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Research Paper

STATISTICAL TREND ANALYSIS OF MONTHLY RAINFALL FOR RAIPUR DISTRICT, CHHATTISGARH

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ABSTRACT

The climatic variability for an area is referred to the long term change in rainfall, temperature, humidity, evaporation, wind speed and other meteorological parameters. Quantification of climate change is necessary in order to detect the change that has already occurred and this will be further helpful to make prediction or forecast for future. This will also lead to a better preparedness for natural disasters. This article presents a trend analysis of monthly rainfall data for Raipur district, Chhattisgarh for the period of 102 years that is from 1901 to 2002. The results reveal a significant decrease for the months of Southwest monsoon i.e. June, July, August and September, thereby inferring for a consequent decrease in annual rainfall.

KEY WORDS: trend, rainfall, Mann-Kendall, Sen Slope.

1. INTRODUCTION

Climate change is a long term process. It has raised as most alarming issue for the whole world. Therefore, quantification of climatic changes has become necessary. Trend analysis is a method to determine the spatial variation and temporal changes for different parameters associated to climate. For a nation like India, this is a crucial issue as our country is having an agro-based economy, which largely depends on rainfall due to monsoon. Thus any change in that phase of a year may ruin the agricultural conditions of the country and thereby the economy. Moreover, it will also cause a threat to the food security of the nation. The climate change is too high for India compared to the global climatic variability. It has further lead to the essence of determining whether the trend is increasing or decreasing. The changes in the most important climatological parameter i.e. rainfall, may be responsible for the natural calamities like drought and flood conditions.

2. STUDY AREA AND DATA USED

The study area is the Raipur district of Chhattisgarh state, India. It is a large district of Chhattisgarh having area of 13083 square kilometres.). Its situated between 22°33' N to 21°14' N Latitude and 82°6' E to 81°38'E Longitude. The District is surrounded by District Bilaspur in North, District Bastar and part of Orissa state in South, District Raigarh and part of Orissa state in East and district Durg in West. The district occupies the south eastern part of the upper Mahanadi valley and the bordering hills in the south and the east. From the hydro-climatological aspects, the annual average rainfall over Raipur is about 1250-1300 mm. More than 90% of the total annual rainfall occurs in the month of June-October.

The monthly precipitation data for Raipur district for the period of 102 years i.e. 1901-2002 is collected from Indian Meteorological Department (IMD) from the Raipur station. This data is then analysed for determining if the trend is upward or downward.

3. METHODOLOGY

The methodology applied in this article is Trend analysis using the statistical non-parametric tests i.e. Mann-Kendall test and Sen's Slope Estimator test on the monthly rainfall data for Raipur for 102 years. Generally, non-parametric tests are preferred over parametric tests because; the problems aroused due to data skew can be evaded by non-parametric ones. Mann-Kendall test is most commonly used test for trend analysis of any hydro-climatic series for checking spatial variation and temporal deviation. This formula was derived by both Mann and Kendall i.e. Mann (1945) formulated it as non-parametric test to detect trend whereas Kendall (1975) gave the test statistic distribution to test non-linear trend and turning point. Sen's Slope Estimator test is also used to determine the magnitude of trend. This was formulated by Sen (1968), in which slope of data pairs are to be used to detect the trend.

3.1. Mann-Kendall Test

The Mann-Kendall statistic S is given as

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

The application of trend test is done to a time series x_i that is ranked from i = 1, 2,……, n-1 and x_j, which is ranked from j = i+1,2, ……., n. Each of the data point x_i is taken as a reference point which is compared with the rest of the data points x_j so that,

$$Sgn(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ 1, < (x_j - x_i) \end{cases} \qquad (2)$$

For n > 8, S follows approximately Normal distribution with mean i.e.

$$E(S) = 0, \qquad (3)$$

The variance statistic is given by,

$$Var(S) = \frac{n(n-1)(2n-5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18}, \qquad (4)$$

where, t_i is considered as the number of ties up to sample i.

The test statistics Z_{mk} (Mann-Kendall Co-efficient) is computed as,

$$Z_{mk} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{cases} \qquad (5)$$

Z_{mk} here follows a standard normal distribution. A positive and negative value of Z_{mk} indicates an upward trend and downward trend respectively. A significance level α is also utilised for testing either an upward or downward monotone trend (a two-tailed test). If Z_{mk} appears greater than $Z_{\alpha/2}$ where α depicts the significance level, then the trend is considered as significant. Generally, Z_{mk} values are 1.645, 1.960 and 2.576 for significance level of 10%, 5% and 1% respectively. But for greater length of data, Z_{mk} /sqrt(n) is also used as Mann-Kendall statistic to determine the trend, where n is the number of data values.

3.2. Sen's Slope Estimator Test

This is better than the linear regression test to analyse trend. The slope is to be obtained to check the trend. Therefore, it is the most powerful method for a linear trend.

The slope T_i of all data pairs can be computed by,

$$T_i = \frac{x_j - x_k}{j - k}, \quad (6)$$

where, x_j and x_k are considered as data values at time j and k (j > k) correspondingly.

The median of N values of T_i is represented as Sen's estimator of slope is given by,

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{cases} \quad (7)$$

After calculating Q_i, for testing the significance, Q_{median} 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. Like Mann-Kendall test, positive and negative value of Q_i represents an upward and downward trend respectively.

4. RESULT AND DISCUSSION

The Mann-Kendall Statistic for different months of a year is represented in the figure 1 above. The Z_{mk} values are 1.0351,-1.4775, 0.1099, 0.0289, 0.8154, -0.9484, -1.2317, -1.1103, -2.1165, 0.5204, 0.0405and -1.2028 for January to December respectively. The months of February, June, July, August, September and December clearly represents a significant decreasing trend in rainfall whereas the months of March, April and May shows no trend for monthly rainfall for 1901-2002. The months of January, May and October shows an increasing trend of rainfall, but among them, trend in January only can be regarded as remarkably increasing.

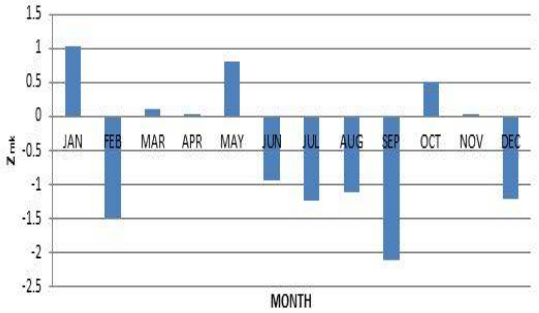

Figure 1: Mann-Kendall Statistic for different months for 1901-2002

Table 1: Sen Slope values for different months of a year

Month	Mean	Variance	Standard Deviation	Median	Sen Slope	Significance (α)
January	8.92	132.44	11.508	4.58	0.019	0.2202
February	10.21	128.97	11.357	5.47	-0.024	-0.2375
March	16.29	235.76	15.354	13.67	0.017	0.1086
April	21.43	322.92	17.970	16.98	0.008	0.0398
May	24.55	265.62	16.298	21.32	0.051	0.2125
June	195.38	5530.43	74.367	191.73	-0.138	-0.0719
July	357.21	9509.15	97.515	347.43	-0.351	-0.1004
August	353.93	7447.54	86.299	346.65	-0.157	-0.0453
September	208.85	5004.48	70.742	202.14	-0.540	-0.2637
October	57.18	1659.44	40.736	52.63	-0.093	0.1652
November	7.11	75.23	8.673	4.73	0.000	0.0000
December	3.55	49.41	7.029	0.66	0.000	0.0000

The mean, variance, standard deviation, median, Sen's slope and corresponding significance values are presented in table 1. Very similar to the results obtained from Mann-Kendall test, Sen Slope Estimator test values are also negative for the months of February, June, July, August and September, thereby representing a downward trend. The months of January, March, April and May represents an upward trend, whereas the months November and December shows no trend. The months of June, July and August shows a high level significance in the downward trend. Furthermore, over 85% rainfall occurs in June-September, in which all the months are showing a remarkable decreasing trend. This implies for a decrease in the annual rainfall for the study area. Such deviation in climate is never desirable. This may lead to drought like conditions in future.

5. CONCLUSION

Quantification of climate change is very necessary to cope up with ever changing conditions. The trend analysis is made for Raipur district of Chhattisgarh for monthly rainfall data for the period of 1901-2002 is performed using non-parametric Mann-Kendall and Sen Slope Estimator test. The results reveal a downward trend for most of the months of a year for the period under investigation. Since the months of Southwest monsoon i.e. June-September shows a significant decreasing trend, it can be inferred for the annual rainfall over Raipur to be decreasing.

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