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Trend Analysis of Rainfall Intensity in Tiruchirappalli District of Tamil Nadu

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Rainfall is the dynamic weather parameter having a significant role in the agriculture livelihood. Growth in agriculture and other related sectors depends mainly on the adequate amount and timely availability of rainfall. Variability in precipitation exerts a huge impact on human beings and agriculture. This variation gives the necessity to study the regular pattern of rainfall. The present study aims at analysing the trends in rainfall intensity across various blocks of Tiruchirappalli district using daily rainfall data for the period 1990 to 2017. Non-parametric tests such as Mann-Kendall test and Sen's slope estimator were employed for this purpose. Results revealed that two blocks showed statistically significant increasing trends (95% confidence level) and one block showed significant decreasing trend (95% confidence level) and the remaining eleven blocks showed no significant trends.

Key words: Rainfall, Trend, Mann-Kendall, Sen's slope.

Rainfall is one of the important weather parameters that having greater effect on the livelihood of majority of individuals in all over the world. Growth in agriculture and other related sectors depends on adequate amount and timely availability of rainfall. Of all the climatic factors, rainfall is of greatest concern to the farmers in rainfed agriculture. The variation of annual and monsoonal rainfall in space and time are well known and this variability of monsoonal rainfall has considerable impact on agricultural production. The term variability refers to the deviation from the long-term average. In the context of rainfall, variability is the extent to which rainfall amounts vary across an area and over time.

Monitoring of real time rainfall distributions on daily basis is required to estimate the progress and status of monsoon and to commence necessary action to control flood/drought situation. This uplifts a question that whether the variability is purely random or is there any identifiable pattern in these variations. Information on temporal and spatial variations is very essential for understanding the hydrological balance on a regional/global scale. The distribution of rainfall is also significant for water management in agriculture and monitoring of drought. (Kwarteng et al., 2009) analysed 27 year rainfall data in the Sultanate of Oman using Mann-Kendall test and reported that the yearly rainfall over Oman was quite variable and irregular. (Kumar et al., 2010) observed long term rainfall trends in India using non-parametric Mann-Kendall test and concluded that no significant trend was detected in the whole of India in annual, seasonal or monthly rainfall. (Babar and Ramesh, 2014) analysed the trends in south west monsoon rainfall over Nethravathi basin using Mann-Kendall (MK) test and Sen's slope estimator. They observed a decreasing trend in some of the months and an increasing trend in few other months. The study also revealed an overall change in precipitation trend during South-west monsoon. (Rai et al., 2014) conducted a study on climate change, variability and rainfall probability for crop planning in a few districts of central India. They obtained initial and conditional rainfall probability of getting 10 mm and 20 mm rainfall per week and concluded that 25th Standard Meteorological Week (SMW) in Damoh district is suitable for seed bed preparation and 27th SMW (2-7 July) in Sagar district is most suitable for sowing operation. With this background the current study is concerned with trend analysis of rainfall in Tiruchirappalli district of Tamil Nadu.

Material and Methods

Study area

Tiruchirappalli district is situated in central south-eastern India, almost at the geographic centre of the Tamil Nadu surrounded by a Perambalur district in the north, Pudukkotai district in the south, Karur and Dindigul districts in the west and Thanjavur district in the east. It lies between the coordinates 10°47'40.56" N latitude and 78°41'6"E longitude. The topology of Tiruchirappalli is almost flat, with an altitude of 78 metres above mean sea level. The district has an area of about 4,404 sq.km. It belongs to Cauvery delta zone, which receives an average annual rainfall of about 842.6 mm.

Data collection

Daily rainfall data for the period from 1990 to 2017 was obtained from the Disaster Management and Mitigation Department, Revenue Administration,

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Government of Tamil Nadu. This consisted of secondary data on daily rainfall of 14 blocks in Tiruchirappalli district.

Tools of analysis

Mann-Kendall trend test

The non-parametric Mann-Kendall test (Mann 1945, Kendall 1975 and Gilbert 1987) is commonly used to identify monotonic trends in climate data or hydrological data. The null and alternative hypothesis are given by

H_0: There is no trend in the series.

H_1: There is a negative or positive trend.

Temporal variation of rainfall across 14 Blocks of the district would be analysed by using Mann-Kendall test. The positive sign indicates a constant increase in trend over time and the negative value indicates a constant decline in trend. The larger the Mann-Kendall statistic, stronger the trend (magnitude is proportional to strength). The first step is to find the sign of difference between consecutive data points.

$$sign(X_j - X_k) = \begin{bmatrix} 1 & if\, x_j - x_k > 0 \\ 0 & if\, x_j - x_k = 0 \\ -1 & if\, x_j - x_k < 0 \end{bmatrix}$$

$Sign(X_j - X_k)$ is an indicator function that results in the values -1, 0, or 1. Based on the sign of $(X_j - X_k)$ where *j* >*k*, the function is calculated as follows.

Test statistic:

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

where *j* = 1,2,3,…, *n*-1 and *k* = *j*+1, *j*+2, *j*+3, ... n.

where x_j and x_k are the annual values in years *j* and *k, j* > *k*, respectively

For large Samples

Case I (no ties): For large sample (about *n*>8) S is normally distributed with

E(*S*) = 0;

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

$$\mathrm{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p - 1)(2t_p + 5)\right]$$

Case II (tied observations): In case of ties, the variance of S is

where, *n* is the number of data points
g is the number of tied group
t_p is the number of data points in the p^th^ group

$$Z = \begin{cases} \dfrac{(s-1)}{\sqrt{VAR(s)}} & S > 0 \\ 0 & S = 0 \\ \dfrac{(s+1)}{\sqrt{VAR(s)}} & S < 0 \end{cases}$$

If, *Z* is negative and p < 0.05, then it is said to be in decreasing trend;

If, *Z* is positive and p < 0.05, then it is said to be in increasing trend;

If, computed probability p > 0.05, then there is no trend.

Sen's slope estimator

The magnitude of the trend in the seasonal and annual data series was estimated using a non-parametric method known as Sen's estimator (Theil, 1950). This method can be used when the trend is assumed to be linear, that is:

f(t) = Qt + B

Where, *Q* - slope,
B - constant and
t - time.

To get the slope Q in the above equation, we first calculate the slope of all data value pairs using the formula:

where i=1,2,…k ; j>k

X_j and X_k are the data values at time j and k respectively.

If there are 'n' values X_j in the time series, we get as many as $N = \frac{n(n-1)}{2}$ slope estimates Q_i. The Sen's slope estimator is the median of these N values of Q_i. The N values of Q_i are ranked in ascending order and the Sen's estimator is given by,

To obtain the constant B in the equation, N values of differences X_i - Qt_i are found. The median of these values gives an estimated of B. The Mann Kendall Zc and Sen's slope estimation were done using XLSTAT 17 Software package.

Results and Discussion

Results of the non-parametric Mann-Kendall test on rainfall at the 95 per cent significance are presented in Table 1.

Table 1. Values of Mann-Kendall test and Sen's slope Estimator

Blocks	Mann Kendall (Z_c)	Sen's Slope (Q)	Probability value	Trend
Andanallur	0.73	8.027	0.46	No trend
Lalgudi	-0.9285	-6.57	0.353	No trend
Manachanallur	2.192	13.24	0.028	Increasing trend
Manapparai	-3.062	-24.699	0.003	Decreasing trend
Manikandam	0.9089	5.402	0.363	No trend
Marungapuri	0.7309	6.298	0.465	No trend
Musiri	-1.0866	-4.97	0.277	No trend
Pullambadi	1.955	10.198	0.049	Increasing trend
Thathaingarpet	0.889	4.937	0.374	No trend
Thiruverumbur	-1.244	-5.772	0.228	No trend
Thottiam	-1.679	-6.83	0.101	No trend
Thuraiyur	-1.244	-7.871	0.228	No trend
Uppiliyapuram	0.8759	12.25	0.381	No trend
Vaiyampatty	-0.2173	-1.274	0.859	No trend

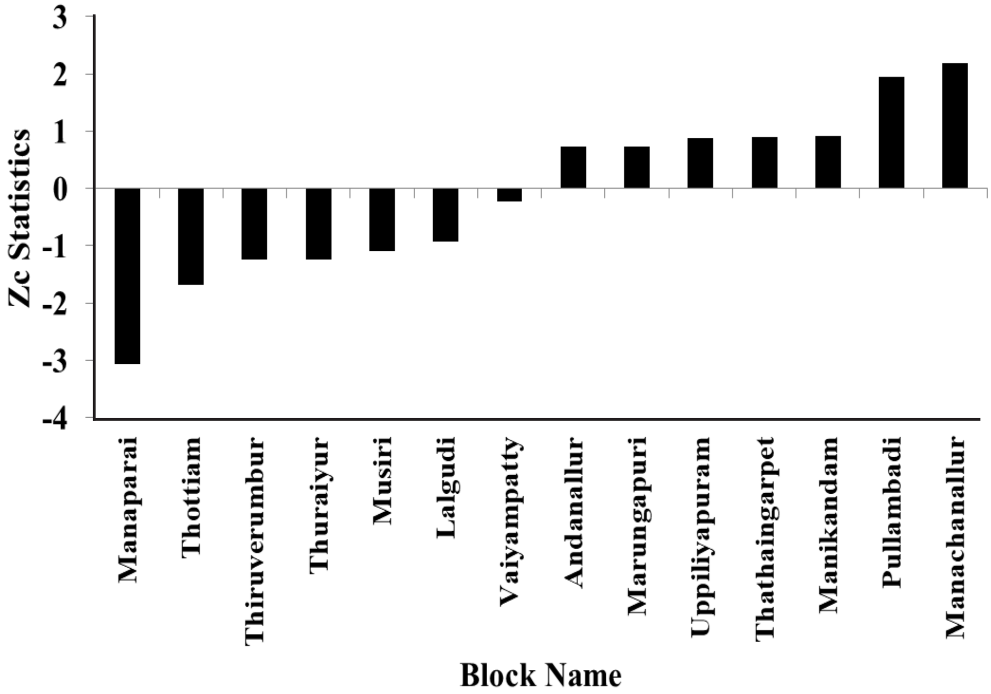
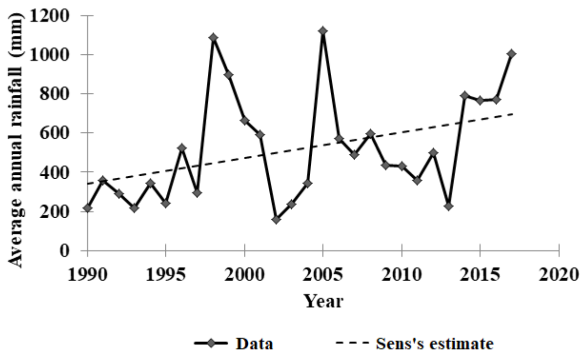
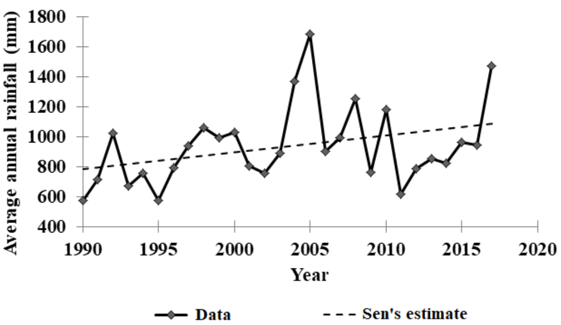


Fig. 1. Trend of Zc for individual blocks for 28 years

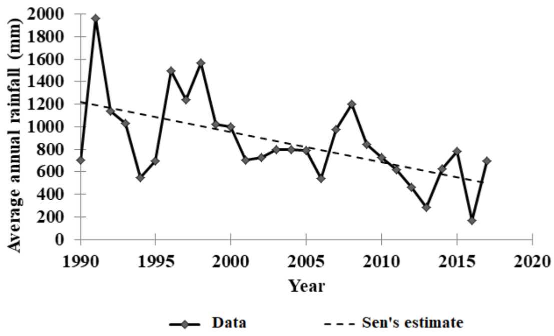
The annual mean rainfall is subjected to the Mann-Kendall test at each block. Table 1 summarizes the significant decreasing and increasing rainfall trends and Sen's Slope estimate (Q) for finding magnitude of each block during the study period 1990-2017.



a. Manachanallur block



b. Pullambadi block



c. Manapparai

Fig. 2. Annual rainfall trends using Sen's slope method

The results exposed that there was both statistically significant (95 % confidence level) positive and negative trends in the mean annual rainfall intensity in the wider area of Tiruchirappalli district. Among the 14 blocks, two blocks *viz.,* Manachanallur and Pullambadi showed statistically significant increasing trend (at 5% level), whereas the Manapparai block showed statistically significant decreasing trend (at 5% level). The other blocks showed insignificant trends. The Z_c values for Andanallur, Manikandam, Marungapuri, Thathaingarpet and Uppiliyapuram blocks showed an insignificant increasing trend, while Lalgudi, Musiri, Thiruverumbur, Thottiam, Thuraiyur and Vaiyampatty showed an insignificant decreasing trend (Fig. 1). Following the Mann Kendall test, Sen's slope estimator was employed to find out the change per unit time of trends and the results are presented in Table 1, where the negative sign indicates a downward slope and the positive sign represents an upward one.

Sen's estimator value was minimum (4.937 mm/year) at Thathaingarpet block and maximum (13.24 mm/year) at Manachanallur block for the positive trends. On the other hand, for the negative trends, the highest slope value was present for Vaiyampatty block (-1.274 mm/year). The estimated Sen's slope (Q) showed ascending magnitude in seven blocks (Andanallur, Manachanallur, Manikandam, Marungapuri, Pullambadi, Thathaingarpet and Uppiliyapuram) and descending slope magnitude in seven blocks (Lalgudi, Manapparai, Musiri, Thiruverumbur, Thottiam, Thuraiyur and Vaiyampatty). Fig. 2a, b & c shows the annual rainfall trends using Sen's Slope method for the three blocks that had shown a significant increasing and decreasing trends in Mann Kendall method. The outcomes of the Sen's Slope test appear to be similar to those obtained from the Mann-Kendall test. Jain and Kumar (2012) studied trends in rainfall, rainy days and temperature over India. Magnitude of the trend has been estimated by Sen's estimator of the slope, while statistical significance was evaluated by Mann-Kendall test. Results indicated that there were both positive and negative trends in the area. Sen's slope estimate also gave results corresponding to the MK test values.

Conclusion

Rainfall intensity trend analysis with Mann-Kendall test showed that statistically significant increasing trends (95% confidence level) appear in Manachanallur and Pullambadi, significant decreasing trend (95% confidence level) found in Manapparai and no significant trends in rest of the blocks. The outcomes of the Sen's Slope test appear to be similar to those attained from the Mann-Kendall test. Data reduction techniques such as Principal Component Analysis can be used to see the spatial and temporal variation.

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