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Trend Analysis of Rainfall in Mahabubnagar District of Telangana State, India

Preethi Ch [a*], Meena A [a], Rathod S [b++] and Balaji naik B [c#]

[a] Department of Statistics and Mathematics, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana-500030, India.
[b] ICAR- Indian Institute of Rice Research (IIRR), Hyderabad, Telangana-500030, India.
[c] Regional Sugarcane and Rice Reseach Station, Rudrur, Telangana-503188, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to analyze the trend analysis of long-term monthly, seasonal and annual rainfall patterns in Mahabubnagar district, Telangana state. Monthly rainfall data from January 1980 to December 2023 was collected from the IMD website. The linear regression trend line and non-parametric tests, such as the Mann-Kendall test, Modified Mann-Kendall test and Innovative Trend Analysis tests were used to understand the trends in the rainfall data. The Wallis and Moore test was applied to assess the randomness of the rainfall data. The linear regression trend method revealed both increasing and decreasing trends in rainfall data for Mahabubnagar district. A significant increasing trend was observed in May, while the remaining months showed non-significant trends according to the Modified Mann-Kendall test. The pre-monsoon, monsoon and

[++] Scientist;
[#] Principal Scientist (Agronomy) and Head;
**Corresponding author: E-mail: preethichinthala1998@gmail.com;*

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post-monsoon periods also exhibited non-significant trends in the rainfall pattern in Mahabubnagar district. The annual rainfall of Telangana showed a non-significant trend pattern based on the Modified Mann-Kendall test. The Innovative Trend Analysis approach indicated a significant increase in rainfall in February and a significant decrease in rainfall in November and December. Accurate identification of rainfall patterns in the area can help create appropriate policy measures in advance to plan for future climate uncertainties.

Keywords: Trend; rainfall; modified Mann-Kendall test; Wallis-Moore test; innovative trend analysis.

1. INTRODUCTION

“Rainfall is a fundamental component of the Earth's hydrological cycle, playing a critical role in shaping ecosystems, influencing agriculture and water resource availability” [1]**.** “Rainfall and temperature are the most significant fundamental physical elements that affect climatic conditions and which intern influence the productivity of agricultural crops” [2]. Kale [3] “demonstrated in their study that climate change is adversely affecting the timing of the monsoon, temperature, and other weather parameters in India. As climate change continues to affect weather patterns globally, understanding these trends becomes increasingly critical for effective decision-making and policy formulation. Several studies have highlighted the importance of analyzing rainfall trends to understand long-term changes in climate and their potential impacts on various sectors”. For instance, Trenberth et al. [4] “emphasized the role of rainfall in the Earth's energy budget and hydrological cycle, noting that changes in rainfall patterns can have profound effects on water availability and ecosystem health”. In a study on rainfall variability and trends in India, Kumar et al. [5] found that significant spatial and temporal variations in rainfall have been observed over the past century. Their analysis indicated that while some regions experienced increasing rainfall trends, others showed a decline, highlighting the complex nature of rainfall patterns and the need for region-specific studies. This variability underscores the importance of localized trend analyses to inform regional water management and agricultural practices.

“Rainfall and temperature trends were studied for Jagtial district of Telangana state using Mann-Kendall and Sen’s slope estimate” [6,7]. “Jyothy et al. [8] studied climate change impacts on seasonal rainfall trends in the regions of Andhra Pradesh and Telangana States using non-parametric and innovative trend analysis”. Junli Li et al. [9] in his study employed “Innovative Trend Analysis (ITA) to assess trends in five natural hazards affecting agricultural areas in China from 1989 to 2014”. 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. MATERIALS AND METHODS

2.1 Study Area

The trend analysis of rainfall was carried outin the Mahabubnagar district of Telangana, which is located at 16.74880° North latitude and 78.00350° East longitude. For this study, monthly rainfall data from January 1980 to December 2023 were collected from the IMD (India Meteorological Department) website. The year is divided into three seasons: pre-monsoon (March to May), monsoon (June to September), and post-monsoon (October to February). The average annual rainfall in Mahabubnagar is 799.29 mm, with the southwest monsoon being the principal source of rainfall. To study the variability in rainfall patterns, various trend analysis methods were applied to the data. The collected information was tabulated, evaluated, and statistically analyzed to understand the trends in the rainfall data for Mahabubnagar district.

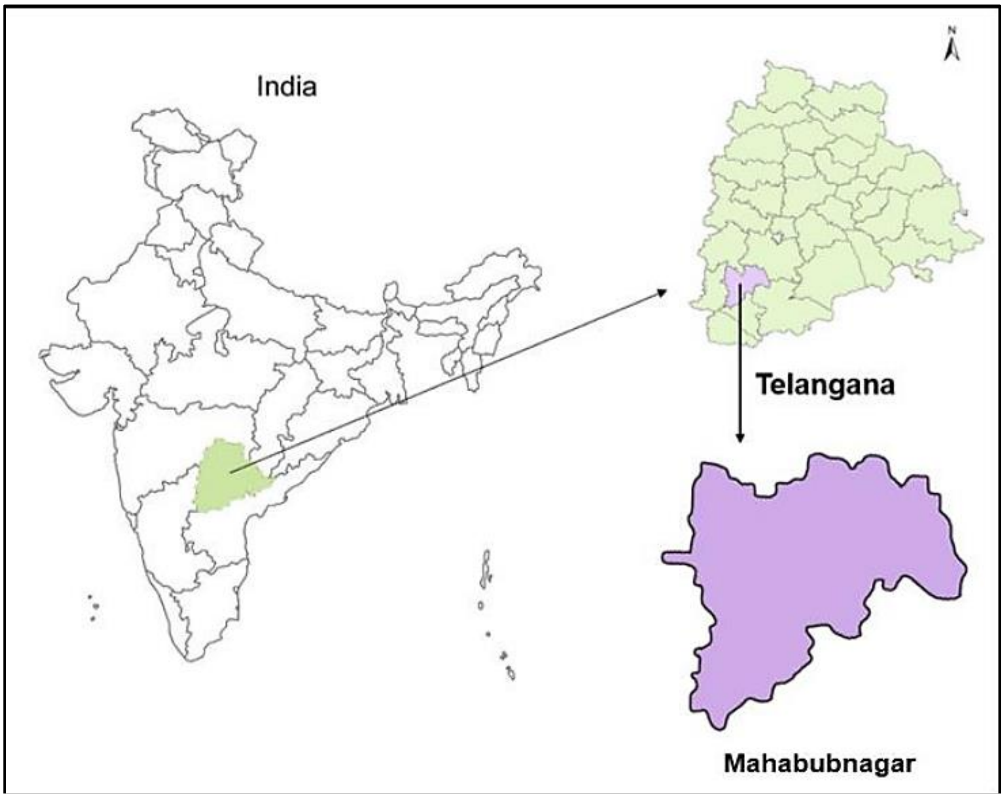

Fig. 1. Location map of Mahabubnagar District of Telangana State

2.2 Trend Analysis

"A trend refers to a pattern observed in a time series dataset, which can be either positive or negative, indicating an upward or downward direction. This trend can be estimated using statistical parametric or non-parametric tests. In this research, both types of tests were employed to assess rainfall data. Methods such as linear regression analysis, the Mann-Kendall test, Sen's slope estimator, and the Modified Mann-Kendall test were used" [10].

2.2.1 Linear regression analysis

Linear regression analysis is one of the most commonly used parametric models for detecting trends in a data series. This method involves applying a linear equation to the collected dataset, establishing a relationship between two variables: the dependent variable and the independent variable. The linear regression model is typically represented by the following equation:

$$Y = a + Mx \tag{1}$$

where Y is the dependent variable, X is the independent variable, m is the slope of the line, and 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 trend analysis was done using Mann- Kendall for the given data sets. Mann - Kendall test is a non-parametric test for finding trends in time series. The benefit of this test is that data need not to conform any particular distribution. The MK test can be used in place of a parametric linear regression analysis, which can be used to test if the slope of the estimated linear regression line is different from zero. The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a nonparametric (distribution-free) test" [11]. 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:

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

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:

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

$$VAR = \frac{1}{18}[n\,(n-1)(2n+5) - \sum_{p-1}^{q} t_p(t_p-12t_p+5)] \quad (4)$$

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:

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

$$= 0 \text{ if } S=0 \quad (6)$$

$$Z_{MK} = \frac{s-1}{\sqrt{VAR(S)}} \text{ if } S<0 \quad (7)$$

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 monotonic 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 serves as a valuable tool for detecting the strength of a trend within a dataset devoid of serial autocorrelation. This method is particularly applicable in scenarios where a linear trend can be reasonably assumed [11]

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

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:

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

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 given as,

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

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 nonparametric statistical method used to examine monotonic upward or downward trends in a series, particularly when positive autocorrelation is present. Furthermore, it effectively addresses concerns regarding serial correlation through the implementation of a variance correction approach. The variance of the S statistic is given as follows:

$$V^*(S) = V(S)\,\frac{n}{n^*} \quad (11)$$

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 ($|Z_{MMK}| \geq Z_{1-\alpha/2}$) [12].

2.2.5 Innovative trend analysis (ITA) method

Many research studies worldwide have used the innovative trend analysis (ITA) approach [9,13] along with various other methods to explore differences in climatological, meteorological, and hydrological data time series around the world due to its advantages over other nonparametric approaches. "The trustworthiness of ITA is proven, however, by matching its results to those with the MK test results. The initial stage in this strategy is to divide time series data into 2 equal halves and position each one in increasing order separately. The second stage involves, the first 1/2 of the sub-series (; i = 1,2 … $\frac{n}{2}$) positioned at X-axis, with the second 1/2 (X_j ;$j = \frac{n}{2}+1, \frac{n}{2}+2 \ldots n$) is positioned at Y-axis of cartesian coordinate system, both the axes (vertical & horizontal) necessarily have the same range. Data values accumulating at the area of triangulation below or above the linear line specify an upward trend or a downward trend within the time series. On computing the average difference between the X_j

and X_i values at every point, the increasing or downward longitudinal trend in the time series can be evaluated. The horizontal and vertical distance from the linear line can be used to calculate this absolute difference. The first half of the time series is used to determine the trend change. As a result, the indicator of trend is derived by dividing the mean difference between the linear line and the time series first 1/2. On multiplying by ten the ITA trend indicator has represented the scale of the Sen's slope estimator and MK test at a 10% significance level as shown in the equation" (12):

$$D = \frac{1}{2}\sum_{i=1}^{n}\frac{10(Y_j - Y_i)}{\mu} \quad (12)$$

"Here, D denotes the indicator of trend, n the number for data points in each sub-series, Y_i and Y_j denote the 1st and 2nd sub-series data points, respectively μ denotes the first subseries average. However, the +ve or −ve values of D represent an increasing or decreasing trend, respectively" [10].

3. RESULTS AND DISCUSSION

For this study, monthly rainfall data was collected for Mahabubnagar district from the year 1980 to 2023. The rainfall data was analysed 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.

"The rainfall variability was more as the average monthly rainfall of coefficient of variation (CV) ranging from 46.46% to 250.55 %, 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" [14]. "The value of skewness is ranging from 0.25 to 4.56 and kurtosis is ranging from -0.74 to 25.3. The highest values of skewness and kurtosis was found in November, i.e., 4.56 rightly skewed and 25.3 indicating leptokurtic, respectively" [10].

The Table 2 depicts the summary statistics for the pre-monsoon, monsoon, post-monsoon and annual rainfall. "The coefficient of variation of annual rainfall was 23.32%. The standard deviation was 184.59 and skewness was 0.66, rightly skewed and urtosis was 0.59 indicating platykurtic shape, respectively. The coefficient of variation among the monsoons was less in monsoon, i.e., 30.78%. Similar findings were found in previous relevant studies" [15].

Table 1. Descriptive statistics of monthly rainfall of Mahabubnagar district, Telangana

Month	Mean	SD	CV	Skewness	Kurtosis
January	4.04	8.02	198.51	1.96	2.67
February	4.53	11.35	250.55	2.54	5.3
March	9.52	20.46	214.91	3.85	18.44
April	20.82	20.75	90.66	1.31	1.28
May	37.14	29.85	80.37	1.22	1.26
June	105.57	49.88	47.24	0.54	-0.16
July	162.51	75.47	46.44	0.3	-0.73
August	176.06	85.61	48.62	0.25	-0.6
September	150.4	70.04	46.46	0.73	0.83
October	100.58	70.5	70.09	0.65	-0.74
November	17.08	31.54	184.66	4.56	25.3
December	2.99	6.61	221.07	2.9	8.87

Table 2. Descriptive statistics of annual and seasonal rainfall pattern

Parameter	mean	SD	CV	skewness	kurtosis
Pre-monsoon	67.5	39.24	40.24	0.8	-0.29
Monsoon	594.55	183.05	30.78	0.6	0.59
Post-monsoon	129.24	77.9	60.27	0.8	0.2
Annual	791.29	184.59	23.32	0.66	0.59

3.1 Trend of Annual Rainfall

Fig. 2 illustrates the monthly and annual rainfall in Telangana. Linear regression analysis was fitted on the annual rainfall data, revealing a linear trend line across the time series from 1980 to 2023. The graph shows the fluctuating rainfall trends in Mahabubnagar during this period on an annual basis. The coefficient of determination (R^2) for the linear equation is relatively low, indicating that the linear regression method is not a suitable fit for this dataset. Similar linear regression analysis for the rainfall variability during the period 1980-2019 in Jagtial district of Telangana state was found in earlier studies [7].

Randomness of the time series for monthly, seasonal and annual rainfall data was identified using Wallis and Moore Phase-Frequency test [16].

Table 3 shows that the monthly, seasonal, and annual rainfall data were random in nature, since the probability value was greater than 5% level of significance. The modified Mann-Kendall test was utilized for the study since it was more efficient when auto-correlation was included in the data [17].

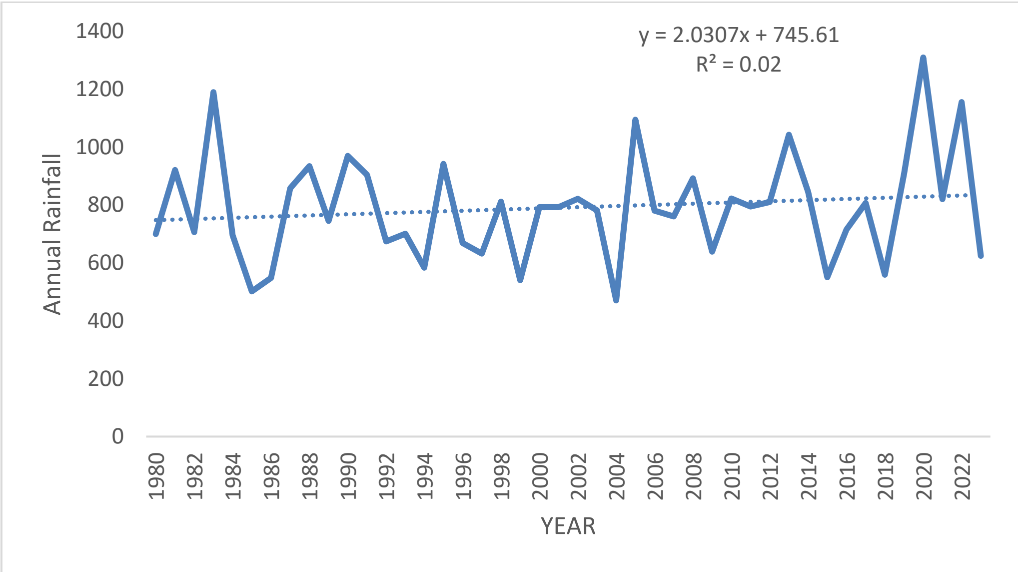

Fig. 2. Trend of annual Rainfall in Mahabubnagar district, Telangana from 1980-2023

Table 3. Wallis and Moore phase frequency test for seasonal and annual rainfall of Mahabubnagar, Telangana

Parameter	Z transformed test statistic	p-value
January	0.91	0.36
February	1.30	0.19
March	0.73	0.46
April	0.73	0.46
May	1.09	0.27
June	0.36	0.71
July	0.1	0.92
August	0.2	0.84
September	1.46	0.14
October	0.36	0.71
November	0.1	0.94
December	1.04	0.3
Pre-monsoon	0.4	0.68
Monsoon	0.36	0.71
Post-monsoon	1.09	0.27
Annual	0.36	0.71

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

Parameter	Corrrected Zc	P-value	Trend	Sen's slope
January	-0.56	0.57	NS	0
February	-0.13	0.88	NS	0
March	0.3	0.75	NS	0
April	0.67	0.49	NS	0.12
May	1.22	0.02	*	0.28
June	0.13	0.89	NS	0.06
July	0.37	0.71	NS	0.61
August	0.28	0.77	NS	0.24
September	0.03	0.97	NS	0.05
October	1.35	0.17	NS	1.08
November	-0.16	0.87	NS	0
December	-1.17	0.24	NS	0

*NS- Non-significant trend *-Significant trend*

Table 5. Modified Mann-Kendall test of trend analysis of annual and seasonal rainfall data

Parameter	Corrrected Zc	P-value	Trend	Sen's slope
Pre-monsoon	0.53	0.59	NS	0.22
Monsoon	0.05	0.95	NS	0
Post-monsoon	1.01	0.31	NS	0.87
Annual	0.89	0.37	NS	2.05

NS- Non-significant trend

Table 6. Innovative trend analysis (ITA) of seasonal and Annual Rainfall of Mahabubnagar, Telangana

			α=0.10		α=0.05		α=0.01	
Parameter	**Trend slope**	**Trend Indicator**	**LCL**	**UCL**	**LCL**	**UCL**	**LCL**	**UCL**
January	-0.07	-3.4	-0.04	0.04	-0.05	0.05	-0.06	0.06
February	0.08	3.27	-0.06	0.06	-0.08	0.08	-0.10	0.10
March	0.18	5.53	-0.16	0.16	-0.19	0.19	-0.25	0.25
April	0.15	1.72	-0.05	0.05	-0.06	0.06	-0.08	0.08
May	0.17	1.07	-0.11	0.11	-0.13	0.13	-0.18	0.18
June	0	0	-0.08	0.08	-0.104	0.104	-0.13	0.13
July	0.78	1.12	-0.16	0.16	-0.19	0.19	-0.25	0.25
August	0.79	1.03	-0.21	0.21	-0.25	0.25	-0.33	0.33
September	-0.14	-0.2	-0.21	0.21	-0.25	0.25	-0.32	0.32
October	1.09	2.72	-0.14	0.14	-0.17	0.17	-0.22	0.22
November	-0.35	-4.16	-0.04	0.04	-0.05	0.05	-0.06	0.06
December	-0.12	-3.54	-0.03	0.03	-0.04	0.04	-0.05	0.05
Pre-monsoon	0.51	1.81	-0.13	0.13	-0.15	0.15	-0.2	0.2
Monsoon	1.43	0.54	-0.69	0.69	-0.82	0.82	-1.09	1.09
Post-monsoon	0.52	0.92	-0.26	0.26	-0.31	0.31	-0.41	0.41
Annual	2.46	0.7	-0.54	0.54	-0.65	0.65	-0.85	0.85

3.2 Results of Rainfall Trend Analysis Using Modified Mann-Kendall Test and Sen's Slope Estimator

The results of Modified Mann-Kendall trend analysis for rainfall in Mahabubnagar, Telangana state was depicted in Table 4. The analysis revealed a significant increasing trend in rainfall for the month of May, as indicated by the Z-transformed test statistic being significant at the 5% level of significance. There was no significant trend was observed in the other months, as the test results were non-significant. Modified Mann-Kendall trend analysis for rainfall in Mahabubnagar district, Telangana state was depicted in the Table 5. The period 1980 to 2023 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 [2] and [18] provide similar results of trend with Modified Mann-Kendall test.

The results of both the Mann-Kendall test and the modified Mann-Kendall test are highly similar [19]. The Z values from the modified Mann-Kendall test, which includes specific corrections, closely match those from the standard Mann-Kendall test. This indicates that the corrections applied to the Z values did not significantly impact the overall trend detection outcome in this analysis.

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. The results indicated that February exhibited increasing trends at the 10%, 5%, and 1% significance levels. Conversely, the data for November and December revealed decreasing trends at the 10% and 5% significance levels, respectively. The remaining months showed no significant trends at the 10%,5%, and 1% significance levels. Similarly, pre-monsoon, monsoon, post-monsoon, winter, and annual rainfall displayed no significant patterns in the data. and similar results were also obtained in [20,21] where Innovative trend analysis accurately identifies the trends compared to the non-parametric test.

4. CONCLUSION

This study employed both parametric and non-parametric methods to analyze long-term trends in monthly, seasonal and annual rainfall patterns for the Mahabubnagar district of Telangana State from 1980 to 2023. The parametric approach used linear regression to identify trends in the rainfall data, revealing both increasing and decreasing patterns. Non-parametric methods, including the Modified Mann-Kendall test and Innovative Trend Analysis (ITA), were also applied. The Modified Mann-Kendall test highlighted a significant increasing trend in rainfall during May, while other months, monsoon seasons and annual rainfall showed no significant trends. The ITA method indicated a significant increasing trend in February and decreasing trends in November and December, with no significant trends observed in other months, the monsoon seasons, and annual rainfall. The variability in rainfall identified through this study underscores the need for improved decision-making to address future climate uncertainties.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vinay HT, Ghosh A, Ojha S, Poddar P, Basak P. Trend Analysis of Rainfall and Detection of Change Point in Terai Zone of West Bengal. International Journal of Environment and Climate Change. 2024; 14(1):603-613.
2. 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.
3. Fulekar M, Kale. Impact of climate change: Indian scenario. University News. 2010; 48(24):14-20.
4. Trenberth KE, 2007. Observation: surface and atmospheric climate change. Climate Change 2007: The Physical Science Basis. Contribution of working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
5. Kumar V, Jain SK, Singh, Y. Analysis of long-term rainfall trends in India. Hydrological Sciences Journal–Journal des Sciences Hydrologiques. 2010;55(4): 484-496.
6. 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.

7. 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.
8. 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.
9. Li J, Wu W, Ye X, Jiang H, Gan R, Wu H, He J, Jiang Y. Innovative trend analysis of main agriculture natural hazards in China during 1989–2014. Natural Hazards. 2019;95: 677-720.
10. Latha KN, Venkataviswateja B, Yamini T, Rao VS, Sarada C. Trend Analysis of Long Term and Seasonal Rainfall in Guntur District of Andhra Pradesh for Implementing Appropriate Measures to Manage Water Resources April - June, 2024. 59-65
11. Pohlert T. Non-parametric trend tests and change-point detection. CC BY-ND. 2016; 4:1-18.
12. Sen PK. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. 1968; 63:1379–1389.
13. Gujree I, Ahmad I, Zhang F, Arshad A. Innovative trend analysis of high-altitude climatology of Kashmir valley, NorthWest Himalayas. Atmosphere. 2022;13(5):764.
14. 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.
15. 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; 5(3):21–38.
16. 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.
17. Jyostna B, Meena A, Rathod S, Tuti MD, Kallakuri S, Bhanusree D, Reddy BNK. Trend analysis of rainfall in Telangana State (India) Using Advanced Statistical Approaches. 2022.
18. 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.
19. Laasya, KNVL, Kallakuri S, Rathod S, Neelima L, Meena A, Jyostna B. Statistical Assessment of Temperature Trends and Change Points in Telangana State, India. International Journal of Environment and Climate Change. 2024;14(4):397-407.
20. Wallis WA, Moore GH. A significance test for time series and other ordered observations. Tech. Rep. 1. National Bureau of Economic Research. New York. 1941.
21. 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.

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