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# Non-Parametric Trend Analysis in South-East Regions of Uttarakhand, India

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**ABSTRACT**

Rainfall estimation plays a vital role in planning irrigation schedule and managing discharge through small or big dams. In the last few years, the total rainfall has been observed to be concentrated only in few rainy days. The consequence of it may be in the form of flood or stability issues on the hydraulic structures. Thus, it is important to study the spread of total rainfall in a year. In the present study, the number of rainy days for Almora District of Uttarakhand has been used. The temporal data between 1987 to 2011 was collected from India Water portal. Statistical trend detection for the data was dome using Moving Average Models, Linear Regression Models and Mann Kendall Test. In this study, trend detection has been done for all the twelve months for the said time series. Moreover, trend detection was performed for annual average rainy days for mentioned said time series. The results showed that the months of February, March, November and December, the number of rainy days showed a decreasing trend, while for the months of January, April, May, June, August, September and October showed an increasing trend. The month of July for the said time series showed no trend. Further, annual rainy days showed no significant trend. Thus, in the said time series, annually seven months had shown an increasing trend, while four months has shown decreasing trend in rainy days.

## 1. Introduction

For sufficiency of water at agricultural, industrial and urban regions, rainfall is a very important source. In last few years, rainfall variation has been increased rapidly in every part of India. Due to low availability of rainfall, many problems like drought, depletion of groundwater, lack of fresh water, and difficulties in the survival of ecosystem, may occur. In order to describe about behavior or pattern of rainfall, it is very necessary to obtain the distribution of rainy days. Rainy days gives a brief knowledge in the forecasting of weather.

In the last few decades many researchers (Parthasarathy and Dhar, 1975; Partal, 2006; Caloiero et al., 2011) applied parametric and non-parametric techniques for detection of trend in rainfall data and also for rainy days.

Kumar and Jain (2010) had studied on rainfall data from 1901 to 2002 for the region of Kashmir valley, India, using Linear Regression (LR) and Mann-Kendall (MK) method. The analysis was done for annual and seasonal basis and the result suggested that three station showed decreasing trend for the period 1903 to 1982 and two stations were found to have low precipitation while one station had experienced high precipitation for the period of 1962 to 2002. Moreover, Pujol et al. 2007 examined trends of maximum rainfall data for rainy days using Maximum Likelihood (ML) and MK

method. The available data was from 1945 to 2004 having 92 rain gauge stations and study was done in the region of France. The results showed that rainy days were found to be decreasing in the month of March to April and increasing in the month of October.

Modarres and Silva (2006) did trend analysis on rainfall data for 30 years in the region of Iran using MK non parametric test. The analysis was carried out for 20 stations on annual and seasonal basis. The result showed that no variability was found in the territory of Iran but in winter and spring seasons, a significant trend was identified.

Furthermore, Jhajharia et al. (2012) worked on trend detection for 24 hours maximum rainfall and rainy days from 1951 to 2003 in region of Assam, India using parametric and non-parametric MK test. The study was carried out for 24-subtropical sites in northern territory of India. The study suggested that a significant trend was found and it was verified by both the tests. Applying MK-test at 95 % level of confidence, two sites showed decreasing trend in seasonal analysis and in monthly analysis, 17 sites were found to have increasing trend in the month of September.

To pin out above all work, we have done trend analysis using MK (non-parametric test), Moving Average (MA) and LR methods for Almora District of Uttarakhand state. The objective of the present study is to detect the seasonal and annual changes and to study the non-parametric trend analysis during the rainy days of Almora stations.

## 2. Study Area and Data Collection

The study was carried out for Kausani, Almora District, Uttarakhand. It is located at an elevation of 1,765m from the mean sea level (MSL) having latitudes and longitudes of 29°50.318 N and 79°36.516 E, respectively. The monthly data used in the present study was from the year 1987 to 2011. The temporal data was collected from India Water Portal (IWP, 2021) and study area is shown in Fig.1.

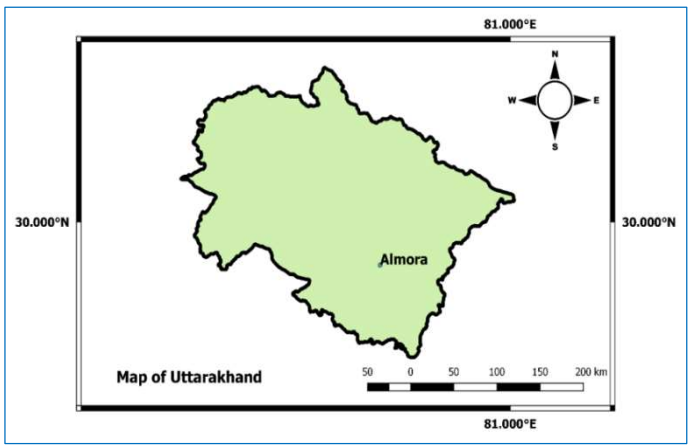


Fig. 1. Detail map of Almora District

## 3. Materials and Methods

In this study, trend detection for rainy days was performed using MK, LR and MA method for the available dataset. The analysis was done on seasonal, annual and monthly basis and the monsoonal months were considered as suggested by the Indian Metrological Department (IMD) as shown in Table 1.

Table 1. Seasonal months

| Seasons | Months |
|---|---|
| Winter | January – February |
| Pre-Monsoon | March – May |
| Monsoon | June – September |

### 3.1. MK Test

The MK (Mann, 1995; Kendall, 1975) test is the non-parametric test (data does not follows any distribution), and it is used to calculate the linear and non-linear trend. It also deals with the missing values in the data set. The MK test statistic for rainfall time series x1, x2, x3……xn of length 'n' is shown in equation 1:

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

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} +1 & if \quad (x_j - x_i) > 0 \\ 0 & if \quad (x_j - x_i) = 0 \\ -1 & if \quad (x_j - x_i) < 0 \end{cases} \quad (2)$$

$$\text{Var(s)} = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad (3)$$

$$Z_{cal} = \begin{cases} \frac{s-1}{\sqrt{Var(s)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{s+1}{\sqrt{Var(s)}} & if \quad S < 0 \end{cases} \quad (4)$$

Where; sgn(*) indicate the signum function and Var(s) shows variance of s. Also, $S$: MK test statistic, $n$: length of time series, $t_p$: number of ties for the p$^{th}$ values, $Z_{cal}$: calculated value of z-statistics, $z$: standard value of z-statistics, $q$: number of tied values and $x_i$ *and* $x_j$ are the sequential data values of the time series in the years $i$ and $j$.

## 4. Results and Discussion

In this study, trend analysis was carried out for all the twelve months for the said time series by LR models. The results indicated that for the months of February, March, November and December, the number of rainy days showed decreasing trend, whereas months of January, April, May, June, August, September and October showed an increasing trend. Thus, in the said time series, annually, seven months had shown an increasing trend, at the same time four months showed decreasing trend in rainy days. In month of July for the said time series showed no trend. Furthermore, in the October month, variations were found more with high and low values of rainy days as shown in the Fig. 2.

In seasonal (i.e., winter, pre-monsoon, post-monsoon, monsoon seasons) and annual analysis, the results suggested

that no significant trend detected as shown in the Fig. 3. Using MA method, a sharp deceasing trend has been detected for average annual rainy days as shown in Fig. 4.

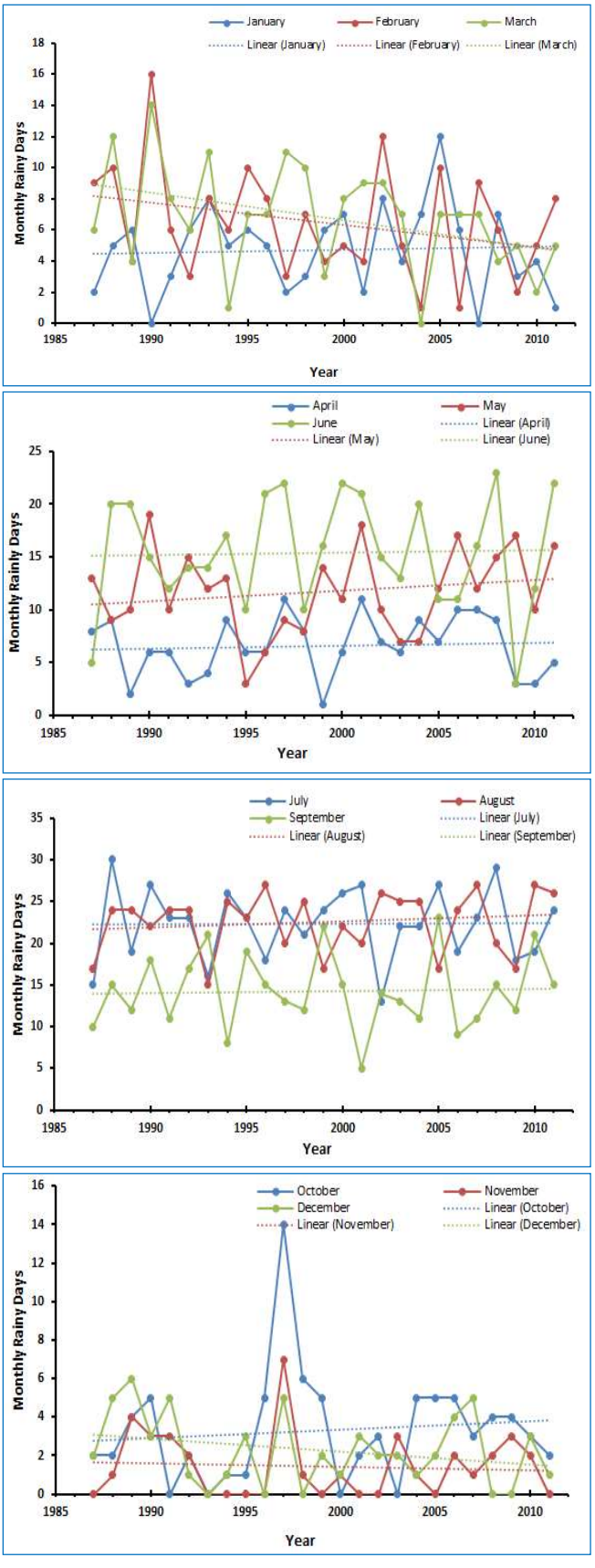


Fig. 2. Monthly analysis of rainy days

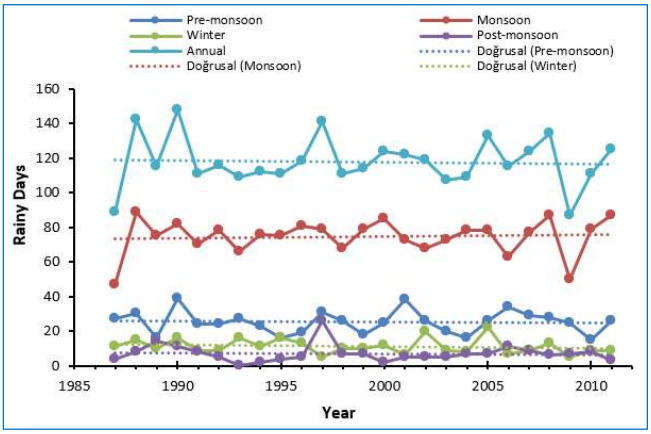


Fig. 3. Seasonal analysis of rainy days

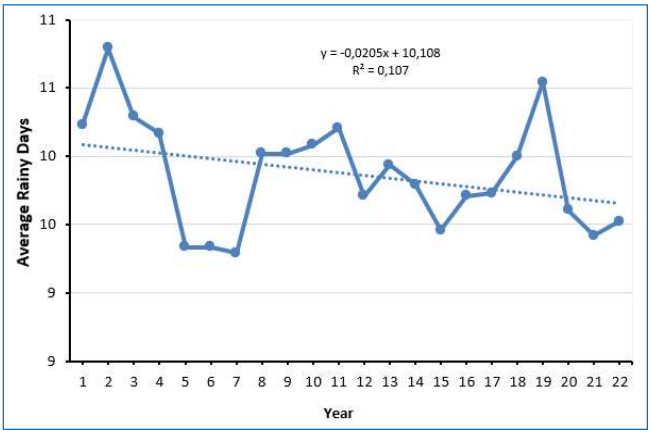


Fig. 4. Average-annual analysis for rainy days using MA method

Applying MK test, the results suggested that in the month of February, March and December had shown negative values and rest of the months except November (zero Z-value) had shown positive value of Z-statistics but in the month of March, estimated Z-value was found significant among all months. In seasonal analysis, pre-monsoon and winter seasons showed negative value whereas in monsoon and post-monsoon seasons indicated positive values of Z-statistics as shown in the Fig. 5.

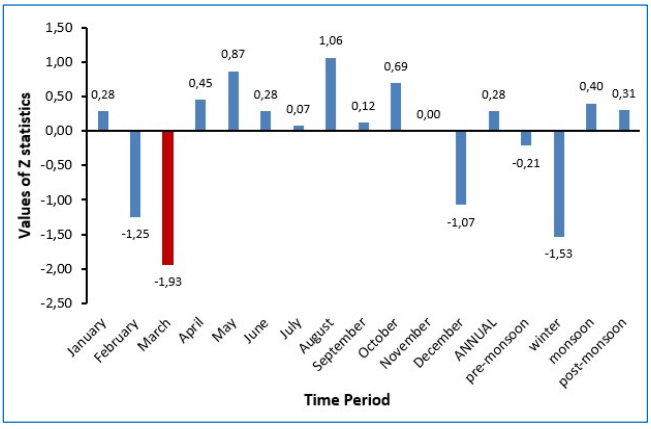


Fig. 5. Result of MK test

## 5. Conclusions

The study has been done for the Almora District of Uttarakhand state for exploring trend in rainy days. In this study no significant trend was found for the annual analysis as well as seasonal analysis of rainy days, but for monthly analysis, out of twelve months, seven months had shown increasing trend, whereas four months had shown decreasing trend. In MK test, calculated Z-value was found significant (95% confidence) for March month as compare to remaining months and seasons.

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