AU DOI: 10.15740/HAS/AU/12.TECHSEAR(6)2017/1557-1562 *Agriculture Update*
Volume **12** | TECHSEAR-6 | 2017 | 1557-1562
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RESEARCH ARTICLE :

Rainfall pattern of Chinnamanur block, Theni district, Tamil Nadu

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ARTICLE CHRONICLE :
Received :
17.07.2017;
Accepted :
01.08.2017

SUMMARY : Identification of temporal variation of rainfall trends provides useful information for sustainable planning and management of water resources in dryland area particularly during flood and drought periods. The present study was conducted to determine trends in the annual and seasonal total rainfall over Theni district of Tamil Nadu using 36 years (1981-2016) monthly rainfall data at Chinnamanur rain-gauge station. The procedure is based on the nonparametric Mann-Kendall test for the trend and the nonparametric Sen's method for the magnitude of the trend. The results indicated significant positive trend were observed during Summerseason followed by North East monsoon rainfall series and significant negative trend has been noticed in the South West monsoon season. The maximum increase in rainfall was found an annual rainfall of 1.18 mm/year and the maximum reduction in rainfall of -0.87 mm/year was found during South West monsoon. The presence of trend in annual and seasonal rainfall series determined by Mann-Kendall Z statistics and Sen's Slope estimator reflected in the linear regression analysis.

KEY WORDS :
Rainfall pattern,
Mann-Kendall test,
Sen's slope estimator,
Regression

How to cite this article : Vinothkumar, R., Marimuthu, P. and Patchaimal, P. (2017). Rainfall pattern of Chinnamanur block, Theni district, Tamil Nadu. *Agric. Update*, **12**(TECHSEAR-6) : 1557-1562; **DOI: 10.15740/ HAS/AU/12. TECHSEAR(6)2017/1557-1562.**

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BACKGROUND AND OBJECTIVES

Climate change is one of the most significant consequences of global warming due to an increase in greenhouse gases, which is likely to have a major impact on the hydrological cycle and consequently affecting water resources, flood and drought frequencies, natural and man-made ecosystem, society and economy (Evans, 1997). Crop production is largely determined by climatic and soil factors. The pattern and amount of rainfall are the most important factors that affect agricultural systems. Rainfall is the limiting factors which governs the crop yield and determine the choice of the crops that can be grown. The analysis of rainfall for agricultural purpose should include information concerning the trends or changes of precipitation.

Various researches have been conducted around the world to assess the present trends of rainfall due to adverse effect of climate change (Jayawardene *et al.*, 2005; Parta and Kahya, 2006; Obot *et al.*, 2010; Kumar *et al.*, 2010; Olofintoye and Adeyemo, 2011). Detailed knowledge of variations in rainfall is essential for proper water management practices. Understanding the variations in rainfall both spatially and temporally and improving the ability of forecasting rainfall may help in planning crop cultivation as well as in designing water storage's, drought management, planning drainage channel's for flood mitigation etc. (Jayawardene *et al.*, 2005). With the growing recognition of the possibility of adverse impacts of global climate change on water resources and the background of previous research, changes in rainfall have been studied to assess the temporal pattern of rainfall trends on seasonal and annual time scales over Chinnamanur raingauge station, Theni.

RESOURCES AND METHODS

Study area :

CENDECT, ICAR KVK, Theni is located in the southern zone, part of Tamil Nadu. This area lies between 9° 51'49" North latitude and 77° 22'09" East longitudes. Altitude ranges from 200 to 400 m in the plains and 2400 m in the hills. This area is drained by major rivers *viz.*, Vaigai, Mullai Periyaru, Vallal and Kottakudi. The Vaigai river has its source in the Varusanadu hills. The total geographical area is 20 km and command area 20 ha covering Chinnamanur block of Theni district. Crops grown in this area are banana, mango, sugarcane, fodder besides annual crops such as paddy, maize, cumbu, sorghum, redgram, greengram, blackgram and vegetables.

The ICAR KVK was chosen as the study area in this research, since the management of water resources in this area has great importance in terms of a wider range of water uses. Chinnamanur rain-gauge station was selected to study the rainfall pattern in the area (Fig. A).

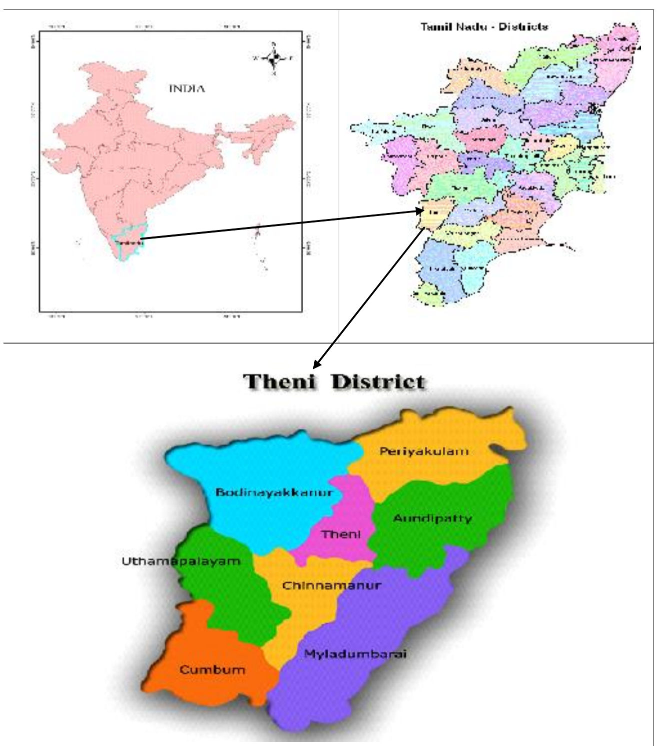

Fig. A : Location map of study area

Data collection and analysis :

Monthly rainfall data of chinnamanur rain-gauge station for the period of 36 years (1981-2016) had been collected from the office of State Surface and Ground Water Data Centre, Public works Department, Chennai. Statistical analysis of rainfall, identification of trends using Mann-Kendal test, estimation of magnitude using Sen's slope estimator, finally trend results were compared with regression analysis.

Rainfall analysis :

The study area is situated in tropical monsoon zone having two distinct periods *i.e.*,1) Monsoon period spanning from June to December and 2) Non-monsoon period spanning from January to May. The monsoon period is further sub-divided into South-west monsoon (June–September) and Northeast monsoon (October–December). Similarly, the non-monsoon period is also divided into winter (January–February) and summer (March–May). Rainfall analysis was carried out for all the seasons as well as the whole year separately. The average seasonal and annual rainfall for raingauge station of Chinnamanur has been computed by arithmetic mean method. The statistical parameters like mean, maximum, minimum, standard deviation, co-efficient of variation, co-efficient of skewness and kurtosis for rainfall data have been computed for seasonal and annual periods. Correlation co-efficients between rainfall and time were also computed to determine the strength of the linear relationship between the rainfall and time.

Trend analysis :

The trend analysis was done in three steps (Olofintoye and Adeyemo, 2011). The first step is to detect the presence of a monotonic increasing or decreasing trend using the nonparametric Mann-Kendall test in the annual and seasonal rainfall time series, second step is estimation of magnitude or slope of a linear trend with the nonparametric Sen's Slope estimator, third one is to develop regression models.

Mann-Kendal test:

The non-parametric Mann-Kendall test, which is commonly used for hydrologic data analysis, can be used to detect trends that are monotonic but not necessarily linear. The null hypothesis in the Mann-Kendall test is independent and randomly ordered data. The Mann-Kendall test does not require assuming normality, and only indicates the direction but not the magnitude of significant trends (Mann, 1945 and Kendall, 1975).

The Mann-Kendall test statistic *S* is calculated using the formula that follows:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} [sgn(x_j] - x_i)$$

Where x_j and x_i are the annual values in years *j* and *i*, *j*>*i* respectively, and N is the number of data points. The value of $sgn(x_j - x_i)$ is computed as follows:

$$sgn(x_j - x_i) = \begin{cases} 1 \ if (x_j - x_i) > 0 \\ 0 \ if (x_j - x_i) = 0 \\ -1 \ if (x_j - x_i) < 0 \end{cases}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

$$E[S] = 0$$

$$Var(S) = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right]$$

Here *q* is the number of tied (zero difference between compared values) groups, and t_p is the number of data values in the p^{th} group. The values of S and VAR(S) are used to compute the test statistic Z as follows

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

The presence of a statistically significant trend is evaluated using the *Z* value. A positive value of *Z* indicates an upward trend and its negative value a downward trend. The statistic *Z* has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at á level of significance, H_0 is rejected if the absolute value of *Z* is greater than $Z_{1-\sim/2}$, where $Z_{1-\sim/2}$ is obtained from the standard normal cumulative distribution tables. The Z values were tested at 0.05 level of significance.

Sen's slope estimator :

The magnitude of the trend in the seasonal and annual series was determined using a non-parametric method known as Sen's estimator (Sen, 1968). The Sen's method can be used in cases where the trend can be assumed to be linear that is:

$$f(t) = Qt + B$$

Where Q is the slope, B is a constant and *t* is time. To get the slope estimate *Q*, the slopes of all data value pairs is first calculated using the equation:

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

Where x_j and x_k are data values at time j and k (*j*>*k*), respectively. If there are *n* values x_j in the time series there will be as many as $N = n(n-1)/2$ slope estimates Q_i. The Sen's estimator of slope is the median of these *N* values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$Q = Q_{\left[\frac{N+1}{2}\right]}$, if N is odd

or

$Q = \frac{1}{2}\left(Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{N+2}{2}\right]}\right)$, if N is even.

To obtain an estimate of B in Equation f(t) the *n* values of differences $x_i - Qt_i$ are calculated. The median of these values gives an estimate of B. In this study the excel template application Makesens was used to facilitate the computation of the Man-Kendall statistics S, Sen's slope Q and intercept B (Salmi *et al.*, 2002).

Regression analysis :

One of the most useful parametric models used to develop functional relationships between variables is the "simple linear regression" model. The model for Y (e.g. rainfall) can be described by an equation of the form $Y = mX + C$, where, X = time in years, m = slope coefficients and c = least square estimates of the intercept.

The slope co-efficient indicates the annual average rate of change in the rainfall characteristic. If the slope is statistically significantly different from zero, the interpretation is that, it is entirely reasonable to interpret. There is a real change occurring over time, as inferred from the data. The sign of the slope defines the direction of the trend of the variable: increasing if the sign is positive and decreasing if the sign is negative. We used the t test to determine if the linear trends were significantly different from zero at the 5% significant level.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Statistical analysis of rainfall:

The graphical representation of annual and seasonal rainfall series for the chinnamanur rain-gauge station is given in Fig. 1. The statistical analysis of rainfall data is presented in Table 1. From the table it can be seen that the highest mean annual rainfall is 699.3 mm and highest seasonal rainfall is 324.27 mm during North East monsoon season. Looking at the amount of rainfall in different seasons (Table 1), it is evident that all the stations receive the maximum rainfall in monsoon seasons and minimum rainfall in winter season followed by summer season.

The co-efficient of variation (CV) of the annual and seasonal rainfall varies between 20 % and 40 %. It has been indicated that there is significant variation in the total amount of rainfall between the locations. It showedthat the maximum co-efficient of variation during North East monsoon (40%) followed by summer season and shows the minimum co-efficient of variation during annualrainfall.

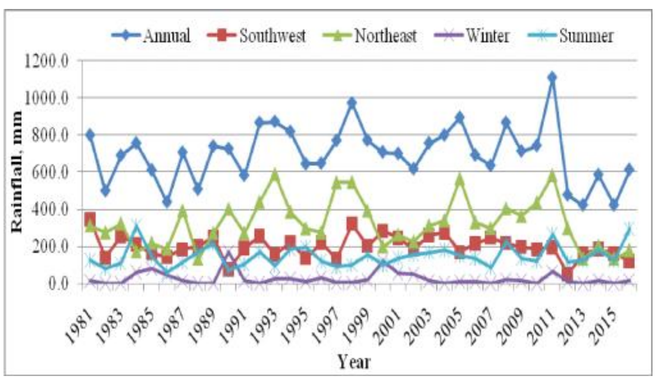

Fig. 1: Temporal variation of annual and seasonal rainfall for Chinnamanur raingauge station

To test whether the annual and seasonal rainfall data follow a normal distribution, the skewness and kurtosis were computed. Skewness is a measure of symmetry, or more precisely, the lack of symmetry. The data set is said to be symmetric if it looks the same to the left and right from the center point. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero. Negative values for the skewness indicate that data are skewed to the left and positive values for the skewness indicate that data are skewed to the right. The co-efficient of skewness of monsoon seasons and annual rainfall is nearly zero indicating a near normal distribution of rainfall in the area. Rainfall during winter season is seen more skewed when compared to the rainfall during monsoon season.

Kurtosis is a measure of data peakeness or flatness relative to a normal distribution. That is, data sets with a high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution.

The correlation co-efficients between rainfall and time for Chinnamanur stations are presented in Table 1. The results indicated that positive correlation with winter season, while annual and north east monsoon season showed negative correlation in the rain-gauge station. The highest correlation co-efficient (0.81) was observed during Winter season whereas lowest correlation (-0.03)

Table 1: Statistical properties of chinnamanur rain-gauge station annual and seasonal rainfall series

Station/ time series	Mean (mm)	Maximum (mm)	Minimum (mm)	Standard deviation	Co-efficient of variation	Skewness	Kurtosis	Correlation co-efficient
Chinnamanur								
Annual	699.30	1109.50	421.80	154.00	0.22	0.20	0.39	-0.02
South West Monsoon	200.15	347.10	51.70	62.11	0.31	0.04	0.49	0.02
North East Monsoon	324.27	588.40	132.80	129.09	0.40	0.54	-0.38	-0.03
Winter	26.16	172.50	0.00	36.73	1.40	2.51	7.19	0.81
Summer	148.71	312.00	61.60	58.62	0.39	1.16	1.29	0.17

was observed during North East monsoon season of Chinnamanur raingauge station.

Significance of rainfall trends analysis :

The result of the Mann-Kendal analysis to deduct the trend is presented in Table 2. The chinnamanur rain-gauge station showed different trends in annual and seasonal rainfall. The results indicated that significant positive trend were observed during Summer season followed by North East monsoon rainfall series and significant negative trend has been noticed in the South West monsoon season at the 0.01 significance level.

Table 2 : Summary of the Mann-Kendall analysis

Rainfall serious	Chinnamanur raingauge station
Annual	- 0.20
SWM	- 1. 06
NEM	0.16
Winter	- 0.64
Summer	1.33*

* existence of a trend with level of significance α = 0.05

Magnitude of the trends :

The magnitude of the trend in the annual and seasonal rainfall as determined using the Sen's slope estimator is presented in Table 3. The analysis revealed a positive trend in annual and seasonal rainfall in Chinnamanur which is similar to calculate Mann-Kendal analysis. The Mann-Kendall statistical value of Z = 1.33 and Sen's slope estimate Q = 1.185 indicates positive trend has been observed during winter season. The maximum increase in rainfall was found an annual rainfall of 1.18 mm/year and the maximum reduction in rainfall of -0.87 mm/year was found during South West monsoon followed by South West monsoon (-0.69 mm/year).

Regression analysis :

The slopes of the regression analysis (linear trend) for Chinnamanur raingauge station is shown in Table 4. The linear regression analysis of annual and seasonal rainfall series have shown significant linear trend of the study area. Significant rising trend was noticed during winter rainfall series (significance level P≤0.05). Significant falling trend has been noticed during South West monsoon followed by summer season. The presence of trend in annual and seasonal rainfall series determined by Mann-Kendall Z statistics and Sen's Slope estimator reflected in the linear regression analysis. A positive trend of 1.15 mm/year was recorded during winter season, which was significantly greater than zero (significance level P≤0.05).

Table 3: Sen's estimator of slope for rainfall

Rainfall series	Chinnamanur	
	Slope	Constant
Annual	- 0.691	717.28
SWM	- 0.875	214.55
NEM	0.196	299.77
Winter	- 0.077	14.48
Summer	1.185	110.39

* existence of a trend with level of significance α = 0.05

Table 4: Linear regression analysis of Chinnamanur raingauge station

Rainfall series	Chinnamanur	
	Slope	Intercept
Annual	- 0.315	705.1
SWM	- 1.103	220.5
NEM	0.224	320.1
Winter	**1.151**	127.4
Summer	- 1.103	220.5

Bold values indicate the existence of trend with the significance level of 0.05

Conclusion :

The annual and seasonal trends of rainfall were investigated by the Mann-Kendall test, the Sen's Slope estimator and the linear regression in this paper. For this purpose, records from Chinnamanur raingauge station, Theni for the period of 1981-2016 were analyzed. The results indicated that significant upward trends were observed during summer season followed by North East monsoon rainfall series and significant downward trend was noticed during the South West monsoon season. The Negative trends could affect agriculture and water supply of this region. However, the trends in the South West monsoon rainfall time series were mostly negative. Most of the trends for seasonal monsoon rainfall were significant at the 95 % confidence level. The maximum increase in rainfall was found an annual rainfall of 1.18 mm/year and the maximum reduction in rainfall of -0.87 mm/year was found during South West monsoon followed by South West monsoon (-0.69 mm/year). The difference between the parametric (the linear regression) and non-parametric (the Mann-Kendall test and the Sen's Slope estimator) methods on the annual and seasonal rainfall series was small. The difference probably related to the degree of normality of the distribution. The knowledge of temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources.

Acknowledgement:

This research work was supported by the Science and Engineering Research Board (SERB), Department of Science and Technology (DST), Government of India, New Delhi under National Post Doctoral Fellowship programme.

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