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Annual and seasonal Trend Analysis of Rainfall for Chamoli Region of Uttarakhand, India

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ABSTRACT: *This study investigates the annual and seasonal rainfall trends in the Chamoli region of Uttarakhand, India, using non-parametric tests such as the Mann-Kendall test and Sen's slope estimator. The analysis focuses on detecting changes in rainfall patterns over time, which are crucial for understanding the hydrological cycle and its impact on agriculture, water resources, and drought management. The results indicate significant positive trends in winter and pre-monsoon seasons, while post-monsoon and monsoon seasons exhibit slight increases without significant trends at the 10% significance level. The study highlights the need for further research into the temporal mapping of rainfall in the Garhwal region, addressing gaps in current literature, and contributing valuable insights for sustainable water resource management in the region.*
KEYWORDS: *Rainfall, Trend Analysis, Mann-Kendal Test, Uttarakhand, India*

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I. INTRODUCTION

The hydrological cycle may change both globally and locally because of rising global surface temperatures, according to the Intergovernmental Panel on Climate Change (IPCC 2018). One of the primary components of the hydrological cycle is rainfall, and an understanding of the patterns of its variability is crucial for comprehending the numerous aspects of climatological, hydrological, meteorological, and agricultural research carried throughout the world (Rana et al 2019, Singh et al 2021). Change in spatiotemporal variation, amount and type of rainfall is consequences of climate changes in most parts of the earth (Rana et al 2022). Rainfall is one of the dynamic elements in the hydrological cycle that can change in spatiotemporal patterns because of an increase in greenhouse gases. For hydrologists and agriculturalists to understand the spatiotemporal pattern and modelling of food and drought control, as well as for surface water storage or groundwater recharge, rainfall trend analysis is crucial around sustainable use of water resources. The distribution of soil moisture, runoff, and the frequency of food and droughts may all be impacted by changes in the spatiotemporal rainfall distribution (Bellu et al. 2016).

Around the world, a growing number of research have been carried out in the past year to use parametric and non-parametric tests to identify spatiotemporal trends in time series data, such as temperature, rainfall, runoff, and rainy days (Nisansala et al 2020, Caloiero et al 2020, Deoli et al 2023). Bera (2017) investigated rainfall trends in the Ganga Basin of India using Mann–Kendall and Sen's slope test. Bhagwati et al (2018) utilised a linear regression method to study trends in rainfall and rainy days for Basar (Arunachal Pradesh) in India between 1975 and 2015. Except for the post-monsoon season, there was no discernible trend in rainfall over the study period, however there was a steady increase. Venkatesh et al (2021) investigated the rainfall patterns in India's Western Ghats. Using the MK test, the authors investigated the trend in yearly rainfall and wet days. Additionally, they calculated the rainfall's spatial distribution and concluded that there was a mixed pattern overall, with a declining trend on rainy days.

Previously, very few studies have been made to study temporal mapping of rainfall for Garhwal Region of Uttarakhand. Most of the studies have been made for the temporal analysis of rainfall only. Changepoint of rainfall and rainy days for districts of Garhwal has not been studied yet so far. Based on the above reviews and research gap, this study was conducted with the following objectives: (i) to analyse the temporal trend in annual rainfall and rainy days using non-parametric test and (ii) to detect the magnitude of trend using Sen Slop Estimators

II. MATERIAL AND METHODS

Study Area: Geographically, Uttarakhand State stands on the northern part of India in the foothill of Himalaya, extending from 28.68 to 31.49° N and 77.51 to 81.10° with an altitude of 210 to 7817 m above mean sea level (Pratap et al. 2020). (Fig. 1). The state consists of 2 administrative division namely Garhwal and Kumaon.

Garhwal consist of 7 districts where as Kumaon consist of 6 districts. Chamoli is situated in the Garhwal which district headquarter is situated at 30.40N and 79.33 E.

Mann- Kendall test: Mann- Kendall test (Mann, 1945 and Kendall, 1975) is a non-parametric test used to determined trend in long term series data to check data follow either positive trend or negative trend or no trend (Deoli et al., 2022). It is the rank-based test for determining statistically trends in a time series data and is not affected by outliers. In the Mann - Kendall test, a time series x_p was ranked from p =1, 2, ..., n-1 and another time series x_q from = 2, 3, ..., n, where n is the number of data points. Each data point in x_p was then used as a reference point and compared with all other data points in xq (q >p), to obtain the values of the sign for each comparison using following equation

$$Sgn(x_q - x_p) = \begin{cases} +1 \text{ if } (x_q > x_p) \\ 0 \text{ if } (x_q = x_p) \\ -1 \text{ if } (x_q < x_p) \end{cases}$$

The Mann – Kendal's statistic S is calculated using following equation

where n is the number of observed data point. For n = 10, the Mann- Kendal's statistic S is approximately normally distributed with zero mean (Mann 1945, Kendall 1975). The variance of S is calculated as

where, m is the number of tied groups (a tied group is a set of sample data having the same value) and t is the number of data points in the p^{th} tied group.

The Z value might be calculated by following formula

if S > 0

Z = 0 if S = 0

if S < 0

Sen's Slope estimator: The magnitude of trend has been calculated as a trend slope using Sen's slope estimator test (Sen, 1968) which is a nonparametric test based on the liner model. The overall slope has been estimated by computing slope for all ordinal time point pair using the median of these slopes.

In this method, first the slope (S_i) of all data pairs is calculated by

S_i = for i = 1,2,3….N

Where y_j and y_k are value j and k for j>k respectively. The median of these N value is Sen's slope estimator and calculated as

for N is odd

for N is even

III. RESULTS

Basic statistical parameters such as mean coefficient of variation (CV), standard deviation (SD), and skewness coefficient (SC) were calculated. The table shows that the more than 75% of rainfall happens in monsoon season followed by 11.18% in pre-monsoon season. The maximum rainfall in monsoon was 1544 mm whereas the minimum rainfall was 980 mm with CV 20.48%.

Table 1: Seasonal rainfall characteristics over Chamoli District

Season	Max	Min	Mean	SD	CV (%)	SC	Contribution to annual Rainfall (%)
Winter	270	9.2	95.76	59.63	58.50	0.4	8.95
Post Monsoon	178.2	0	45.8	47.6	103.2	1.05	4.54
Pre-Monsoon	380	0	175.68	102.1	60.60	0.54	11.18
Monsoon	1544	405	980	215	20.48	0.02	75.33

Rainfall Trend Analysis and Magnitude of Trend: The graphical representation of Mann-Kendall z-statistic has been shown in figure 2 and tabulated in table 2. In Chamoli district, a significant positive trend was found based on MK test in winter and pre-monsoon season whereas in post-monsoon and monsoon season the rainfall trend in slightly increase from zero and no significant trend were found at 10% significance level.

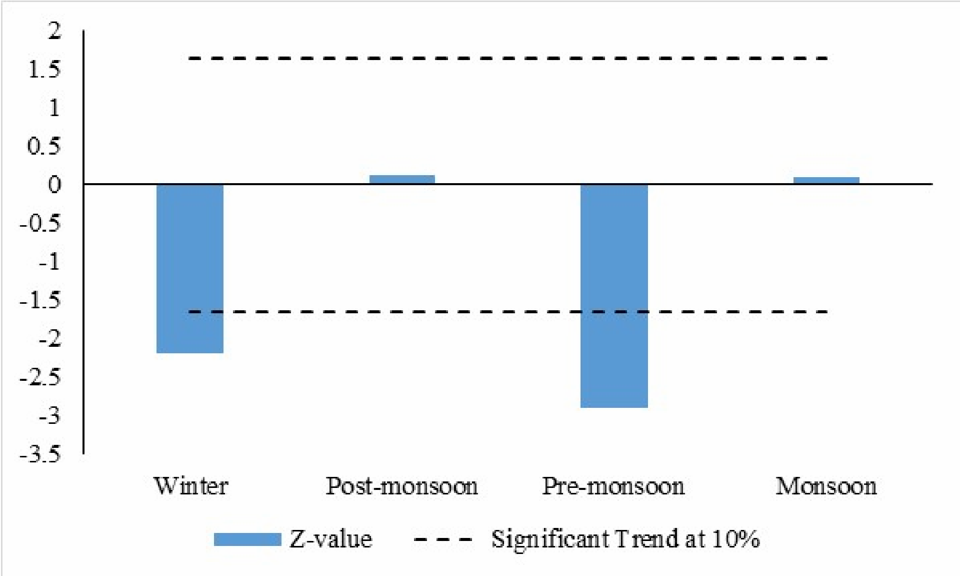

Figure 2: Mann-Kendall Z statistic for Chamoli District

Table 2: Z-value and trend magnitude for seasonal rainfall of Chamoli District

Season	Winter	Post-monsoon	Pre-monsoon	Monsoon
Z-value	-2.2	0.12	-2.9	0.1
Trend Magnitude (mm/year)	-2.51	1.12	-5.1	3.52

The magnitude of the trend of annual rainfall and rainy days was found using Sen's slope estimator test, and the results obtained from this test are reported in table 2. The trend magnitude was negative in winter (-2.51 mm/year), pre-monsoon (-5.1 mm/year) whereas the trend magnitude was positive in post monsoon season (1.12 mm/year) and monsoon season (3.52 mm/year).

IV. CONCLUSIONS

The analysis of rainfall trends in Chamoli district using the Mann-Kendall test and Sen's slope estimator reveals varied seasonal patterns. Significant negative trends were observed in winter and pre-monsoon seasons, while the post-monsoon and monsoon seasons showed slight positive trends, though not statistically significant. These findings underline the region's susceptibility to climatic variations, particularly in winter and pre-monsoon seasons, which could impact water resource management, agriculture, and drought preparedness. The study emphasizes the importance of continued monitoring and research to better understand and mitigate the effects of changing rainfall patterns in the Chamoli region.

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