Trend analysis of rainfall in Telangana state (India) using advanced statistical approaches

ABSTRACT

This study was carried out to analyse the trend analysis of the long-term annual and seasonal rainfall pattern in Telangana state, India. For this study monthly rainfall data of Telangana state from January 1982 to December 2021 was collected from the NASA power website (https://power.Iarc.nasa.gov). The linear regression trend line and the non-parametric tests, such as 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. 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 the non-significant trend in the Modified Mann Kendall test as well as in the 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. There was a significant increasing trend of rainfall in the month of May and remaining months showed a non-significant trend and no significant trend in the monsoon periods. These accurate identification of rainfall patterns over the area may help to create the 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, which increases the risk of droughts and floods as well as their frequency of occurring in future [1]. Drought and flooding are extreme weather events as their severity affects agriculture and hydrology due to the climate change [2]. Precipitation and temperature are the most significant fundamental physical elements that affect climatic conditions and which intern influence the productivity of agricultural crops [3]. Previous study [4] revealed minor positive global trend which 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]. Other studies [6] analysed the temperature and precipitation data for 139 major Indian cities from 1901 to 2015 and observed the decreasing temperature trends in the northwest cities, increasing temperature trends in southeast cities and heterogeneous patterns of trend in the rainfall data, i.e., with the 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], which 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 upcoming 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). The economy of Telangana is primarily based on agriculture. Therefore, climate change in terms of rainfall variability is considered to be the greatest challenge for Telangana. 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. In this study, we presented the statistical analysis of rainfall moving trend in Telangana state using statistical methods of linear regression, t-test, ANOVA, Tukey's post-Hock test, which enabled to reveal 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]. Earlier studies [14-17] carried out time series analysis and forecasted the rainfall using advanced statistical models. For instance, [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 carried out trend analysis using the 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, the paper is arranged in different sections as follows: 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 sections and finally the outcome of the work is highlighted in the 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 $15° 55'N$ to $19° 55'N$ latitude and $77° 10'E$ to $81° 50'E$ longitude. It is situated on the Deccan Plateau, in the central stretch of the 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 the NASA power website. (https://power.Iarc.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.

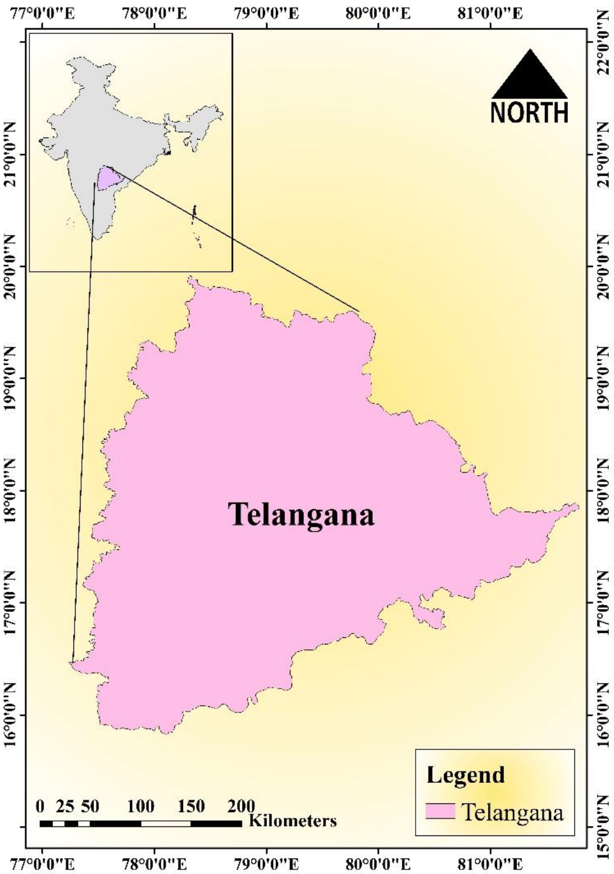

Fig 1: Study area map of Telangana state

2.2 Trend Analysis:

Trend refers to a pattern found in a time series dataset. The trend may be positive or negative, with upward or downward directions. It can be estimated by using statistical parametric or non-parametric tests. In this research, parametric and non-parametric test were used for assessing rainfall data. Linear regression analysis, Mann-Kendall's test, Sen's slope estimator, Modified Mann-Kendall test were used. Furthermore, to test the randomness of the data, we applied the Wallis and Moore phase-frequency test with details explained 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 the linear regression analysis. By applying a linear equation to the collected data, this model creates a relationship between the two variables:the dependent and independent ones. The linear regression model is generally described by the following equation:

$$Y = a + mX \quad \ldots (1)$$

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.

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 the trends in the data of the time series but trend may or may not be linear in different cases. 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 the following equation:

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

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 $sign(x_j - x_i) = 0$. 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 the following mean and variances:

$$E[S] = 0 \quad \ldots (3)$$

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

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

$$Z_{MK} = \frac{S-1}{\sqrt{VAR(S)}} \text{ if } S>0 \quad \ldots (5)$$

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

(6)

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

(7)

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

2.2.3 Sens's slope estimator

Sen's slope is used 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.

$$f(t) = Qt + B \qquad \text{.... (8)}$$

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 are calculated using the following equation:

$$Q_i = \frac{x_j - x_k}{j-k} \qquad \text{.... (9)}$$

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

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

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. Besides, it also deals with the issue of serial correlation using the variance correction approach. The variance of s statistic is given as follows:

$$V\ \ (S) = V(S)\frac{n}{n} \qquad \text{.... (11)}$$

Where $\frac{n}{n}$ is a correction factor. V(S) is calculated as in the original MK test. The null hypothesis H_0 indicates that there is no trend in the given series. In such a way, 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 Table 1, as presented 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 that the spread of data points in the data series is around the mean. The rainfall variability was understood by CV, i.e., 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 %, respectively [2]. The value of skewness is ranging from 0.26 to 3.57 and kurtosis is 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 the 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 the monsoons was less in monsoon, i.e., 20.01%. Similar findings were found in previous relevant studies [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 the coefficient of determination (R^2) for linear equation is at lower magnitude, which indicates that linear regression method is not a better fit for the data under consideration. Similar linear regression analysis for the rainfall variability during the period 1980-2019 in Jagtial district of Telangana state was found in earlier studies [12].

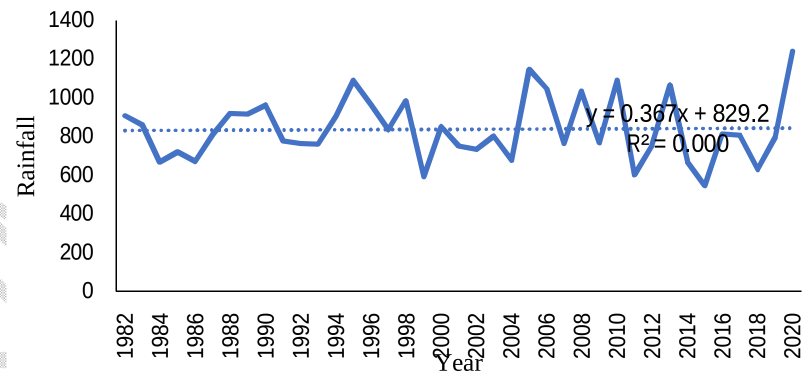

Fig 2: Trend of annual rainfall of Telangana district from 1980 to 2021.

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 were random in nature, since the probability value was greater than 5% level of significance. The modified Mann-Kendall test was used for the analysis as it was more efficient if the auto-correlation was present in the data. As the data were 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 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	∝= 0.10		∝= 0.05		∝= 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 the data on January and February showed the decreasing trends at 10, 5 and 1 % level of significance, respectively. The data on December month showed the 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 for the month of April. 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 the 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, the significant increasing trend of rainfall in the month of May was revealed. Besides, we found no significant trend in the 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, while April month showed significantly increasing trend. The monsoon seasons and annual rainfall showed no significant trend. The variability of rainfall was major concern and the findings of this study helps policy makers to take the improved decisions to avoid future climate uncertainties. Further, similar trend analysis methods can be employed in other datasets for validation purpose.

REFERENCES

1. Pal AB, Mishra PK. Trend analysis of rainfall, temperature and runoff data: a case study of Rangoon watershed in Nepal. International Journal of Student's Research in Technology & Management. 2017; 2321–2543,5(3);21–38.

2. Naveena K, Elzopy AK, Chaturvedi KA, Chandran MK, Gopinath G, Surendran U. Trend analysis of long-term rainfall temperature data for Ethopia. South African Geographical Journal. 2020; https://doi.org/10.1080/03736245.2020.1835699.
3. Singh O, Arya P, Chaudhary BS. On rising temperature trends at Dehradun in Doon valley of Uttarakhand, India. Journal of Earth System Science. 2013; 122, 613–622.
4. Zhang X, Vincent LA, Wd H, Niitsoo A. Temperature and Rainfall Trends in Canada during the 20th Century. Atmosphere-Ocean. 2000;38(3):395-429.
5. Fulekar M, Kale. Impact of Climate Change: Indian Scenario. University News. 2010; 48(24):14-20.
6. Mohammad P, Goswami A. Temperature and precipitation trend over 139 major Indian cities: an assessment over a century. Modeling Earth Systems and Environment. 2019. vol 5: 1481–1493 (2019). https://doi.org/10.1007/s40808-019-00642-7
7. Gajbhiye S, Meshram C, Singh SK, Srivastava PK, Islam T. Precipitation trend analysis of Sindh River basin, India, from 102-year record (1901-2002). Atmospheric Science Letters. 2016; 17:71–77.
8. Kumar R, Gautam HR. Climate change and its impact on agricultural productivity in India. Journal of Climatology and Weather Forecasting. 2014; 2, 109. https://doi.org/10.4172/2332-2594. 1000109.
9. Goswami BN. Increasing trend of extreme rain events over India in a warming environment. Science. 2016;314,1442–1445; https://doi.org/10.1126/science.1132027.
10. Dash SK, Jenamani RK, Kalsi SR, Panda SK. Some evidence of climate change in twentieth-century India. Climate Change. 2007; 85:299– 321.
11. Vittal B, Reddy KM. Statistical Analysis of Rainfall Moving Trend in Telangana State. International Journal of Scientific Research in Mathematical and Statistical Sciences. 2019; 6(4):08-15.
12. Navatha N, Sreenivas G, Umareddy R. Rainfall and temperature trends in Jagtial district of Telangana state. International Journal of Environment and Climate Change. 2021;11(11):47-59.
13. Jyothy AS, Murthy SD, Mallikarjuna P. Climate change impacts on seasonal rainfall trends in the regions of Andhra Pradesh and Telangana States, India. Journal of The Institution of Engineers (India). 2021;102 (3):673-685.
14. Bhavana CP, Munirajappa R, Surendra HS, Rathod S. Modeling of daily rainfall using Gamma probability distribution. Environment and Ecology. 2012; 30(3B):884-887.
15. Praveen B, Talukdar S, Shahfahad, Mahato S, Mondal J, Pritee S, Islam TMdR, Rahman A. Analyzing trend and forecasting of rainfall changes in India using non-parametrical and machine learning approaches. Nature Journal. 2020; 10:10342.
16. Saha A, Singh KN, Ray M, Rathod S. A hybrid spatiotemporal modelling: an application to space-time rainfall forecasting. Theoretical and Applied Climatology. 2020; 142:1271-1282.
17. Ray, M., Singh, K. N., Ramasubramanian, V., Paul, R. K., Mukherjee, A.and Rathod, S. (2020). Integration of wavelet transform with ANN and WNN for time series forecasting: Anapplication to Indian monsoon rainfall. National Academy Science Letters, 43, 509–513.

18. Bhavana CP, Munirajappa R, Surendra HS, Rathod S. Effect of rainfall patterns on crop yield in southern dry zone of Karnataka. 2012; 30(3B):888-891.
19. Surendran U, Anagha B, Gopinath G, Joseph EJ. Long-term rainfall analysis towards detection of meteorological drought over Kozhikode district of Kerala. Journal of Climate Change. 2019; 5(2):29–34. https://doi.org/10.3233/JCC190010.
20. Mann HB. Nonparametric tests against trend, Econometrica. 2014; 13, 245-259.
21. Kendall MG. Rank Correlation Methods. 4th Ed. Griffin. 1976.
22. Gilbert RO. Statistical Methods for Environmental Pollution Monitoring, Wiley, NY. 1987.
23. Sen PK. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. 1968; 63:1379–1389.
24. Yue S, Wang C. The Mann-Kendall Test Modified by Effective Sample Size to Detect Trend in Serially Correlated Hydrological Series. Water Resources Management. 2014; 18,201-218.
25. Wallis WA, Moore GH. A significance test for time series and other ordered observations. Tech. Rep. 1. National Bureau of Economic Research. 1941. New York.
26. Bora LS, Bhuyan K, Hazarika JP, Gogoi J, Goswami K. Analysis of rainfall trend using non-parametric methods and innovative trend analysis during 1901–2020 in seven states of North East India. Current Science. 2022;122(7):801-811.