August	32.018	1.911	5.97
September	35.142	2.36	6.714
October	36.494	1.582	4.335
Nov	32.834	1.414	4.307
Dec	29.458	1.078	3.66
Annual	35	0.8	2.28
Pre-Monsoon	40	0.75	1.88
Monsoon	35.24	1.31	3.74
Post-Monsoon	34.73	1.29	3.72
Winter	29.75	0.91	3.07

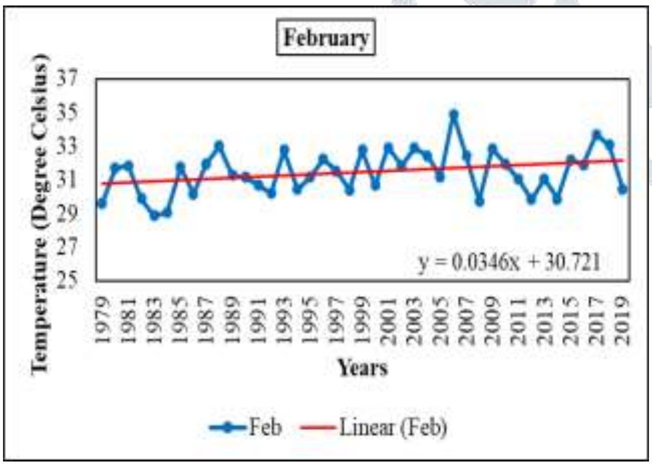
Table 4: Results of Average Maximum Temperature Trend analysis using Linear Regression Method

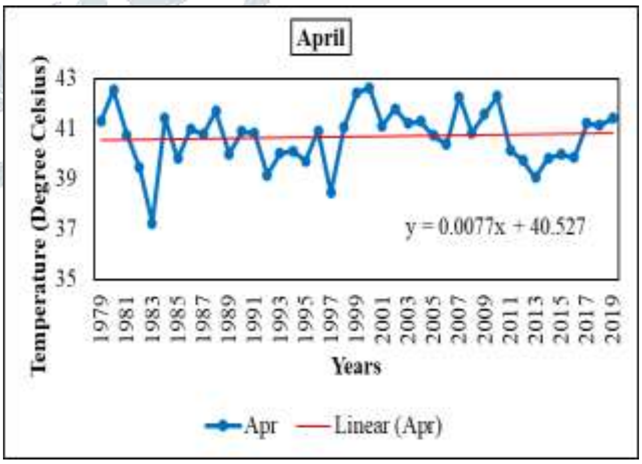
Time Series	Regression Line Slope
Jan	0.0129
Feb	0.0346
Mar	0.0269
Apr	0.0077
May	0.0043
June	-0.0441
July	-0.0088
August	0.0075
Sep	-0.049
Oct	-0.0043
Nov	0.0447
Dec	0.0172
Annual	0.0032
Pre-Monsoon	0.013
Monsoon	-0.0236
Post-Monsoon	0.0202
Winter	0.0216

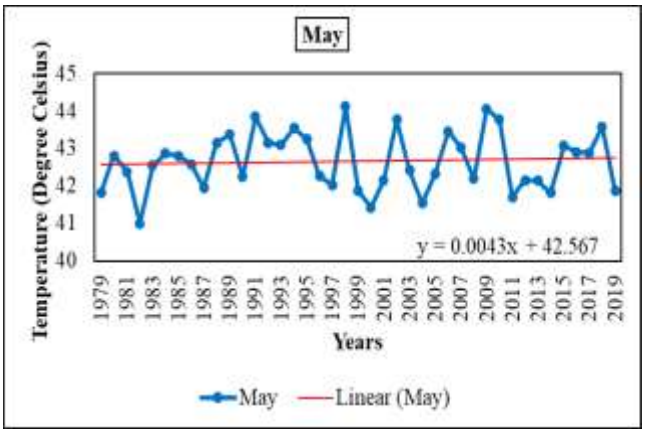
Note: Significance Level is 5%

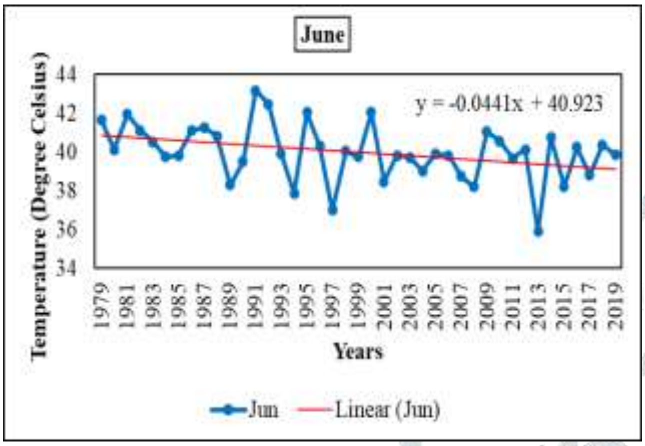


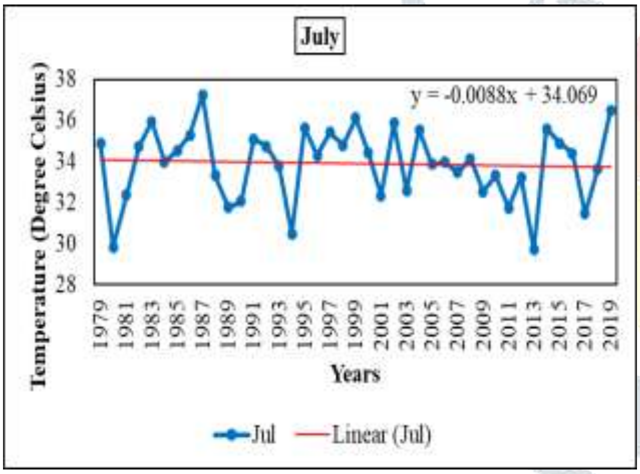


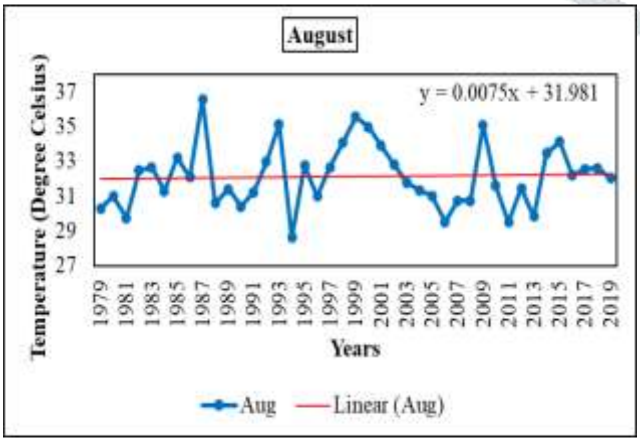


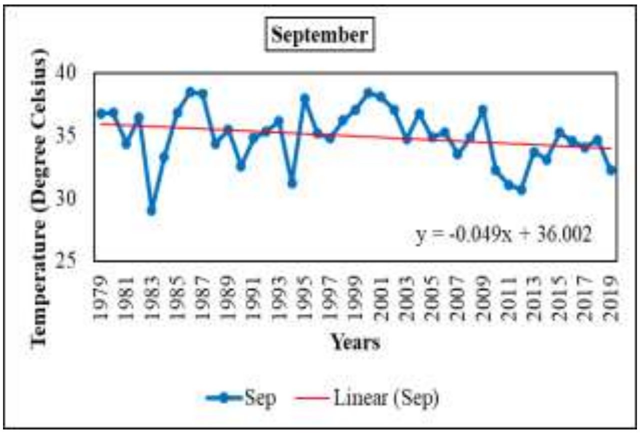


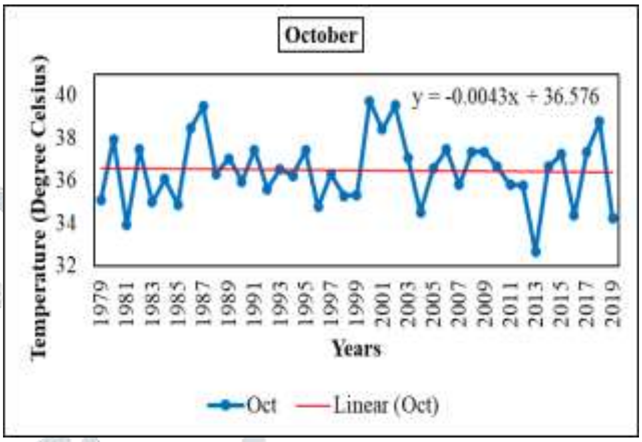

May
Temperature (Degree Celsius)
y = 0.0043x + 42.567
Years
May
Linear (May)

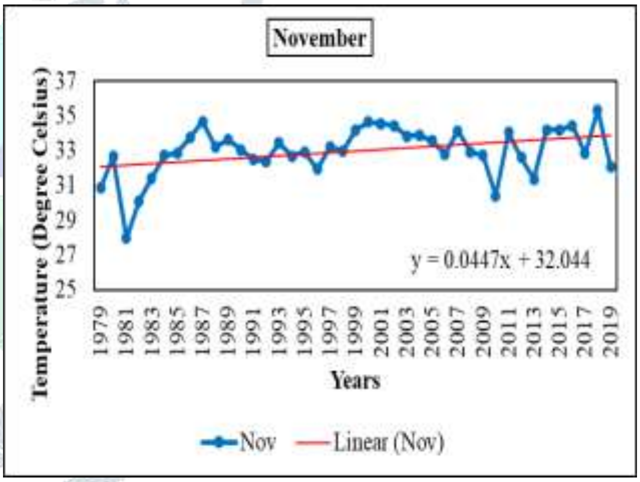

June
Temperature (Degree Celsius)
y = -0.0441x + 40.923
Years
Jun
Linear (Jun)

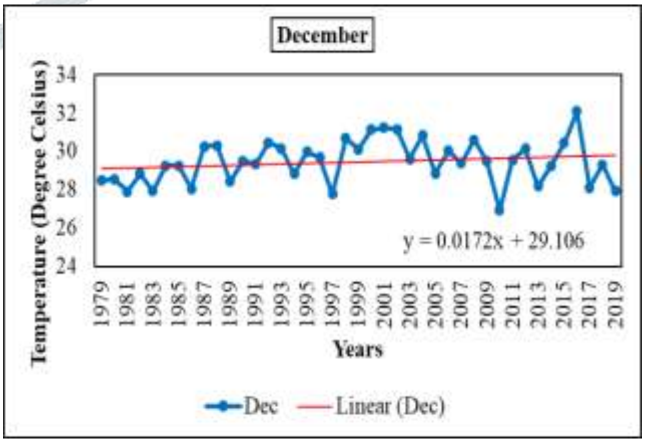

July
Temperature (Degree Celsius)
y = -0.0088x + 34.069
Years
Jul
Linear (Jul)

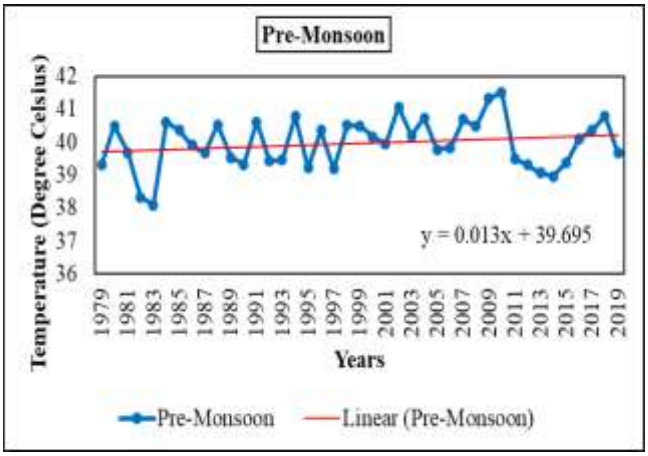

August
Temperature (Degree Celsius)
y = 0.0075x + 31.981
Years
Aug
Linear (Aug)

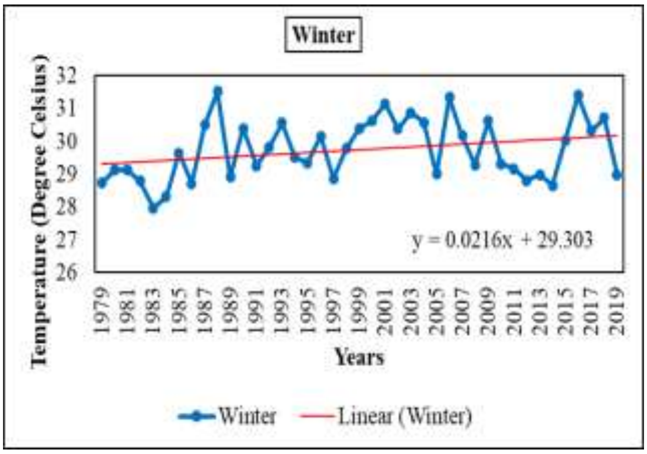

September
Temperature (Degree Celsius)
y = -0.049x + 36.002
Years
Sep
Linear (Sep)

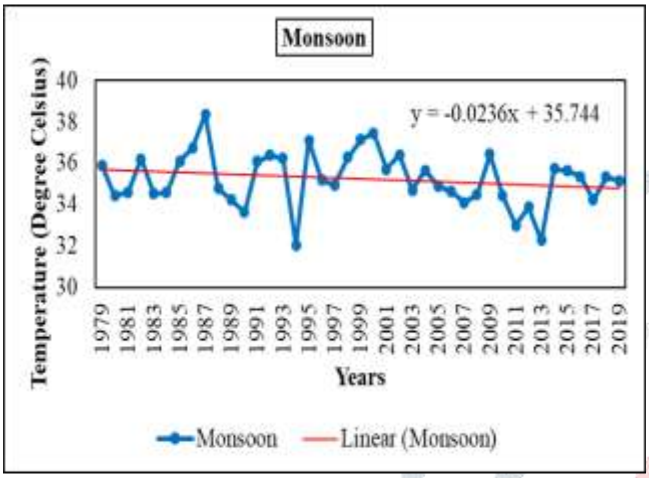

October
Temperature (Degree Celsius)
y = -0.0043x + 36.576
Years
Oct
Linear (Oct)

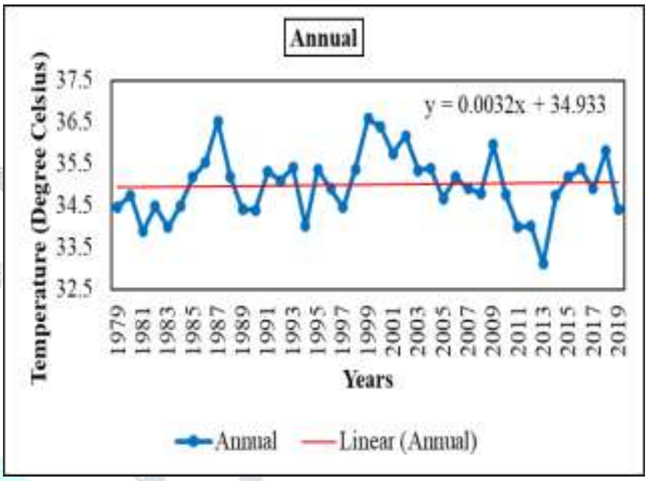

November
Temperature (Degree Celsius)
y = 0.0447x + 32.044
Years
Nov
Linear (Nov)


December
Temperature (Degree Celsius)
y = 0.0172x + 29.106
Years
Dec
Linear (Dec)









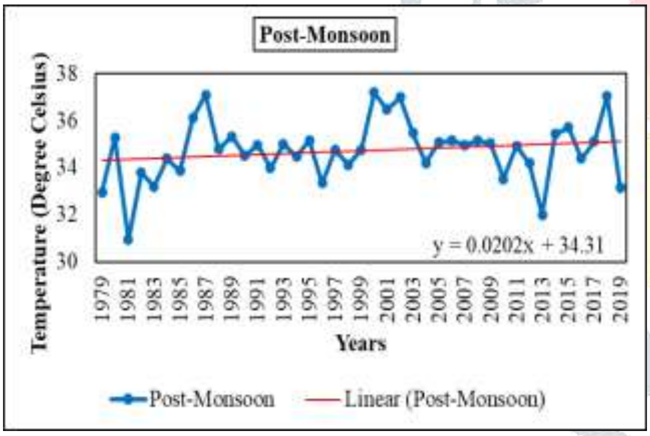


Figure 4 Linear Regression Trend of monthly, seasonal and annual mean of maximum temperature

4.2.2 Minimum Temperature

Table 5: Statistical Parameters of Monthly, Annual and Seasonal Average Minimum Temperature

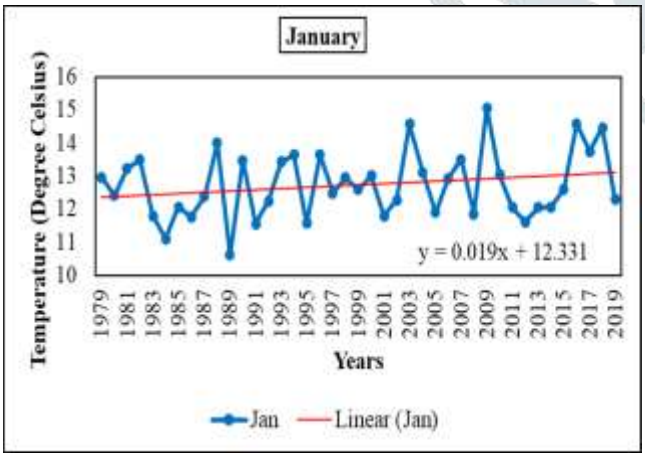
Time series	Mean	Standard Deviation	Coefficient of variation
Jan	12.73	1.006	7.90
Feb	15	1.404	9.36
March	19.58	1.12	5.76
April	23.21	1.025	4.41
May	26.31	0.784	2.98
June	27.83	0.445	1.6
July	26.39	0.59	2.22
August	25.2	0.68	2.7
September	24.7	0.77	3.11

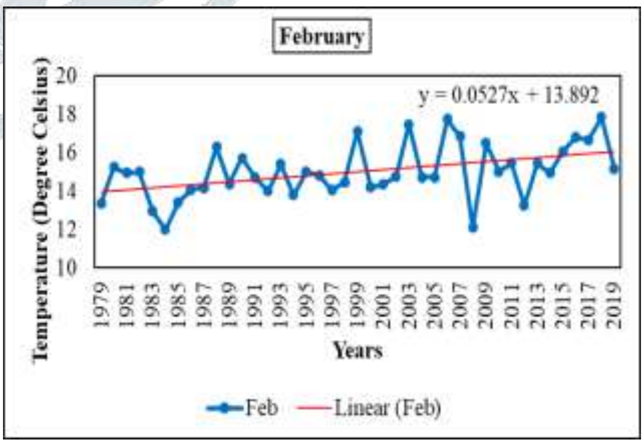
October	22.67	1.07	4.71
Nov	18.22	1.384	7.59
Dec	14.35	1.063	7.40
Annual	21.38	0.582	2.724
Pre-Monsoon	23.03	0.808	3.51
Monsoon	26.03	0.446	1.71
Post-Monsoon	20.45	0.973	4.76
Winter	14.02	0.846	6.03

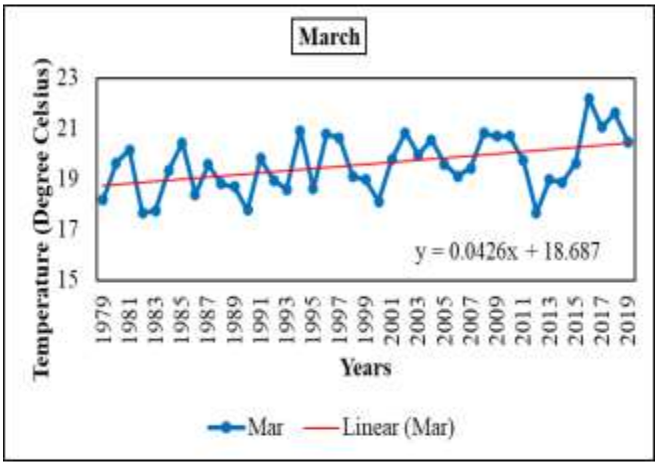
Table 6: Results of Average Minimum Temperature Trend analysis using Linear Regression

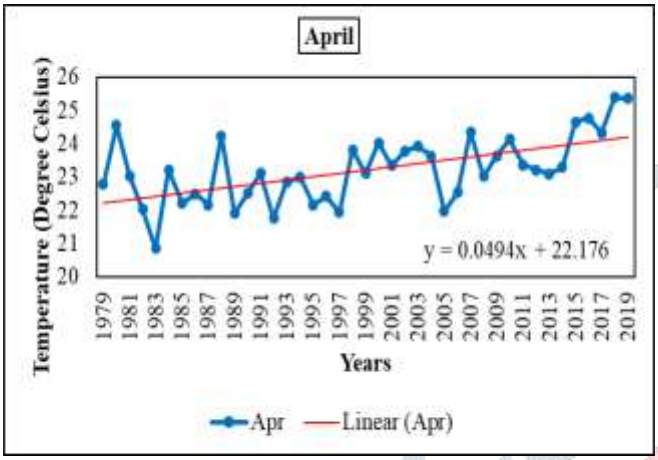
Time Series	Slope of Regression Line
Jan	0.019
Feb	0.0527
Mar	0.0426
Apr	0.0494
May	0.0356
June	0.0072
July	0.0058
August	0.0141
Sep	0.0119
Oct	0.0279
Nov	0.0424
Dec	0.0266
Annual	0.029
Pre-Monsoon	0.0425
Monsoon	0.0097
Post-Monsoon	0.0351
Winter	0.0328

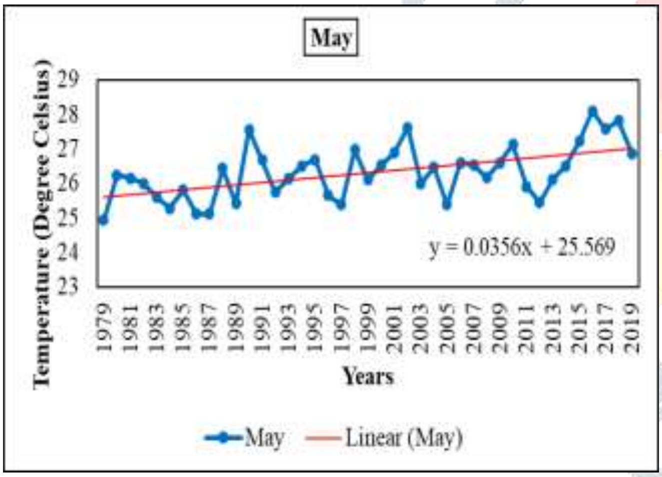
Note: Significance level is 5%

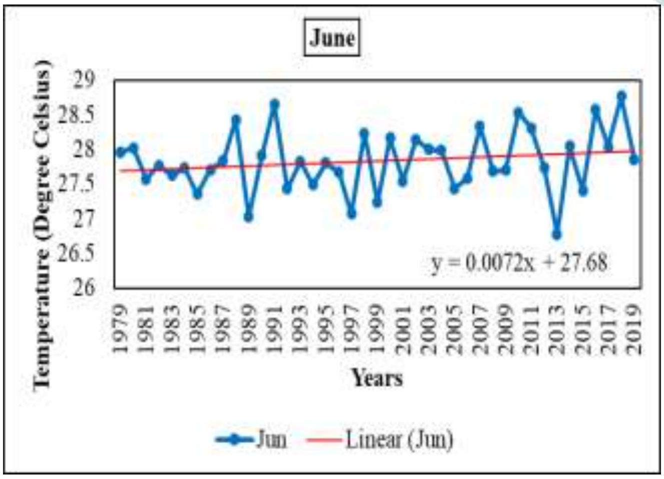


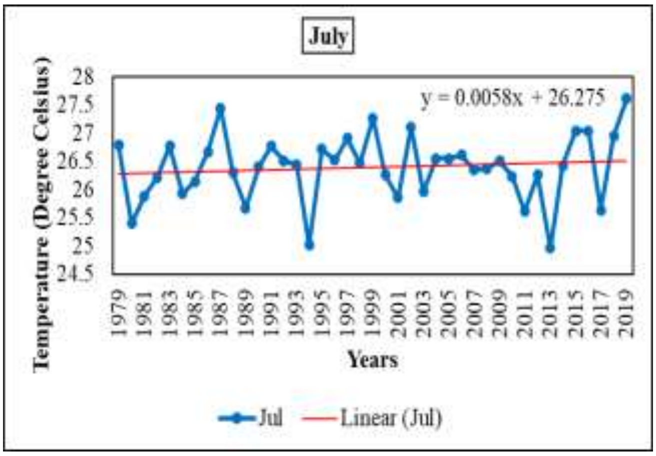


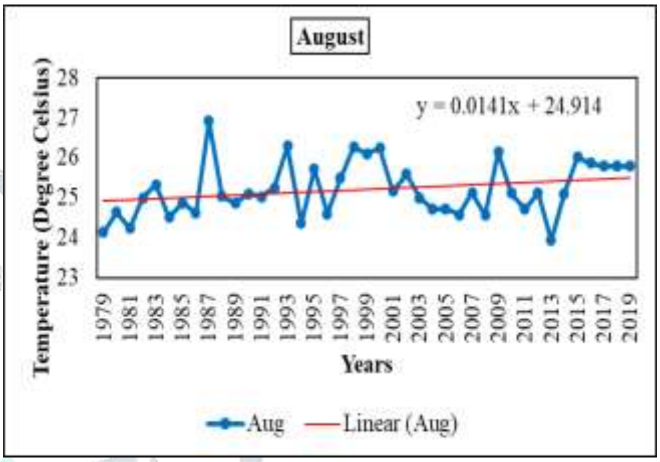

March
Temperature (Degree Celsius)
y = 0.0426x + 18.687
Years
Mar
Linear (Mar)

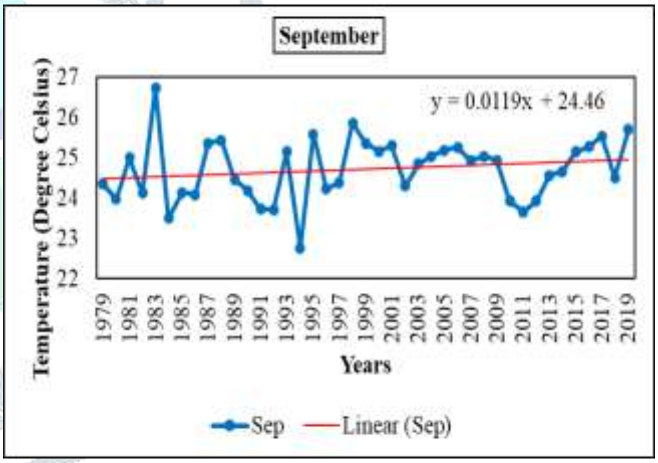

April
Temperature (Degree Celsius)
y = 0.0494x + 22.176
Years
Apr
Linear (Apr)

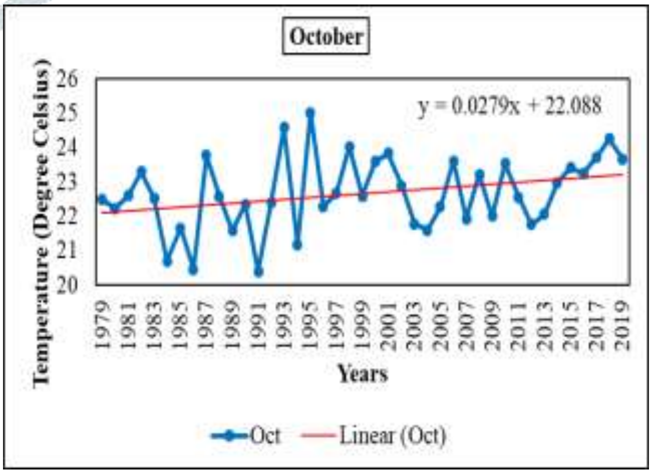

May
Temperature (Degree Celsius)
y = 0.0356x + 25.569
Years
May
Linear (May)


June
Temperature (Degree Celsius)
y = 0.0072x + 27.68
Years
Jun
Linear (Jun)


July
Temperature (Degree Celsius)
y = 0.0058x + 26.275
Years
Jul
Linear (Jul)


August
Temperature (Degree Celsius)
y = 0.0141x + 24.914
Years
Aug
Linear (Aug)


September
Temperature (Degree Celsius)
y = 0.0119x + 24.46
Years
Sep
Linear (Sep)


October
Temperature (Degree Celsius)
y = 0.0279x + 22.088
Years
Oct
Linear (Oct)

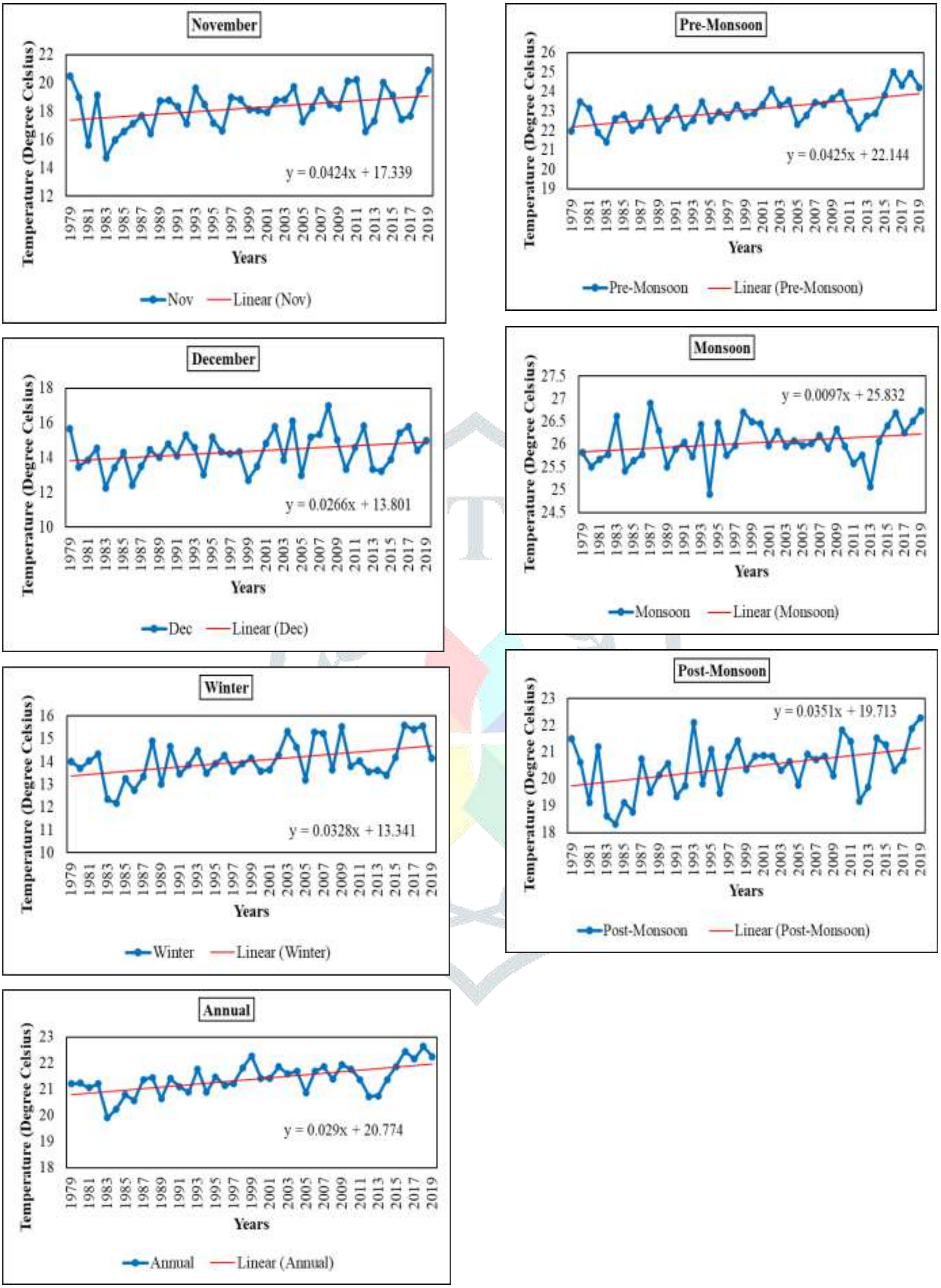


Figure 5 Linear Regression Trends of mean monthly, seasonal and annual minimum temperature

Table 1 shows the preliminary data analysis that was carried out to find the statistical parameters (mean, standard deviation and coefficient of variation) of total monthly, annual and seasonal rainfall for the period 1979-2019. The trends of total rainfall for 1979-2019 were obtained using linear regression best fit lines.

The results shown in Table 2 indicated a falling trend in the month of January, May, October and November and an increasing trend in February to April and June to September months. A falling trend is observed in Post-Monsoon Season. Annual Precipitation in Bhogavo River Watershed showed an increasing trend.

Table 3 shows the preliminary data analysis that was carried out to find the statistical parameters (mean, standard deviation and coefficient of variation) of average monthly, annual and seasonal maximum temperature for the period 1979-2019. The mean annual maximum temperature is 35ºC with 0.8 standard deviation. The trends of average maximum temperature for 1979-2019 were obtained using linear regression best fit lines.

The results shown in Table 4 indicated a falling trend in June, July, September and October months. An increasing trend in average maximum temperature is observed in January to May, August, November and December months. A falling trend is observed in average maximum temperature in Monsoon Season. Annual Average Maximum Temperature in Bhogavo River Watershed showed an increasing trend with significant at 0.05 level of significance.

The preliminary data analysis that was carried out to find the statistical parameters (mean, standard deviation and coefficient of variation) of average monthly, annual and seasonal minimum temperature for the period 1979-2019 is represented in Table 5. The mean annual minimum temperature is 21.38ºC with 0.582 standard deviation.

The results shown in Table 6 indicated an increasing trend in average minimum temperature for all the months and all the seasons. Annual Average Minimum Temperature in Bhogavo River Watershed showed an increasing trend with significant at more than 0.05 level of significance.

V. CONCLUSION:

The meteorological data is taken from 1979-2019 for rainfall and temperature trend analysis of the study area. The linear regression trend analysis of rainfall revealed the slope of linear regression from January to December months as -0.0148, 0.0357, 0.0561, 0.0379, -0.0834, 1.3595, 3.6976, 0.9488, 3.0635, -0.2745, -0.667 and 0.0383 respectively. The months from Feb to April, June to September and December have positive slope value that indicates a rising trend in rainfall while the negative slope value shows a falling trend in rainfall for January, May, October and November months. The annual rainfall data series shows rising trend with significant increase of rainfall. The seasonal rainfall trend analysis shows rising trend in monsoon season with significant increase of rainfall. The annual average maximum temperature trend analysis shows rising trend with nonsignificant increase in temperature. The trend analysis of the hydroclimatic factors can be helpful to the water resources managers to mitigate the maximum event and minimize the damage to the low-lying areas.

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