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Trend Analysis of Rainfall and Detection of Change Point in *Terai* Zone of West Bengal

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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

Analyzing rainfall trends is crucial for understanding climate patterns to managing water resources and planning agriculture. Trends in rainfall can reveal shifts in climate conditions, whether it is an increase, decrease, or fluctuate over time. The present study intends to examine the long-term trend in monthly, seasonal and annual rainfall in Cooch Behar district of West Bengal spanning from 1969 to 2022. Wallis and Moore test applied to determine the randomness of rainfall, whereas,

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linear regression trend line, Mann-Kendall (MK) test, Modified-Mann Kendall (MMK) test, and Innovative Trend Analysis (ITA) are used to understand the trend pattern in rainfall. MMK test reveals a significant decreasing trend in November month. In contrast, the remaining months, seasonal and annual rainfall revealed non-significant trend. According to the ITA approach, there was a significant increase in rainfall of January and a significant decrease in rainfall of November and December. The Pettitt's test identified November 2006 as a trend changing year and there was no significant change point for the remaining months, seasonal and annual rainfall.

Keywords: Rainfall; Trend Analysis; Mann-Kendall test; Innovative Trend Analysis and Pettitt's test.

1. INTRODUCTION

Rainfall is a fundamental component of the Earth's hydrological cycle, playing a critical role in shaping ecosystem and influencing agriculture and water resource availability. Extreme weather events such as droughts and floods, caused by climate change, significantly impact agriculture and hydrology. Therefore, understanding the trends and variations in rainfall patterns is helpful for rainfall forecasting, water resources planning, irrigation practices, and construction of water storage structures. The rainfall data can also help industrial development, water supply systems, and climatic disaster management in the present and future. The agricultural economy in India heavily relies on the regular distribution of rainfall, with over 80% of it occurring during the monsoon months from June to September. Deviations in the spatial and temporal patterns of Southwest Monsoon rainfall (SWM) present significant challenges to the agricultural production system, impacting the Indian economy. The SWM rainfall over India was in decreasing trend during 21st century, while increasing trend observed in pre-monsoon and post-monsoon season [1]. It was evident that negative monsoon rainfall shocks in India lead to a 16% decrease in agricultural output, while positive shocks have no significant effects [2]. Similarly, a positive increasing trend in rainfall with a magnitude of 2.13 mm per year in Visakhapatnam, Andra Pradesh [3]. The trend and magnitude of rainfall were studied in the Jaisalmer district of Western Rajasthan, India, using data over a period of 121 years [4]. It was identified that the year 1992 was the trend-changing year and it was also noted a significant rise in mean annual rainfall after that year. A significant decreasing trend in the total annual rainfall at a rate of 14.31mm per year was found in the Dinhata subdivision of Cooch Behar [5]. Furthermore, in West Bengal, wide variations in both annual and seasonal rainfall were noted, with abrupt changes in rainfall distribution directly impacting the predominant agricultural system. As a result, the proper knowledge of inter annual and seasonal rainfall variability, their trends in rainfall are necessary for decision-making in sectors such as agriculture, water resource management, and disaster management. Analyzing rainfall distribution patterns in a particular region requires trend analysis to ascertain changes in precipitation over a specified time period. Two commonly employed nonparametric methods for capturing monotonic trends are the Mann-Kendall (MK) and Spearman's rho (SR) methods, as highlighted in various studies [6-8]. Recent literature, including investigations by [9,10,5,11-13] has further delved into the application of MK tests and Sen's slope estimator for rainfall trend analysis. However, MK and SR approaches face limitations associated with assumptions such as the presence of normality and absence of serial correlation of the time series. To overcome these constraints, Innovative Trend Analysis (ITA) method was introduced for investigating trends in hydrometeorological variables. Significantly, the ITA method eliminates the necessity for prewhitening time series data [14]. The effectiveness of ITA method in detecting rainfall trends was demonstrated in several studies [15,16]. This research seeks to contribute valuable insights in rainfall trends in Cooch Behar district of West Bengal by employing statistical techniques such as Mann-Kendall, Modified Mann-Kendall, and Sen's slope but these methods are highly dependent on sample size and data distribution. Therefore, Innovative Trend Analysis (ITA) was employed to enhance understanding of the complex dynamics of rainfall trends, fostering a more resilient and sustainable approach to addressing the challenges posed by a changing climate thereby assisting policymakers, scientists, and stakeholders in formulating adaptive strategies to address the consequences of evolving rainfall patterns.

2. METHODOLOGY

2.1 Study Area

Cooch Behar is a former princely state, it is located in the *Terai* agro-climatic zone of West Bengal. It lies between 25°57'47" to 26°36'2" North latitude and between 88°47'44" to 89°54'35" East longitude. The district area is about 3387 km^2 and contributes about 3.87 per cent of West Bengal's mass land. Fig. 1 depicts the study area map of Cooch Behar district, West Bengal State. For this study monthly rainfall data of Cooch Behar district from January 1969 to December 2022 was collected from IMD (India Meteorological Department), Pune and Govt. of West Bengal. To investigate the variability in rainfall patterns, various trend analysis methods have been applied to the data. The analysis aims to elucidate the trend patterns in pre-monsoon (March-May), southwest monsoon (June-September), post-monsoon (October-November), winter (December-February), and annual rainfall [17].

2.2 Trend Analysis

A trend in a time series dataset denotes a discernible pattern, which can either be positive or negative, indicating an upward or downward direction. Estimating this trend involves the application of statistical tests, which may be parametric or non-parametric. In this study, parametric and non-parametric tests such as Linear regression, Wallis and Moore Phase-Frequency test, Mann-Kendall's test, Sen's slope estimator, Modified Mann-Kendall test and Innovative Trend Analysis (ITA) were employed to identify the trend in rainfall data and Pettitt's test was used to detect the change point over a period of year.

2.2.1 Wallis and moore phase-frequency test

This test is used to test the randomness in time series [18].

Test procedure:

Null Hypothesis (H_0) =Time series is random in nature.
Alternative Hypotheses (H_1) = Time series is non-random in nature.

Test statistic:

$$Z = \frac{\left|h-\left(\frac{2n-7}{3}\right)\right|}{\sqrt{\frac{16n-29}{90}}}$$

Where,

h is the number of phases.

2.2.2 Linear regression

The linear regression analysis is one of the most often used parametric models for detecting trends in data series. This model defines a relationship between the two variables, dependent and independent, by applying a linear equation to the collected data. The linear regression model is broadly defined by the equation:

$$Y = a + mX$$

Where, *Y* is the dependent variable, *X* is the independent variable, *m* is the slope of the line, *a* is the intercept constant.

2.2.3 Mann-Kendall (MK) test

Mann-Kendall trend (MK) test is a nonparametric test, which is an alternative method to the parametric method of trend analysis. It is the most suitable test for detecting the trend for rainfall data. The Mann-Kendal statistic (S) is given in the following equation:

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

Where, x_j and x_i are the annual values in year's j and i, j $> i$ respectively. 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:

$$\mathrm{E}(S) = 0$$
$$Var(S) = \frac{1}{18} n(n-1)(2n+5) - \sum_{i=1}^{n} t_i\,(i)(i-1)(2i+5)$$

Computing the MK test statistic, Z_{MK} , is performed as follows:

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

A positive and negative value of z 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 $||z_{MK}| \geq z_{1-\alpha/2}$.

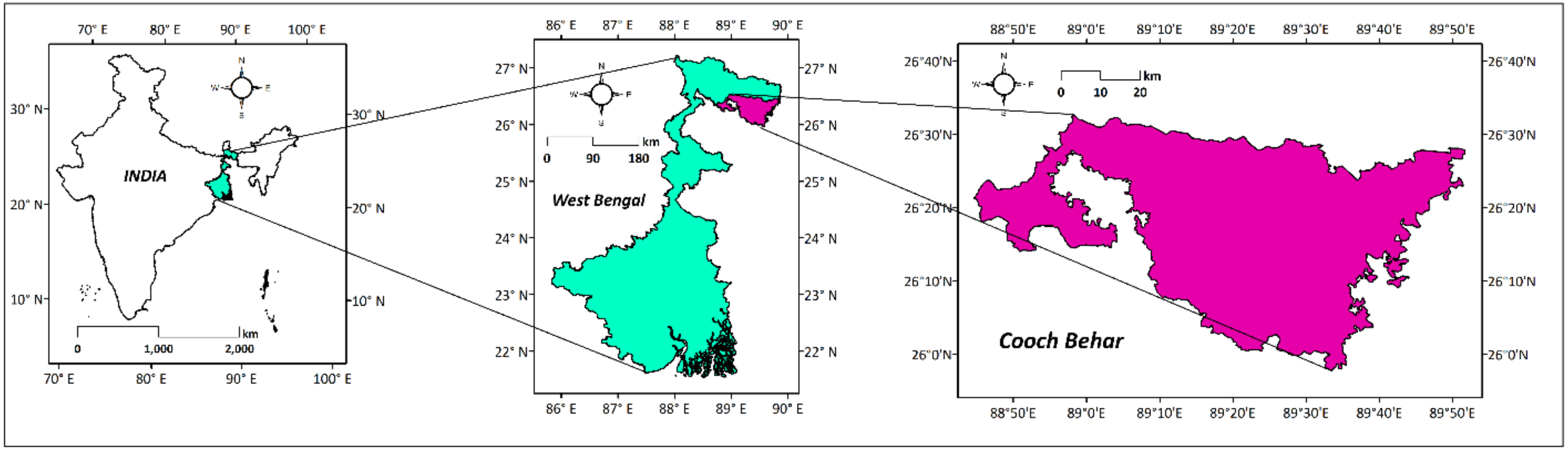

Fig. 1. Study area map of Cooch Behar district, West Bengal

2.2.4 Modified Mann-Kendall (MMK) test

The modified Mann-Kendall test is a non-parametric statistical technique employed to assess monotonic trends, whether upward or downward, in a series characterized by positive autocorrelation. Additionally, it addresses the challenge of serial correlation by incorporating a variance correction approach [19]. The variance of s statistic is given as follows:

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

Where, n is the Actual Sample Size (ASS) of data, n/n^{*} is termed the Correction Factor (C F). $V(S)$ is s 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 ($||z_{MMK}| \geq z_{1-\alpha/2}$).

2.2.5 Sen's slope estimator

Sen's slope estimator has been widely used for determining the magnitude of a trend. The Sen's slope estimator is a linear slope estimator that works most effectively on monotonic data. Unlike linear regression, it is not greatly affected by data errors, outliers, or missing data. Here, the slope (T_i) of all data pairs can be computed by

$$T_i = \frac{x_j - x_i}{j-i} \quad \text{for } i = 1,2,\ldots,n$$

Where, x_j and x_i are considered as data values at time j and i (j > i) correspondingly. The median of these n values of T_i is represented as Sen's estimator of the slope, which is given as

$$Q_{Med} = \begin{cases} T_{\frac{N+1}{2}} \; if \; N \; is \; odd \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) \; if \; N \; is \; even \end{cases}$$

Sen's estimator is computed as $Q_{Med} = T_{\frac{N+1}{2}}$ if N appears odd, and it is considered as $Q_{Med} = \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right)$ if N appears even. In the end, $Tmed$ is computed by a two-sided test at $100(1-\alpha)$ % confidence interval and then a true slope can be obtained by this non-parametric test [20].

2.2.6 Innovative trend analysis

ITA is not sensitive to the serial correlation present in the data. This method is based on dividing the data series into two halves and comparing them. The two halves are arranged in ascending order, and the first and second halves are plotted on X-axis and Y-axis respectively, with a $1:1$ (45^0) straight line on them. If the data are gathered on the straight line, then they show no trend, and gathering of data points above and below the straight line represents increasing and decreasing trend respectively. The trend slope is calculated by

$$S_{ITA} = \frac{10(\bar{x} - \bar{y})}{n}$$

The confidence limits of the trend slope are given by

$$CL_{(1-\alpha)} = 0 \pm S_{cri} \times \sigma_S$$

Where, α is the significance level, $S_{cri}$the critical value and σ_S is the standard deviation of the slope. The slope S_{ITA} of time series is statistically significant if it falls outside the confidence limits.

2.2.7 Pettitt's test

It is used for detection of change point. The non-parametric [21] test makes no assumptions regarding the distribution of the data. Pettitt's test modifies the Mann–Whitney test based on ranks to determine the shift's time of occurrence. The null hypotheses under the test is no change in distribution of time series.

$$\text{Test Statistic } U_t = \sum_{i=1}^{t}\sum_{j=t+1}^{n} sign(x_i - x_j)$$

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

The most significant change point selected using test statistic K_t is given by $K_T = Max|U_t|$.

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistics

The descriptive statistics, which included mean, standard deviation (SD), coefficient of variation (CV), skewness, and kurtosis, are shown in Table 1. July had the highest monthly average rainfall of 756.13mm, followed by June. The rainfall variability was explained by CV, *i.e.,* rainfall variability is less if CV is less than 20%, moderate if CV is 20 to 30%, and high if CV is greater than 30% [22]. The CV of rainfall for the current study ranged from 36.34 to 183.64%, indicating that there is increased variability in the rainfall data over time. The skewness values range from 0.10 to 2.62, and kurtosis values range from -0.74 to 7.96. The maximum skewness and kurtosis readings were observed in January, with 2.62 rightly skewed and 7.96 indicating leptokurtic, respectively. The summary figures for the monsoon seasons, and annual rainfall are shown in Table 2. The annual precipitation CV was 21.71%. The standard deviation was 723.10, the skewness was 0.10, suggesting rightly skewed, and the kurtosis was - 0.13, indicating platykurtic form. The CV among monsoons was lower in the monsoon, at 23.49%, and higher in the winter, at 107.33%. The distribution of Annual and Seasonal rainfall pattern is depicted in Fig. 2.

3.2 Linear Regression Trend

The annual rainfall in Cooch Behar, West Bengal is depicted in Fig. 3. Annual rainfall is subjected to a linear regression analysis. It showed a linear trend line falling over the annual rainfall time series from 1969 to 2022. On an annual basis,

Table 1. Descriptive statistics of monthly rainfall (mm) of Cooch Behar, West Bengal

Months	Mean	SD	CV	Skewness	Kurtosis
January	7.34	13.08	178.37	2.62	7.94
February	16.31	23.43	143.71	2.60	7.96
March	43.30	39.61	91.49	0.71	-0.74
April	156.49	101.46	64.84	1.59	4.06
May	342.94	143.61	41.88	1.58	2.76
June	708.67	257.54	36.34	0.10	-0.66
July	756.13	312.09	41.27	0.44	-0.03
August	597.42	320.33	53.62	1.28	2.43
September	530.54	253.36	47.75	1.53	3.24
October	156.50	119.53	76.38	1.18	1.58
November	9.85	14.36	145.74	1.68	2.21
December	4.86	8.93	183.64	2.15	3.82

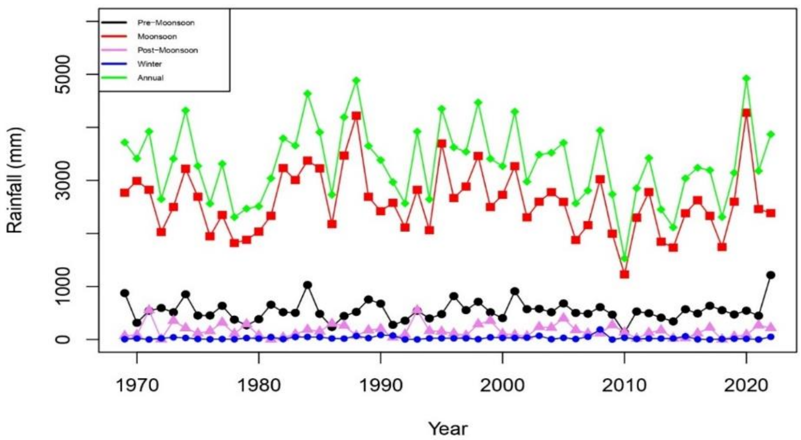

Fig. 2. Annual and Seasonal rainfall distribution pattern of Cooch Behar, West Bengal

Table 2. Descriptive statistics of seasonal and annual rainfall (mm) of Cooch Behar, West Bengal

Seasons	Mean	SD	CV	Skewness	Kurtosis
Pre-monsoon	542.73	193.10	35.58	1.07	2.42
Monsoon	2592.76	609.04	23.49	0.59	0.72
Post-monsoon	166.35	124.98	75.13	1.22	1.74
Winter	28.50	30.59	107.33	3.01	13.60
Annual	3330.34	723.10	21.71	0.10	-0.13

the graph displays the increasing and decreasing rainfall trend pattern from 1969 to 2022. The Coefficient of Determination (R^2) is of lower magnitude, which indicates that linear regression method is not a better fit for the data under consideration. The results of linear regression analysis were presented in Table 3.

3.3 Wallis and Moore Phase-Frequency Test

Randomness of the time series for monthly, seasonal and annual rainfall data was identified using Wallis and Moore Phase-Frequency test [23]. Table 4 shows that the monthly, seasonal, and annual rainfall data were non-random in nature as exact level of significances for all series were found to be greater than 5%. The MMK test was utilized for the study since it was more efficient when auto-correlation was included in the data [19].

3.4 Modified Mann-Kendall Trend Test and Sen's Slope Estimator

Table 5 shows the findings of MMK trend analysis for monthly rainfall in Cooch Behar, West Bengal state. A significant decreasing trend (-0.08mm year $^{-1}$) was observed in the month of November, as the Z transformed test statistic is significant at 5% level of significance and there was no significant trend in the subsequent months; similar results were found by [5]. The Z transformed test statistic is non-significant, indicating that there was no significant trend in the monsoon seasons and annual rainfall during the study period, as shown in Table 6.

3.5 Innovative Trend Analysis of Monthly, Seasonal and Annual Rainfall Data

The trend slope, trend indicator, Lower Confidence Level (LCL) and Upper Confidence Level (UCL) at 90%, 95% and 99% of monthly, seasonal and annual rainfall of Cooch Behar, West Bengal state is depicted in Table 7. The results demonstrated that in the month of January showed the increasing trends at 10, 5 and 1% level of significance, respectively. The data for the months of November and December revealed a decreasing trend at the 10 and 5 % level of significance, respectively, whereas the remaining months showed no significant trend at the 10, 5 and 1% level of significance. Pre-monsoon, monsoon, post-monsoon, winter, and annual rainfall also exhibited no significant pattern in the data.

Table 3. Linear regression analysis of annual rainfall

Parameter	Coefficients	Standard Error	Table value	P-value
Intercept	3481.20	200.04	17.40	<0.05*
Rainfall(mm)	-5.48	6.33	-0.87	0.39^{NS}

NS: Non-significant trend
**Statistically significant trends at the 5% significant level*

Table 4. Wallis and moore phase frequency test of monthly, seasonal and annual rainfall(mm) of Cooch Behar, West Bengal

Months/Seasons	Z- value	P- value
January	0.44	0.66
February	0.87	0.38
March	1.09	0.27
April	1.53	0.12
May	0.54	0.58
June	0.77	0.44
July	1.53	0.12
August	0.44	0.67
September	0.55	0.58
October	1.20	0.23
November	1.09	0.27
December	0.11	0.91
Pre-monsoon	0.11	0.91
Monsoon	1.20	0.23
Post-monsoon	1.86	0.06
Winter	0.22	0.83
Annual	1.20	0.23

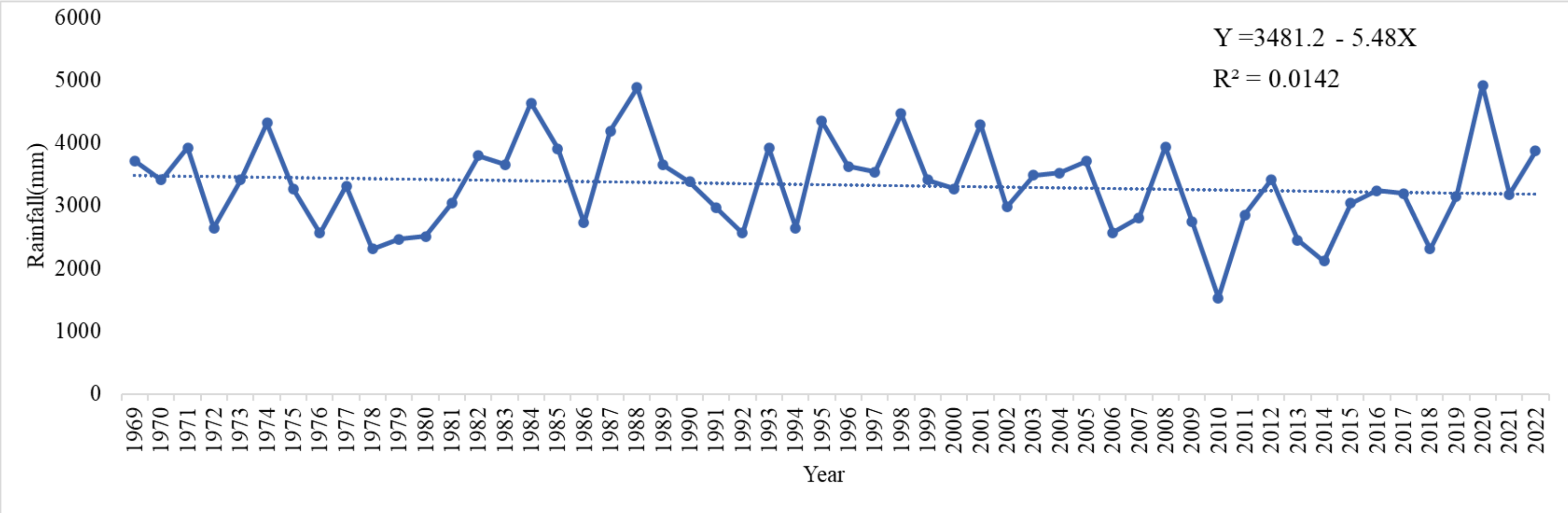

Fig. 3. Trend of annual rainfall of Cooch Behar, West Bengal

Table 5. Modified Man-Kendall test of trend analysis and Sen's slope estimator of monthly rainfall (mm) of Cooch Behar, West Bengal

Months	Modified Man-Kendall test				Sen's slope Estimator
	Z-value	P- value	Tau value	Trend	
January	-1.33	0.18	-0.12 NS	No Trend	-0.01
February	0.79	0.43	0.07 NS	No Trend	0.07
March	1.35	0.18	0.10 NS	No Trend	0.29
April	0.76	0.44	0.06 NS	No Trend	0.48
May	0.00	1.00	0.00 NS	No Trend	0.00
June	-0.62	0.53	-0.06 NS	No Trend	-1.57
July	-1.14	0.25	-0.09 NS	No Trend	-2.63
August	0.12	0.90	0.01 NS	No Trend	0.33
September	-1.07	0.28	-0.10 NS	No Trend	-1.90
October	-0.38	0.70	-0.04 NS	No Trend	-0.41
November	-4.46	**<0.01**	-0.24 **	**Decreasing**	-0.08
December	-0.88	0.37	-0.08 NS	No Trend	0.00

NS: Non-significant trend
Z: normalized test statistics
**Statistically significant trends at the 5% significant level*
***Statistically significant trends at the 1% significant level*

Table 6. Modified Man-Kendall test of trend analysis and Sen's slope estimator of seasonal and annual rainfall (mm) of Cooch Behar, West Bengal

Seasons	Modified Man-Kendall test				Sens's slope Estimator
	Z-value	P- value	Tau value	Trend	
Pre-monsoon	0.11	0.91	0.01 NS	No Trend	0.21
Monsoon	-1.41	0.15	-0.11 NS	No Trend	-6.24
Post-monsoon	-0.59	0.55	-0.06 NS	No Trend	-0.62
Winter	0.00	1.00	0.00 NS	No Trend	0.00
Annual	-0.99	0.32	-0.09 NS	No Trend	-6.44

NS: Non-significant trend

Table 7. Innovative trend analysis (ITA) for monthly, seasonal and annual rainfall(mm) of Cooch Behar, West Bengal

Months / seasons	Trend Slope (mm/year)	Trend Indicator	$\propto = 0.10$		$\propto = 0.05$		$\propto = 0.01$	
			LCL	UCL	LCL	UCL	LCL	UCL
January	**0.08**	**3.60**	**-0.02**	**0.02**	**-0.03**	**0.03**	**-0.05**	**0.05**
February	0.16	3.27	-0.06	0.06	-0.08	0.08	-0.10	0.10
March	0.74	6.02	-0.11	0.11	-0.13	0.13	-0.17	0.17
April	1.02	1.93	-0.29	0.29	-0.34	0.34	-0.44	0.44
May	-0.35	-0.27	-0.32	0.32	-0.39	0.39	-0.52	0.52
June	-1.07	-0.40	-0.59	0.59	-0.70	0.70	-0.92	0.92
July	-3.37	-1.13	-0.57	0.57	-0.68	0.68	-0.90	0.90
August	0.14	0.06	-1.10	1.10	-1.31	1.31	-1.72	1.72
September	-2.48	-1.19	-0.64	0.64	-0.76	0.76	-1.00	1.00
October	-0.67	-1.09	-0.26	0.26	-0.31	0.31	-0.41	0.41
November	**-0.32**	**-6.09**	**-0.04**	**0.04**	**-0.05**	**0.05**	-0.06	0.06
December	**-0.15**	**-6.01**	**-0.04**	**0.04**	**-0.05**	**0.05**	-0.06	0.06
Pre-monsoon	1.41	0.72	-0.49	0.49	-0.58	0.58	-0.76	0.76
Monsoon	-6.79	-0.68	-1.36	1.36	-1.62	1.62	-2.13	2.13
Post-monsoon	-0.99	-1.48	-0.24	0.24	-0.29	0.29	-0.38	0.38
Winter	0.09	0.97	-0.13	0.13	-0.15	0.15	-0.20	0.20
Annual	-6.26	-0.49	-1.60	1.60	-1.90	1.90	-2.50	2.50

3.6 Detection of Change in Point by Using Pettit's Homogeneity Test

Table 8. Detection of change in point by using Pettit's homogeneity test of monthly, seasonal and annual rainfall (mm) of Cooch Behar, West Bengal

Months / Seasons	Pettitt's test		
	KT	P- value	Change point (Year)
January	273	0.12	No
February	174	0.64	No
March	235	0.25	No
April	203	0.42	No
May	77	1.00	No
June	188	0.53	No
July	217	0.34	No
August	127	1.00	No
September	179	0.60	No
October	136	1.00	No
November	**332**	**0.03***	**2006**
December	207	0.40	No
Pre-monsoon	126	1.00	No
Monsoon	259	0.16	No
Post-monsoon	156	0.80	No
Winter	182	0.57	No
Annual	235	0.25	No

**Statistically significant trends at the 5% significant level*

The change detection analysis of monthly, seasonal, and annual rainfall (mm) has been conceded using Pettitt's test, and the results are shown in Table 8. A significant change point was found for the month of November in the year 2006, and all other remaining months were found to be non-significant, indicating absence of change point for rainfall data in the remaining months. Similarly, non-significant result for pre-monsoon, monsoon, post-monsoon, winter and annual rainfall also indicates the absence of change point in seasonal and annual rainfall.

4. CONCLUSIONS

The study investigated the monthly, seasonal and annual trends in rainfall at Cooch Beahr district of West Bengal state from 1969 to 2022. Wallis and Moore Phase-Frequency test revealed the presence of auto-correlation in the data over time. To find long-term trends in the data, the parametric method, namely, linear regression trend, and non-parametric tests, such as Modified-Mann Kendall (MMK) test and Innovative trend analysis (ITA), were utilized. The linear regression trend results indicated that there were both increasing and decreasing trend patterns in the rainfall data. The MMK test found a significant decreasing (-0.08 mm year $^{-1}$) trend of rainfall in the month of November. Furthermore, we observed no statistically significant trend in the other months, as well as seasonal and annual rainfall. The ITA method reveals that the January month exhibited a significantly increasing trend, while the November and December months showed a significantly decreasing trend. The remaining months, as well as the monsoon seasons and annual rainfall, showed no significant trend. The Pettitt's test revealed the presence of significant change point in November of 2006, whereas, all other months, seasons, and annual rainfall showed no change in distribution of time series. The fluctuation of rainfall is a big issue, and the study findings may assist policymakers in making better decisions to combat with future climate risks and aid in comprehending the seasonal water budget, which is critical for crop planning, water security, and overall livelihood security of the farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ghosh MK, Dutta MK. Study & Analysis of Trends & Variability of Rainfall over Gangetic West Bengal. Int. Res. J. Mod. Eng. Technol. 2020; 2:18-27.
2. Hertweck M, Brey B. The Persistent Effects of Monsoon Rainfall Shocks in India: A Nonlinear VAR Approach; 2017.

3. Rao G, Sowjanya A, Shekhar D, Naik B, Kiran BVS. Rainfall analysis over 31 years of Chintapalle, Visakhapatnam, high altitude and Tribal zone, Andhra Pradesh, India. MAUSAM. 2023;74(3):685-698.
4. Singh H, Choudhary MP. Trend and homogeneity test analysis for rainfall over a 121-year time period in the desert district of Western Rajasthan, India. Water Practice & Technology. 2023;18(7):1681-1695.
5. Das J, Bhattacharya SK. Trend analysis of long-term climatic parameters in Dinhata of Koch Bihar district, West Bengal. Spatial Information Research. 2018;26:271-280.
6. Kendall MG. A new measure of rank correlation. Biometrika. 1938;30(1/2):81-93.
7. Mann HB. Nonparametric tests against trend. Econometrica: Journal of the Econometric Society. 1945;245-259.
8. Daniel WW. Applied Nonparametric Statistics; 1978.
9. Gajbhiye S, Meshram C, Mirabbasi R, Sharma SK. Trend analysis of rainfall time series for Sindh River basin in India. Theoretical and Applied Climatology. 2016; 125:593-608.
10. Verma MK, Verma MK, Swain S. Statistical analysis of precipitation over Seonath river basin, Chhattisgarh, India. International Journal of Applied Engineering Research. 2016;11(4):2417-23.
11. Isioma IN, Rudolph II, Omena AL. Non-parametric Mann-Kendall test statistics for rainfall trend analysis in some selected states within the coastal region of Nigeria. Journal of Civil, Construction and Environmental Engineering. 2018;3(1):17-28.
12. Hu Z, Liu S, Zhong G, Lin H, Zhou Z. Modified Mann-Kendall trend test for hydrological time series under the scaling hypothesis and its application. Hydrological Sciences Journal. 2020;65(14):2419-2438.
13. Halder P, Dey RK, Mandal S. Long-period trend analysis of annual and seasonal rainfall in West Bengal, India (1901-2020). Theoretical and Applied Climatology. 2023;154(1-2):685-703.
14. Sen Z. Innovative trend analysis methodology. Journal of Hydrologic Engineering. 2012;17(9):1042-1046.
15. Bora SL, Bhuyan K, Hazarika PJ, 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.
16. Chowdari KK, Deb Barma S, Bhat N, Girisha R, Gouda KC, Mahesha A. Trends of seasonal and annual rainfall of semi-arid districts of Karnataka, India: application of innovative trend analysis approach. Theoretical and Applied Climatology. 2023;152(1-2):241-264.
17. Datta P, Das S. Analysis of long-term seasonal and annual temperature trends in North Bengal, India. Spatial Information Research. 2019;27(4):475-496.
18. Wallis WA, Moore GH. A significance test for time series and other ordered observations. In A Significance Test for Time Series and Other Ordered Observations NBER.1941;1-67.
19. 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(3):201-218.
20. Mondal A, Kundu S, Mukhopadhyay A. Rainfall trend analysis by Mann-Kendall test: A case study of north-eastern part of Cuttack district, Orissa. International Journal of Geology, Earth and Environmental Sciences. 2012;2(1):70-78.
21. Pettitt A N. A non-parametric approach to the change-point problem. Journal of the Royal Statistical Society: Series C (Applied Statistics).1979;28(2):126-135.
22. Elzopy KA, Chaturvedi AK, Chandran KM, Gopinath GKN, Surendran U. Trend analysis of long-term rainfall and temperature data for Ethiopia. South African Geographical Journal. 2021;103(3): 381-394.
23. 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.

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