ISSN: 2456-1452
Maths 2025; 10(1): 22-27

https://www.mathsjournal.com
Received: 08-11-2024
Accepted: 06-12-2024

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Trend analysis of weather parameters in Bastar District of Chhattisgarh

Bhojraj Kaushal and Devendra Pratap Singh

Abstract
An assessment of trend analysis on monthly and annual time series data of Bastar district of Chhattisgarh. For the study 40 years secondary data pertaining to weather parameters was collected from metrological observatory SGCARS Jagdalpur. The trend analysis has been analyzed using non-parametric test including linear regression, Mann-Kendall test and Sen's slope estimator test.
A trend analysis of rainfall in January indicates a noticeable increasing tendency. March, April and decreasing trends show in August and September month. For maximum temperature there is most of the month showed increasing trends and only October month showed significantly decreasing trends. For minimum temperature we analyzed there is only December month showed decreasing trends. For relative humidity (morning) there is mostly months showed positive trends except October month that showed significantly decreasing trend. For relative humidity (evening) we analyzed some of the month showed increasing trend and some months showed decreasing trends, only April and September months showed significantly decreasing trends.

Keywords: Bastar District, Chhattisgarh, weather parameters, significantly decreasing trends

1. Introduction
The climate is one of the most crucial elements of the earth system. Temperature, precipitation, air pressure, and humidity are just a few of the elements that make up the weather. An essential job in research on the detection of climate change is the examination of long-term changes in climatic variables. Long-term rainfall patterns may vary as a result of changes in the global climate, which could affect water supply and increase the risk of droughts and floods. Future agriculture production will need to be significantly boosted in order to feed expanding populations, which the United Nations projects will number an additional 1.5 to 2.0 billion people by 2025. In India, where crop output is heavily influenced by the amount and distribution of monsoon rains, dryland and rainfed agriculture is highly dependent on rainfall.
The most significant variables affecting the climate are the temperature and rainfall because they influence the climatic conditions in a certain area, which have an impact on agricultural productivity. Agriculture, energy, and food security are all vitally dependent on each other in any region. on timely access to sufficient water supplies and an appropriate environment. The pattern and amount of rainfall are two of the most important factors that influence agricultural production because agriculture is the mainstay of India's economy and way of life.
The statistical analysis of time series data can be used to quantify changes in trends for various climate variables. One of the intriguing research areas in climatology is the statistical detecting trends in climate and precipitation time series**.** It is important to note that large scale spatial and temporal variation may exist in climatically distinct places and that the quantum change of several climatic variables, including temperature and precipitation, is not uniform globally (Yue and Hashino 2003) [30]. In addition to the effects of temperature and rainfall, wind speed and relative humidity have an impact on livestock and agriculture (Sivakumar *et al.* 2012) [22].
The statistical approach's parametric or non-parametric methods are used to determine whether the data in a given set follow a distribution or exhibit a trend at a specified level of significance.

Sen's slope estimator test and the Mann-Kendall test are two common non-parametric tests used to find trends in time series of climatic and hydrological data. In the current study, the climatic parameters of the Bastar District of Chhattisgarh State of India, which is transforming into the industrial hub in the region due to scale industries and human intervention because, since 1980, have been analysed using statistical methods of trend analysis. These climatic parameters include maximum temperature, minimum temperature, rainfall, relative humidity (evening, morning)

The statistical significance of the Mann Kendall and Sen's slope gave us insights into the tendencies of weather variables. Planning sustainable agriculture methods that support environmental preservation will be made easier by it. Keeping this in a view, the Bastar district's "Statistical Assessment of Weather Parameters in Bastar District of Chhattisgarh" was examined using both parametric (linear regression) and non-parametric tests in the current investigation.

2. Materials and Methods

2.1 Description of the study area, study period, source of data and data description

This study was carried out in the Bastar district of Chhattisgarh for several meteorological characteristics. Bastar district is located in the South Zone of Chhattisgarh. Its latitude is between 18.9215 and 19.2291 N, while its longitude is between 81.696 E and 81.860 SE. Required time series data from 1980 to 2021, a 41-year period, were used. The data was gathered from Jagdalpur SG College of Agriculture and Research Station. In the analysis, the different statistical test were applied on the rainfall, maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening) on monthly, and annual for the determination of change point analysis for identification of climate change impact.

2.2 Analytical tools and techniques applied

Sen's slope estimator test, the Mann-Kendall test, and the linear regression test have been used to evaluate the trends in time series data.

2.2.1 Linear Regression Test

In the linear regression test, a straight line is fitted to the data, and the slope of the line can be substantially different from zero or not. For a series of observation x_i, $i = 1,2,3,\ldots\ldots n$. The data is fitted with a straight line in the form of y=a + bx, and the test statistics (t) can be obtained as:

$$a = \bar{y}\text{-}b\bar{x}$$

$$b = \frac{\sum(x_i-\bar{x})(y_1-\bar{y})}{\sum(x_i-\bar{x})^2}$$

$$\sum\varepsilon^2 = \sum(y_i-\bar{y})^2\text{-}\, b\sum(x_i-\bar{x})^2$$

$$S_b = \frac{\varepsilon_i^2}{(n-2)\Sigma(x-\bar{x})^2}$$

$$t = \frac{b}{S_b}$$

here a and b are the fitted line's intercept and slope, respectively, $\sum\varepsilon^2$ is the sum of square of residuals or errors and $S_b$is the standard error of b. Students' t-test is used to confirm the test's hypothesis.

2.2.2 Mann-Kendall Test

The Mann Kendall test is a non-parametric test that does not require the data to be normally distributed. It has limited sensitivity to sudden breakdowns owing to inhomogeneous time series (Tabari *et al.* 2011) [25]. This test has been extensively suggested by the World Meteorological Organization for public use. Every value in the series is compared to every other value in this test, always in sequential order.

The Mann-Kendall statistics can be written as:

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

Where, n is the total length of data, x_i and x_j are two genetic sequential data values, and function $\text{sign}(x_i - x_j)$ assumes the following values

$$\text{Sign}(x_i - x_j) = \begin{bmatrix} 1, \text{if } (x_i - x_j) \\ 0, \text{if } (x_i - x_j) \\ -1, \text{if } (x_i - x_j) \end{bmatrix}$$

In this test, the statistics S is roughly regularly distributed, with the mean E(S) and the variance Var (S) is calculated as follows:

$$E(S) = 0$$

$$\text{Var}(S) = \frac{1}{n}\left[\, n(n-1)(2n+5) - \sum_t t(t+1)(2t+5)\right]$$

Here, n is length of time series, and t is the extent of any given tie and $\sum t$ denotes the summation over all tie number of values.

The standardized statistics Z for this test can be obtained using by the following equation:

$$Z = \begin{bmatrix} \frac{s+1}{\sqrt{\text{Var}(S)}}, \text{if } S > 0 \\ 0, \text{if } S = 0 \\ -1, \text{if } S < 0 \end{bmatrix}$$

In this test, the null hypothesis H_o is confirmed if a data set of n independent randomly distributed variables has no trend with equally likely ordering. Any positive value of test statistics 'Z' indicates a rising, while a negative value may conclude a declining trend in series.

The computed absolute value of Z is compared with the standard normal cumulative values of Z(1-p/2*)* at p*%* significance level obtained from standard table to accept or reject null hypothesis and ascertain the significance of trend.

2.2.3 Sen's Slope Estimator Test

The magnitude of trend is predicted by the Sen's estimator. Here, the slope (Q_i) of all data pairs is computed as (Sen, 1968) [19].

$$Q_i = \frac{x_j - x_k}{j-k}$$

For i= 1, 2, 3,... N

Where x_j and x_k are considered as data values at time j andk (j>k) correspondingly. The median of these N values of $Q_i$is represented as Sen's estimator of slope which isgiven as:

$$Q_i = \begin{cases} Q_{\frac{N+1}{2}}, \text{ if N is odd} \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right), \text{ if N is Even} \end{cases}$$

Sen's estimator is computed as Q_{med}= Q (N+1)/2 if N appears odd, and it is considered as Q_{med}= $[Q_{N/2}+Q_{(N+2)/2}]/2$ if N appears even. At the end, Q_{med} is computed as 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_i indicates an upward or increasing trend and a negative value of gives a downward or decreasing trend in the time series.

3. Result and Discussion

3.1.1 Trend analysis of rainfall

The variation in rainfall data on monthly and annual basis was calculated individually for each month using Mann-Kendall method and magnitude of slope was also calculated with Sen's slope estimators as presented in Table 1. It was analysed that there is significant changes in monthly rainfall data, some of the month showed increasing (upward) trend and some of the months showed decreasing trends. Three months (January, March, and April) give significant positive trend while August and September represent significant falling trend.

Table 1: Monthly and annual trend analysis of rainfall for Bastar district

Month	Mann-Kendall	Sens Slope
January	1.853*	2.121
February	0.080	1.332
March	2.032*	3.823*
April	2.092*	3.011
May	0.098	0.392
June	0.170	1.817
July	0.070	1.045
August	-2.108*	-4.036*
September	-1.737*	-0.123
October	0.107	0.000
November	0.123	0.001
December	-0.046	0.001
Annual	-0.229	-2.515

3.1.2 Trend analysis of maximum temperature

The variation in maximum temperature data on monthly and annual basis was calculated individually for each month using Mann-Kendall method and magnitude of slope was also calculated with Sen's slope estimators as presented in Table 2. It was analyzed that there is significant changes in monthly maximum temperature, most of the month showed increasing (upward) trend and only October months showed significantly decreasing trends.

Table 2: Monthly and annual trend analysis maximum temperature for Bastar district

S. No.	Month	Mann-Kendall	Sens Slope
1	January	0.134	0.513
2	February	0.101	0.602
3	March	0.177	0.329
4	April	0.175	0.388
5	May	0.157	0.229
6	June	0.135	0.009
7	July	0.146	0.000
8	August	0.073	0.019
9	September	0.104	0.389
10	October	-2.68**	-1.238
11	November	0.124	0.743
12	December	-0.086	-0.363
13	Annual	0.169	0.049

3.1.3 Trend analysis of minimum temperature

The variation in minimum temperature data on monthly and annual basis was calculated individually for each month using Mann-Kendall method and magnitude of slope was also calculated with Sen's slope estimators as presented in Table 3. It was analyzed that there is significant changes in monthly minimum temperature, most of the month showed increasing (upward) trend and only December months showed significantly decreasing trends.

Table 3: Monthly and annual trend analysis of minimum temperature for Bastar district

S. No.	Month	Mann-Kendall	Sens Slope
1	January	0.234	0.622
2	February	0.273	0.000
3	March	0.196	0.123
4	April	0.074	0.589
5	May	0.002	0.097
6	June	0.037	0.000
7	July	0.887	0.000
8	August	0.073	0.024
9	September	0.009	0.416
10	October	0.070	0.811
11	November	0.035	0.071
12	December	-2.099*	-0.709
13	Annual	0.134	0.061

3.1.4 Trend analysis of relative humidity in morning

The variation in relative humidity in the morning data on monthly and annual basis was calculated individually for each month using Mann-Kendall method and magnitude of slope was also calculated with Sen's slope estimators as presented in Table 4. It was analyzed that there is significant changes in monthly relative humidity in the morning, some of the month showed increasing (upward) trend and some months showed decreasing trends. For the relative humidity in the morning only October months showed significantly decreasing trends.

Table 4: Monthly and Annual trend analysis relative humidity (morning) for Bastar district

S. No.	Month	Mann-Kendall	Sen's Slope
1	January	0.454	0.420
2	February	-0.531	-0.139
3	March	0.597	0.489
4	April	-0.559	-0.800
5	May	0.408	0.260
6	June	0.294	0.000
7	July	0.389	0.000
8	August	0.396	0.181
9	September	-0.424	-0.653
10	October	-2.386*	-1.534
11	November	0.424	0.702
12	December	0.41	0.438
13	Annual	-0.632	-0.199

3.1.5 Trend analysis of relative humidity in evening

The variation in relative humidity in the evening data on monthly and annual basis was calculated individually for each month using Mann-Kendall method and magnitude of slope was also calculated with Sen's slope estimators as presented in Table 5. It was analyzed that there is significant changes in monthly relative humidity in the evening, some of the month showed increasing (upward) trend and some months showed decreasing trends. For the relative humidity in the morning only April and September months showed significantly decreasing trends.

Table 5: Monthly and Annual trend analysis Relative Humidity (evening) for Bastar district

S. No.	Month	Mann-Kendall	Sens Slope
1	January	0.215	0.162
2	February	-0.776	-0.021
3	March	-0.084	-0.103
4	April	-2.073*	-0.593
5	May	0.044	-0.031
6	June	0.106	0.000
7	July	0.277	0.000
8	August	0.366	0.020
9	September	-2.315*	-0.496
10	October	0.295	1.062
11	November	0.296	0.553
12	December	0.186	-0.331
13	Annual	-0.189	-0.175

3.2 Trend analysis of weather parameters for Bastar district

The result of trend analysis for weather parameters such as rainfall, maximum and minimum temperature, and relative humidity (morning and evening) were presented in Table 6 to Table 10, which shows the value of regression coefficient for all the weather parameters along with its test of significance and R^2 value.

3.2.1 Trend analysis of rainfall

The parameters and R^2 value of monthly and annual weather parameters for Bastar district are presented in Table 6 with test of significance. A linear regression analysis of 40 years monthly and annual rainfall data, in which significant regression parameters were found only in two months *i.e.* January and September. The highest R^2 was obtained for the month of September (0.43) followed by January (0.42) and annual (0.39). The regression coefficient was significant at 5% for January, September and annual. No significant trend found in other month.

Table 6: Results of linear trend analysis of rainfall of Bastar district

S. No.	Month	Equation	R^2
1	January	Y= 6.65- 0.074 *X	0.42
2	February	Y=9.42 + 0.74 X	0.24
3	March	Y=14.82 + 0.211* X	0.38
4	April	Y=37.01 +0.44 X	0.12
5	May	Y=94.19 - 0.84 X	0.13
6	June	Y=222.80 +0.56 X	0.14
7	July	Y=322.70 +1.14 X	0.11
8	August	Y=330.03 -1.99 X	0.14
9	September	Y=157.10 - 3.06 *X	0.43
10	October	Y=65.21 +1.78 X	0.13
11	November	Y=17.63 +0.12 X	0.11
12	December	Y=4.58 -0.04 X	0.11
13	Annual	Y=1285.18 -7.93* X	0.39

3.2.2 Trend analysis of maximum temperature

The parameters and R^2 value of monthly and annual maximum temperature parameters for Bastar district are presented in Table 7 with test of significance. A linear regression analysis of 40 years monthly and annual maximum temperature data, in which significant regression parameters were found only in one month's *i.e.* October. The highest R^2 was obtained for the month of October (0.47) followed by May (0.31) and annual (0.27). The regression coefficient was significant at 5% for October. No significant trend found in other month.

Table 7: Results of trend analysis of maximum temperature

S. No.	Month	Equation	R^2
1	January	Y=28.34 +0.01 X	0.21
2	Feb	Y=31.67 + 0.02 X	0.31
3	March	Y=35.56 +0.06 X	0.11
4	April	Y=37.42 +0.03 X	0.14
5	May	Y=37.99 +0.02 X	0.31
6	June	Y=33.21+0.03 X	0.04
7	July	Y=28.95+0.01 X	0.24
8	August	Y=27.78+0.01 X	0.16
9	Sep	Y=29.76+0.01 X	0.19
10	October	Y=29.78-0.53* X	0.47
11	Nov	Y=28.23+0.05 X	0.18
12	Dec	Y=26.95 - 0.09 X	0.29
13	Annual	Y=31.31+0.01 X	0.27

3.2.3 Trend analysis of minimum temperature

The parameters and R2 value of monthly and annual minimum temperature parameters for Bastar district are presented in Table 8 with test of significance. A linear regression analysis of 40 years monthly and annual minimum temperature data, in which significant regression parameters were found only in three month's i.e. January, February and December.

The highest R2 was obtained for the month of December (0.52) followed by January (0.46) and February (0.44) and annual (0.19). The regression coefficient was significant at 5% for January, February and December month. No significant trend found in other month.

Table 8: Results of trend analysis of minimum temperature

S. No.	Month	Equation	R^2
1	January	Y=11.57+ 0.05* X	0.46
2	Feb	Y=14.25+ 0.05* X	0.44
3	March	Y=18.56+ 0.03 X	0.16
4	April	Y=21.78+ 0.01 X	0.19
5	May	Y=23.81+ 0.05 X	0.11
6	June	Y=23.48+ 0.05 X	0.12
7	July	Y=22.56+ 0.05 X	0.15
8	August	Y=22.37+ 0.05 X	0.13
9	Sep	Y=21.96+ 0.01 X	0.25
10	Oct	Y=19.15+ 0.01 X	0.13
11	Nov	Y=14.12+ 0.06 X	0.11
12	Dec	Y=10.64 -0.83 *X	0.52
13	Annual	Y=18.61+ 0.11 X	0.19

3.2.4 Trend analysis of relative humidity in the morning

The parameters and R^2 value of monthly and annual relative humidity in the morning parameters for Bastar district are presented in Table 9 with test of significance.

A linear regression analysis of 40 years monthly and annual relative humidity in morning data, in which significant regression parameters were found only in one month's *i.e.* October. The highest R^2 was obtained for the month of October (0.48) followed by November (0.34). The regression coefficient was significant at 5% for October month. No significant trend found in other month.

Table 9: Results of trend analysis of relative humidity (in morning)

S. No.	Month	Equation	R^2
1	January	Y=77.73+0.46 X	0.15
2	Feb	Y=65.87- 0.75 X	0.17
3	March	Y=55.47+0.83 X	0.25
4	April	Y=50.33-0.79 X	0.28
5	May	Y=55.07+0.49 X	0.27
6	June	Y=74.01+0.23X	0.14
7	July	Y=86.93+0.09X	0.10
8	August	Y=88.84+0.02 X	0.07
9	Sep	Y=85.98+0.16X	0.18
10	Oct	Y=81.13 - 0.33*X	0.48
11	Nov	Y=78.01+0.42 X	0.34
12	Dec	Y=78.27+0.40X	0.23
13	Annual	Y=73.14- 0.41 X	0.21

3.2.5 Trend analysis of relative humidity in the evening

The parameters and R^2 value of monthly and annual relative humidity in the evening parameters for Bastar district are presented in Table 10 with test of significance. A linear regression analysis of 40 years monthly and annual relative humidity in evening data, in which significant regression parameters were found only in one month's *i.e.* September. The highest R^2 was obtained for the month of September (0.41) followed by annual (0.29). The regression coefficient was significant at 5% for September month. No significant trend found in other month.

Table 10: Results of trend analysis of relative humidity (in evening)

Month	Equation	R^2
January	Y=45.46+0.20X	0.15
Feb	Y=35.39-0.04 X	0.12
March	Y=26.91-0.11 X	0.11
April	Y=28.17-0.10 X	0.11
May	Y=37.49+0.07 X	0.17
June	Y=62.93+0.14 X	0.12
July	Y=79.77+0.17X	0.12
August	Y=82.74+0.24X	0.23
Sep	Y=77.68- 0.28*X	0.341
Oct	Y=68.94+0.36X	0.15
Nov	Y=59.56+0.37X	0.14
Dec	Y=50.57+0.24 X	0.25
Annual	Y=54.63-0.16X	0.29

4. Summary and Conclusion

The evaluation of temporal inconsistency in different climatic variables due to possible climate change is important for water resources planning and management at the district level. In this study, various non-parametric statistical tests have been used to detect change points and then analyze trends. The change point has been detected using Von Neumann ratio test, and Buishand's range test on monthly, and annual long-term series of rainfall, minimum temperature, maximum temperature, relative humidity of Bastar district. The change point analysis results of rainfall, minimum temperature, maximum temperature, and relative humidity confirmed a significant change point in few months. The significant change points in these weather parameters observed during 1995 to 2005 may attribute the influence of fast growing industrial and commercial activities in the region.

The major findings of study are briefed below:

4.1 Trend analysis

- For rainfall, it was obtained that there is significant changes in the month of January, March, and April give significant positive trend while August and September represent significant falling trend.
- For maximum temperature, it was obtained that there is significant the month of October showed significantly decreasing trends.
- For minimum temperature, it was obtained that there is significant changes in monthly minimum temperature, most of the month showed increasing (upward) trend and only December months showed significantly decreasing trends.
- For relative humidity in the morning, it was obtained that there is significant changes in the month of October showed significantly decreasing trends.

- For relative humidity in evening, it was obtained that there is significant decreasing changes in the month of April and September.

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