

# Trend analysis of rainfall in Telangana state using advanced statistical approaches

## ABSTRACT

**Aim:** This study was carried out to analyse the trend analysis of long- term annual and seasonal rainfall pattern in Telangana state.

**Data description:** For this study monthly rainfall data of Telangana state from January 1982 to December 2021 was collected from NASA power website (<https://power.larc.nasa.gov>).

**Methodology:** The linear regression trend line and non-parametric tests like Mann-Kendall test, Modified-Mann Kendall test and Innovative trend analysis tests were used to understand the trend present in the rainfall data of Telangana. Wallis and Moore test was used to test the randomness of the rainfall data under consideration.

**Result:** Both increasing and decreasing trend was seen in linear regression trend method for Telangana rainfall data. The significant result was found in the month of May which showed an increasing trend, whereas remaining months showed non-significant trend in Modified Mann Kendall test as well as in Innovative trend analysis. The pre-monsoon, monsoon and post-monsoon periods showed a non-significant trend in the rainfall pattern of Telangana state. The annual rainfall of Telangana showed a non-significant trend pattern by Modified Mann-Kendall test.

**Conclusion:** There was significant increasing trend of rainfall in the month of May and remaining months showed non-significant trend and there was no significant trend in the monsoon periods. These accurate identification of rainfall patterns over the area may help to create appropriate policy measures in advance to plan the future climate uncertainties.

**Keywords:** Trend, Rainfall, Mann-Kendall test, Modified Mann-Kendall Test, Wallis-Moore test, Innovative Trend Analysis.

## 1. INTRODUCTION

Rainfall refers to the amount of precipitation that falls as rain (water from clouds) on the earth's surface, whether on land or on water. Due to the global climate change long term rainfall pattern may alter and which increases the risk of droughts and floods and also their frequency of occurring in future [1]. Drought and flooding are extreme weather events as their severity affects the agriculture and hydrology due to the climate change [2]. Precipitation and temperature are the most significant fundamental physical elements that effect the climatic conditions and which intern influence the productivity of agricultural crops [3]. Previous study [4] revealed minor positive global trend was observed in rainfall and temperature data. Kale [5] in their study revealed that climate change is having a negative impact on the timing of the monsoon, temperature and other weather parameters in India [5].

[6] analysed the temperature and precipitation data for 139 major Indian cities from 1901 to 2015 and observed decreasing temperature trends in northwest cities and increasing temperature trends in southeast cities and heterogeneous patterns of trend in the rainfall data i.e., with decreasing rainfall in the eastern part as compared to the western part. One of the most important factors affecting agricultural production is the pattern and amount of rainfall [7] and which intern affects the livelihood through agriculture [8].

In India, many places have abundant rainfall during the monsoon season, while others experience water scarcity. India receives the majority of its precipitation during the monsoon season, whose management is very much essential to manage the future uncertain calamities. In the coming decades, major changes in land use patterns and population increase are anticipated in monsoon countries and India has abundant proof of the past century's consequences of climate change [9]. Telangana is a semi-arid region with a predominant hot and dry climate where the monsoon season begins in June and lasts through September with precipitation of 755 mm (29.7 inches). Telangana's economy is primarily based on agriculture. Climate change in terms of rainfall variability is considered to be the greatest challenge. The yields and profitability of rainfed farming can be severely impacted by both climate fluctuation and change. Telangana's production and productivity of rain-fed crops are being negatively impacted by the South-West monsoon. Moisture stress due to prolonged dry spells or thermal stress due to heat wave conditions also significantly affect the crop productivity when they occur in critical life stages of the crop. A statistical analysis of rainfall moving trend in Telangana state using linear regression, t-test, ANOVA, Tukey's post-Hock test and revealed non-significant trend [10].

In this changing environment, a thorough understanding of rainfall patterns will aid in improved decision-making and enhance communities' capacity to adapt to catastrophic weather occurrences. Rainfall and temperature trends were studied for Jagtial district of Telangana state using Mann-Kendall and Sen's slope estimate [11-12]. Climate change impacts on seasonal rainfall trends in the regions of Andhra Pradesh and Telangana States using non-parametric and innovative trend analysis [13]. Daily rainfall was modelled using Gamma Probability Distribution [14]. [14-17] carried out time series analysis and forecasted the rainfall using advanced statistical models. [18] studied the effect of rainfall patterns on crop yield in Southern Dry Zone of Karnataka using cluster analysis.

Most of the studies available in literature about trend analysis in Telangana regions were carried out in patches using classical linear regression trend analysis and some nonparametric methods also. In this study we have carried out the trend analysis using advanced statistical methods of trend analysis like linear regression trend (Parametric) and non-parametric tests viz., Mann-Kendall test, Sens slope estimate, Modified Mann-Kendall test and Innovative trend analysis. Further, paper is arranged in different sections as; the methodological frame work begins with basic descriptive statistics, linear regression trend, Mann-Kendall test, Sen's slope estimation, Modified-Mann Kendall test and Innovative trend analysis. The results obtained under each section are explored and discussed in results and discussion section and finally the outcome of the work is highlighted in conclusion section.

## **2. MATERIAL AND METHODS**

### **2.1 Study Area**

The research was carried out in the Indian state of Telangana which is located in southern India between  $15^{\circ} 55'N$  to  $19^{\circ} 55'N$  latitude and  $77^{\circ} 10'E$  to  $81^{\circ} 50'E$  longitude and it is situated on the Deccan Plateau, in the central stretch of eastern seaboard of the Indian peninsula. For this study the monthly rainfall data of Telangana state was collected from January 1982 to December 2021 from NASA power website. (<https://power.larc.nasa.gov>). Fig 1 depicts the study area map of Telangana State. To study the variability in rainfall pattern different trend analysis methods have been employed on rainfall data of Telangana. The information gathered was tabulated, evaluated and statistically analysed in order to forecast the rainfall trend in Telangana state. The data was analysed to explain the trend pattern of Monsoon, pre-monsoon, post-monsoon and annual rainfall.

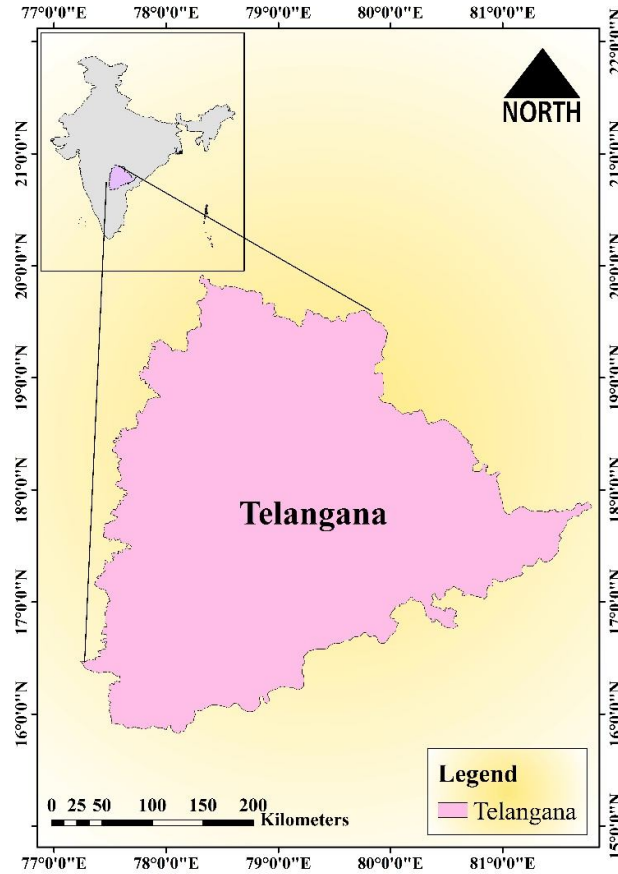


Fig 1: Study area map of Telangana state

## 2.2 Trend Analysis:

Trend refers to a pattern found in the time series dataset. The trend may be positive or negative and upward or downward. It can be estimated by using statistical parametric or non-parametric tests. In this research work for assessing rainfall parametric and non-parametric test were used. Linear regression analysis, Mann-Kendall's test, Sen's slope estimator, Modified Mann-Kendall test and to test the randomness of the data Wallis and Moore phase-frequency test was used and those details were given as follows;

### 2.2.1 Linear Regression Analysis

To detect a trend in a data series one of the most commonly used parametric model is linear regression analysis. By applying a linear equation to the collected data, this model creates a relationship between two variables (the dependent and independent variables). The linear regression model is generally described by the following equation:

$$Y = a + mX \quad \dots$$

(1)

Where Y is the dependent variable, X is the independent variable, m is the slope of the line, a is the intercept constant. The t-test is used to determine whether the linear trends are significantly different from zero at the 5% significance level or not.

### 2.2.2 The Mann–Kendall’s Trend Test

The significance of the trends was tested using Mann–Kendall (MK) nonparametric test [19-21]. It identifies trends in the data of time series but trend may or may not be linear. Let  $x_1, x_2, x_3, x_n$  represents  $n$  data points, where  $x_j$  represents the data points at time  $j$ . The Mann-Kendal statistic (S) is given in following equation

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sign}(x_j - x_i) \quad \dots (2)$$

Where  $x_i$  and  $x_j$  are the annual values in years'  $j$  and  $i, j > i$  respectively and N is the number of data points. The values of  $\text{sign}(x_j - x_i) = 0$ . This statistic represents the number of positive differences minus number of negative differences for all the differences considered. For large samples ( $N > 10$ ), the test is conducted using Z statistic with following mean and variances;

$$E[S] = 0 \quad \dots$$

(3)

$$\text{VAR}(S) = \frac{1}{18} [n(n-1)(2n+5) - \sum_{p=1}^q t_p(t_p-1)(2t_p+5)] \quad \dots (4)$$

Where  $q$  is the number of tied groups and  $t_p$  is the number of observations in the  $p^{\text{th}}$  group. Compute MK test statistic,  $Z_{\text{MK}}$ , as follows:

$$Z_{\text{MK}} = \frac{S-1}{\sqrt{\text{VAR}(S)}} \quad \text{if } S > 0 \quad \dots$$

(5)

$$= 0 \quad \text{if } S = 0 \quad \dots$$

(6)

$$= \frac{S-1}{\sqrt{VAR(S)}} \text{ if } S < 0 \quad \dots$$

(7)

A positive and negative value of  $Z_{MK}$  indicates that the data tend to increase or decrease with time respectively. To test either an upward or downward monotone trend at  $\alpha$  level of significance  $H_0$  is rejected if  $|Z_{MK}| \geq Z_{1-\alpha/2}$ .

### 2.2.3 Sen's slope estimator

Sen's slope is to identify the magnitude of trend in a data series which not serially auto-correlated. The Sen's method [22] can be used in cases where the trend can be assumed to be linear.

$$f(t) = Qt + B \quad \dots (8)$$

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

$$Q_i = \frac{x_j - x_k}{j - k} \quad \dots (9)$$

Where  $x_j$  and  $x_k$  are the 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  $N = \frac{n(n-1)}{2}$  slope estimates  $Q_t$ . The  $N$  values of  $Q_t$  are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{\left[\frac{n(n+1)}{2}\right]}, \text{ if } N \text{ is odd or } Q = 1/2 \left( Q_{\left[\frac{N}{2}\right]} + Q_{\left[\frac{(N+2)}{2}\right]} \right), \text{ if } N \text{ is even.} \quad \dots (10)$$

To obtain the estimate of  $B$  in equation  $f(t)$  the  $n$  values of differences  $x_i - Q_{ti}$  values are calculated. The median of the values gives an estimate of  $B$ .

### 2.2.4 Modified Mann-Kendall Test

The modified Mann-Kendall test is a non-parametric statistical method used to examine monotonic upward or downward trend of the series when there is a positive autocorrelation and also deals with the issue of serial correlation using the variance correction approach. The variance of  $s$  statistic is given as follows;

$$V^*(S) = V(S) \frac{n}{n^*} \dots$$

(11)

Where  $\frac{n}{n^*}$  is a correction factor.  $V(S)$  is calculated as in the original MK test. The null hypothesis  $H_0$  indicate there is no trend in the given series, the null hypothesis is rejected when the Z-transformed statistic value is greater than the Z critical value at 5% level of significance ( $|Z_{MMK}| \geq Z_{1-\alpha/2}$ ) [23].

### 3. Results and Discussion

For this study, monthly rainfall data was collected for all the districts of Telangana state from the year 1982 to 2021. The rainfall data was processed in the excel sheets to estimate the trend and further analysis. The data was tabulated and the descriptive statistics namely mean, standard deviation (SD), coefficient of variation (CV), skewness and kurtosis were depicted in Table1 given below;

Table 1: Descriptive statistics of monthly rainfall of Telangana state.

Month	Mean	SD	CV	Skewness	Kurtosis
January	8.96	13.70	152.94	1.86	2.84
February	6.62	10.21	154.23	2.31	5.50
March	13.73	23.99	174.68	3.57	15.93
April	18.00	16.38	90.96	1.05	0.19
May	30.55	29.16	95.46	2.19	7.09
June	118.94	42.70	35.90	0.51	-0.27
July	192.18	78.14	40.66	0.93	0.97
August	190.86	65.36	34.25	0.28	-0.27
September	137.09	59.79	43.61	0.26	-0.78
October	91.93	59.07	64.26	0.84	-0.05
November	22.50	29.57	131.46	2.50	8.45
December	5.23	7.78	148.74	2.03	4.00

The rainfall variability was more as the average monthly rainfall of coefficient of variation (CV) ranging from 35.90 to 174.68 % which means spread of data points in the data series around the mean. The rainfall variability was understood by CV, rainfall variability is less if CV is less than 20 %, the variability is moderate if CV is 20 to 30 % and variability is high if it is more than more than 30 % [2]. The value of skewness ranging from 0.26 to 3.57

and kurtosis ranging from -0.05 to 15.93. The highest values of skewness and kurtosis was found in March i.e., 3.57 rightly skewed and 15.93 indicating leptokurtic respectively.

Table 2: Descriptive statistics of annual and seasonal rainfall Pattern

	Mean	SD	CV	Skewness	Kurtosis
Pre-monsoon	62.28	40.01	64.24	1.33	1.57
Monsoon	639.06	127.91	20.01	0.47	-0.07
Post-Monsoon	135.24	71.20	52.65	0.87	0.35
Annual	836.58	163.90	19.59	0.48	-0.26

The Table 2 depicts the summary statistics for pre-monsoon, monsoon, post-monsoon and annual rainfall. The coefficient of variation of annual precipitation was 19.59 %. The standard deviation was 163.90 and skewness was 0.48, rightly skewed and kurtosis was -0.26 indicating platykurtic shape respectively. The coefficient of variation among monsoons was less in monsoon i.e., 20.01%. Similar findings were found in [1].

### 3.1 Trend of Annual Rainfall:

Fig 2 represents the monthly annual rainfall of Telangana. The linear regression analysis was carried out for annual rainfall. It indicated the linear trend line falling on the time series for annual rainfall from 1982-2021. The graph depicts the increasing and decreasing rainfall trend pattern of the Telangana state for the period 1982 to 2021 on the annual basis. The value of Coefficient of determination ( $R^2$ ) for linear equation is at lower magnitude which indicate the linear regression method is not a better fit for the data under consideration. Similar linear regression analysis for rainfall variability during the period 1980-2019 in Jagtial district of Telangana state was found [12].

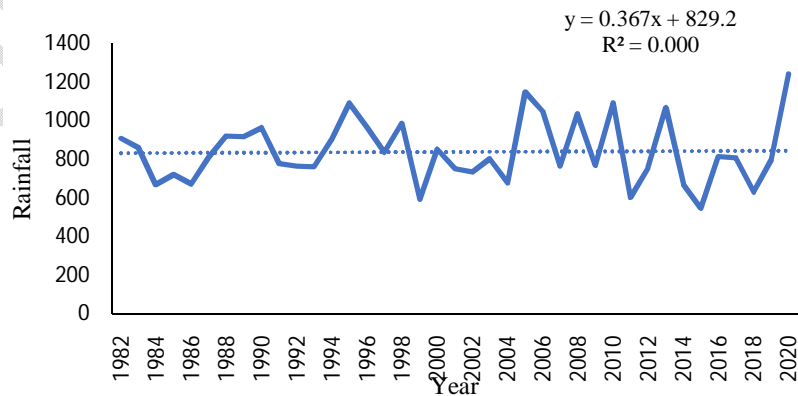


Fig 2: Trend of annual rainfall of Telangana district from 1980 to 2021.

Wallis and Moore Phase – Frequency test was conducted for seasonal and annual rainfall data [24].

Table 3: Wallis and Moore phase frequency test for seasonal and annual rainfall data

Month	Z transformed test statistic	Probability
January	0.26	0.80
February	0.52	0.60
March	0.91	0.36
April	1.04	0.30
May	0.91	0.36
June	1.43	0.15
July	0.13	0.90
August	1.30	0.19
September	0.65	0.52
October	0.26	0.80
November	0.13	0.90
December	0.91	0.36
Pre-monsoon	0.91	0.36
Monsoon	0.26	0.80
Post-monsoon	0.13	0.90
Annual	0.13	0.90

Table 3 depicts that seasonal and the annual rainfall data was random in nature. As the probability value was greater than 5% level of significance, the data was random in nature. Modified Mann-Kendall test was used for the analysis as it was more efficient if the autocorrelation was present in the data. As the data was autocorrelated in nature modified Mann-Kendall test was used.

### 3.2 Results of rainfall trend analysis using modified Mann-Kendall test and Sens slope estimator.

The results of Modified Mann-Kendall trend analysis for rainfall of Telangana state were depicted in Table 4. It revealed that there was a significant increasing trend of rainfall in the month of May as the Z transformed test statistic is significant at 5% level of significance. There was no significant trend in the remaining months as the test was non-significant.

Table 4: Modified Mann-Kendall test of trend analysis of monthly rainfall data.

Parameter	Z- Transformed test Statistic	Trend	Sens slope
January	-0.65	NS	-0.01
February	-0.18	NS	0.00
March	1.03	NS	0.04
April	1.60	NS	0.24

May	1.99	*	0.38
June	-0.50	NS	-0.27
July	-0.59	NS	-0.73
August	0.25	NS	0.27
September	1.23	NS	1.51
October	-0.52	NS	-0.34
November	-1.14	NS	-0.11
December	-1.02	NS	-0.03

NS - Non-significant trend      \* - significant trend

Modified Mann-Kendall trend analysis for rainfall of Telangana state was depicted in the Table 5. The period 1982 to 2021 did not showed any significant trend in the Pre-Monsoon, Monsoon and Post-Monsoon as well as Annual rainfall as the Z transformed test statistic is non- significant, indicates there was no significant trend in the rainfall monsoon seasons. Various studies [3 and 16] provide the similar results of trend with Modified Mann-Kendall test.

Table 5: Modified Mann-Kendall Test of trend analysis of rainfall of monsoon seasons:

Parameter	Z-transformed test statistic	trend	Sens slope
Pre-monsoon	1.62	NS	0.61
Monsoon	-0.10	NS	-0.42
Post-Monsoon	-0.98	NS	-1.15
Annual	0.92	NS	-0.42

NS – Non-significant trend

### 3.3 Innovative Trend Analysis of rainfall:

The trend slope, trend indicator, Lower Confidence Level (LCL) and Upper Confidence Level (UCL) at 90%, 95% and 99% of annual and seasonal rainfall of Telangana state was depicted in Table 6.

Table 6: Innovative trend analysis (ITA) of seasonal and Annual rainfall of Telangana state

Parameter	Trend slope	Trend Indicator	$\alpha = 0.10$		$\alpha = 0.05$		$\alpha = 0.01$	
			LCL	UCL	LCL	UCL	LCL	UCL
January	-0.13	-0.13	-0.04	0.04	-0.04	0.04	-0.05	0.05
February	-0.12	-2.88	-0.03	0.03	-0.04	0.04	-0.05	0.05
March	0.42	8.64	-0.13	0.13	-0.15	0.15	-0.20	0.20
April	0.29	3.65	-0.05	0.05	-0.07	0.07	-0.09	0.09
May	0.09	0.62	-0.17	0.17	-0.20	0.20	-0.26	0.26

June	-0.41	-0.66	-0.15	0.15	-0.18	0.18	-0.24	0.24
July	-0.98	-0.96	-0.40	0.40	-0.48	0.48	-0.63	0.63
August	-0.48	-0.49	-0.14	0.14	-0.16	0.16	-0.21	0.21
September	1.47	2.39	-0.12	0.12	-0.14	0.14	-0.19	0.19
October	-0.59	-1.20	-0.17	0.17	-0.20	0.20	-0.27	0.27
November	-0.66	-4.44	-0.18	0.18	-0.22	0.22	-0.29	0.29
December	-0.15	-4.33	-0.03	0.03	-0.04	0.04	-0.05	0.05
Pre-Monsoon	0.80	2.88	-0.12	0.12	-0.14	0.14	-0.19	0.19
Monsoon	-0.40	-0.12	-0.32	0.32	-0.39	0.39	-0.51	0.51
Post-Monsoon	-1.65	-2.15	-0.30	0.30	-0.35	0.35	-0.46	0.46
Annual	-1.25	-0.29	-0.84	0.84	-1.00	1.00	-1.31	1.31

The results revealed that January and February showed decreasing trends at 10, 5 and 1 % level of significance. The December month showed decreasing trend 10, 5 and 1 % level of significance and the remaining months showed no significant trend at 10, 5 and 1 % level of significance except the April month. The April month showed a significant increasing trend at 10% level of significance. The Pre-Monsoon, Monsoon, Post-Monsoon and Annual rainfall showed no significant trend and similar results were also obtained in [25] where Innovative Trend Analysis accurately identifies the trends compared to the non-parametric tests.

#### 4. CONCLUSION:

This study used parametric method i.e. linear regression trend and non-parametric tests viz., Modified-Mann Kendall test and Innovative trend analysis to identify long-term trends to analyse annual and seasonal rainfall in the Telangana State (1982 to 2021). From the results of linear regression trend it was interpreted that there were both increasing and decreasing trend present in the rainfall data. From the Modified Mann-Kendall test it revealed significant increasing trend of rainfall in the month of May and there was no significant trend found in remaining months and monsoon seasons showed no significant trend of rainfall in Telangana state. The innovative trend analysis methods reveal that January, February and December months showed significantly decreasing trend and April month showed significantly increasing trend. Monsoon seasons and annual rainfall showed no significant trend. Variability of rainfall was major concern and the findings of this study helps the policy makers to take improved decisions to avoid the future climate uncertainties. Further the similar trend analysis methods can be employed in other data sets for validation purpose.

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