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TRENDS DETECTION OF RAINFALL IN ALLUVIAL GANGETIC PLAIN OF UTTARAKHAND

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ABSTRACT

The study intends to evaluate the trend of rainfall in gangatic alluvial plain of Uttarakhand. Rainfall data of 41 years (1976-2016) has been collected from Department of Hydrology, Indian IIT, Roorkee. Trends in annual, winter, pre-monsoon, monsoon, post-monsoon rainfall have been examined to show changing pattern of rainfall due to climate change. Significance and magnitude of trend has been determined using Mann-Kendall test and Sen's slope estimator respectively. Pre-whitening should be adopted to eliminate the effect of autocorrelation on trend in time series having significant autocorrelation. However no time series showed significant autocorrelation in our study. Results show that annual & all seasonal rainfall exhibited insignificant trend. An insignificant increasing trend of 2.638 mm/year is present in annual rainfall. Only Monsoon rainfall contribute major portion of annual rainfall, So trend nature of monsoon rainfall is same as of annual rainfall. Except monsoon rainfall, all time series of seasonal rainfall exhibited decreasing trend.

Index Terms- : Climate change, Mann-Kendall test, Rainfall, Sen's slope estimator

I. INTRODUCTION

Rain is a very precious gift of nature that is undoubtedly necessary for human beings, agriculture, animals and hydrological processes. Rainfall & some other parameters like temperature, humidity, and wind speed etc. shapes the environmental condition of particular region altogether. Studies to detect climate change and its impact on the various sectors deserve urgent attention in light of the impact of climate change on agriculture, increased risk of hunger and water scarcity, rapid melting of glaciers and decrease in river flows [1]. Rainfall is key parameter of climate. A significant change in rainfall pattern can cause increase in occurrence of droughts & floods, impact on water quality and many environmental conflict. Climate change may be described as any significant long-term change in the expected pattern of average weather of region (or the whole earth) over long period of time. Studies have found that human activities have contributed to an increase in concentrations of atmospheric greenhouse gases contributing to intensification of heavy rainfall events [2]. Many studies have been performed to address the issue of trends in rainfall in India since last century. Kumar V. et al. (2010) examined trends in the monthly, seasonal and annual rainfall on the meteorological sub-division scale, the regional scale, and for the whole of India [3]. A large data set was used, consisting of 306 stations with the length of data series of 135 years. As expected, the sub-divisional rainfall trends show a large variability. Nearly half of the sub-divisions have shown an increasing trend in annual rainfall and the remainders have shown the opposite trend.

Agriculture is contributing 21% to the country's GDP, employing 56.4% of the total workforce and supporting 600 million people directly and indirectly [4]. In Uttarakhand, Upper Ganga canal passing through the Haridwar district has a wide network of distributaries & minors. In addition, presence of loamy soil makes the gangetic

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plain more suitable for agriculture. Rainfall plays a great role to achieve high productivity. So it is highly necessary to detect the trend in rainfall so that appropriate crop selection, planning of irrigation can be done. Different researchers have used different-different methodologies to detect trend in record of hydrological data. Many change detection methodologies for climate parameters have been discussed by Kundzewicz (2004) [5]. Trends in annual, winter, pre-monsoon, monsoon, post-monsoon rainfall at Roorkee (Uttarakhand) have been analyzed in this study. Methods used to evaluate the trend in rainfall are Mann-Kendall test [6][7]and Sen's Slope estimator [8]. Mann Kendall test has been used to ascertain the existence of trend in hydrologic climatic variables with reference to climate change. Sen's Slope estimator method is used to determine the magnitude of trend in time series. Pre-whitening has been used to detect trend in time series having significant autocorrelation.

II. STUDY AREA & DATA USED

To detect rainfall trend in alluvial gangetic plain of Uttarakhand, Roorkee station has been taken as data collection station. Due to finer climatic & geographical heterogeneities, this data can provide only approximate overview of changing rainfall pattern in alluvial gangetic plain of Uttarakhand. Roorkee city is located at 29^o 52' N 77^o 53'E with an average height of 268 m from mean sea level. It is spread over a flat terrain having Himalayas in east & north-east direction. An absolute unpredictable continental climate exists over Roorkee due to its closeness to giant Himalaya. Climate is temperate & warm. There is lot of rain in driest month. Average annual temperature & annual rainfall of Roorkee is 23.7 ^{o}C and 1170 mm. Figure 1 shows the index map of study area.

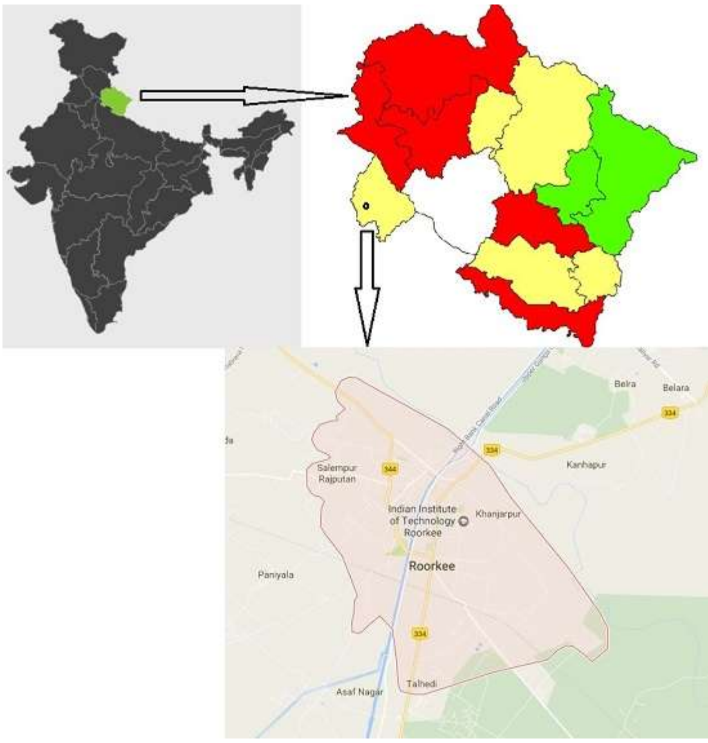

Figure 1: Index map of study area (Roorkee)

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Daily data of rainfall have been collected from Department of Hydrology, Indian Institute of Technology, Roorkee (Uttarakhand) for the duration 1976 to 2015 (40 years).

III. METHODOLOGY

Rainfall have significant influence on the hydrology of an area. Trend analysis is used to detect trends in the annual & seasonal time series of rainfall. Different types of trends in each climatic variable interpret different implications on water resources. In trend analysis of any time series, the magnitude & statistical significance of the trend have been derived. There are many parametric and non-parametric tests to detect the trend in time series of climatic variable. In the present study, Statistical significance of trend has been determined using a nonparametric method known as Mann-Kendall (MK) Test. Sen's slope estimator has been used to determine the magnitude of trend. A number of studies have been attempted using both methods to investigate the trend of climatic variables at Country scale [3][9] and regional scale [10][11].

3.1 Mann–Kendall test

To ascertain the presence of statistically significant trend in climatic variables such as rainfall and temperature with reference to climate change, Non-parametric Mann–Kendall (MK) test has been widely employed in earlier research [12][13][[14]. The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of rising or falling trend. The statistics (S) is defined as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \operatorname{sgn}(x_j - x_i) \qquad \ldots(1)$$

Where,

x_i = 1, 2, 3, 4 ……. N-1

x_j = i+1, i+2, i+3, i+4 ..…... N

Where N is the number of data points. Assuming $(x_j - x_i) = \theta$, the value of sgn(θ) is computed as follows:

$$\operatorname{sgn}(\theta) = \begin{cases} 1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases} \qquad \ldots(2)$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N > 10), the test is conducted using a normal distribution, with the mean and the variance as follows:

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

$$\operatorname{var}(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18} \qquad \ldots(4)$$

Where n is the number of tied groups (zero difference between compared values) and t_k is number of data points in the k^{th} tied group. The standard normal deviate (Z-statistics) is then computed as

$$Z = \begin{cases} \frac{S-1}{\sqrt{\operatorname{var}(S)}} & \text{if } S>0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\operatorname{var}(S)}} & \text{if } S<0 \end{cases} \qquad \ldots(5)$$

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If the computed value of $|Z| > z_{\alpha/2}$, the null hypothesis (H_0) is rejected at α level of significance in a two-sided test. In this study, the null hypothesis is tested at 90 %, 95%, 99 % & 99.9 % confidence level.

3.2 Sen's slope estimator

Sen's slope estimator has been widely used for determining the magnitude of trend in hydro- meteorological time series [15][16][17]. In this method, the slopes (T_i) of all data pairs are first calculated by:

$$T_i = \frac{(x_j - x_k)}{(j - k)} \qquad \ldots(6)$$

Where x_j and x_k are data values at time j and k ($j > k$) respectively. The median for these N values of T_i is Sen's estimator of slope which is calculated as:

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+1}{2}}\right) & N \text{ is even} \end{cases} \qquad \ldots(7)$$

A positive value of β indicates an increasing trend and a negative value indicates a decreasing trend in the time series.

3.3 Pre-whitening

Pre-whitening is used to detect the trend in time series having significant autocorrelation [13][18]. It has been performed by several techniques in earlier studies to limit the influence of autocorrelation on trend. Positive & negative autocorrelation may tend to overestimate & underestimate the probability of detecting trends respectively on applying Mann-Kendall test. Pre-whitening suggested by Von Storch (1995) has been employed in present study [19]. Many researchers used it to reduce the influence of an AR(1) component on the application of the MK test. Series having autocorrelation can be pre-whitened using following formula:

$$Y_t = X_t - r_1 X_{t-1} \qquad \ldots(8)$$

Where X_t is data of initial time series and Y_t is the data of pre-whitened time series. r_1 denotes autocorrelation coefficient at lag-1.

IV. RESULTS & DISCUSSION

Trend analysis has been performed for annual, winter, pre-monsoon, monsoon, post-monsoon time series of rainfall for the duration 1976 to 2016. The time series showing significant autocorrelation at 95 % confidence should be pre-whitened before trend analysis. In our study no time series showed significant autocorrelation. Graphs have been prepared to visualize the trend in these climatic parameters.

Table 1 shows the Mann-Kendall statistics Z & Sen's slope Q value for observed annual & seasonal rainfall at Roorkee station. Mann Kendall statistics Z is unitless whereas Sen's slope Q is in mm for rainfall. A positive value of Sen's slope shows increasing trend, whereas negative value of Sen's slope shows decreasing trend. Figure 2 shows the trend analysis graphs of observed rainfall at Roorkee station.. These graph show the changing pattern of rainfall in past (1976 to 2016). Results showed that annual & all seasonal rainfall exhibited insignificant trend. Rainfall increased in monsoon season. Since Only Monsoon rainfall contributed major portion

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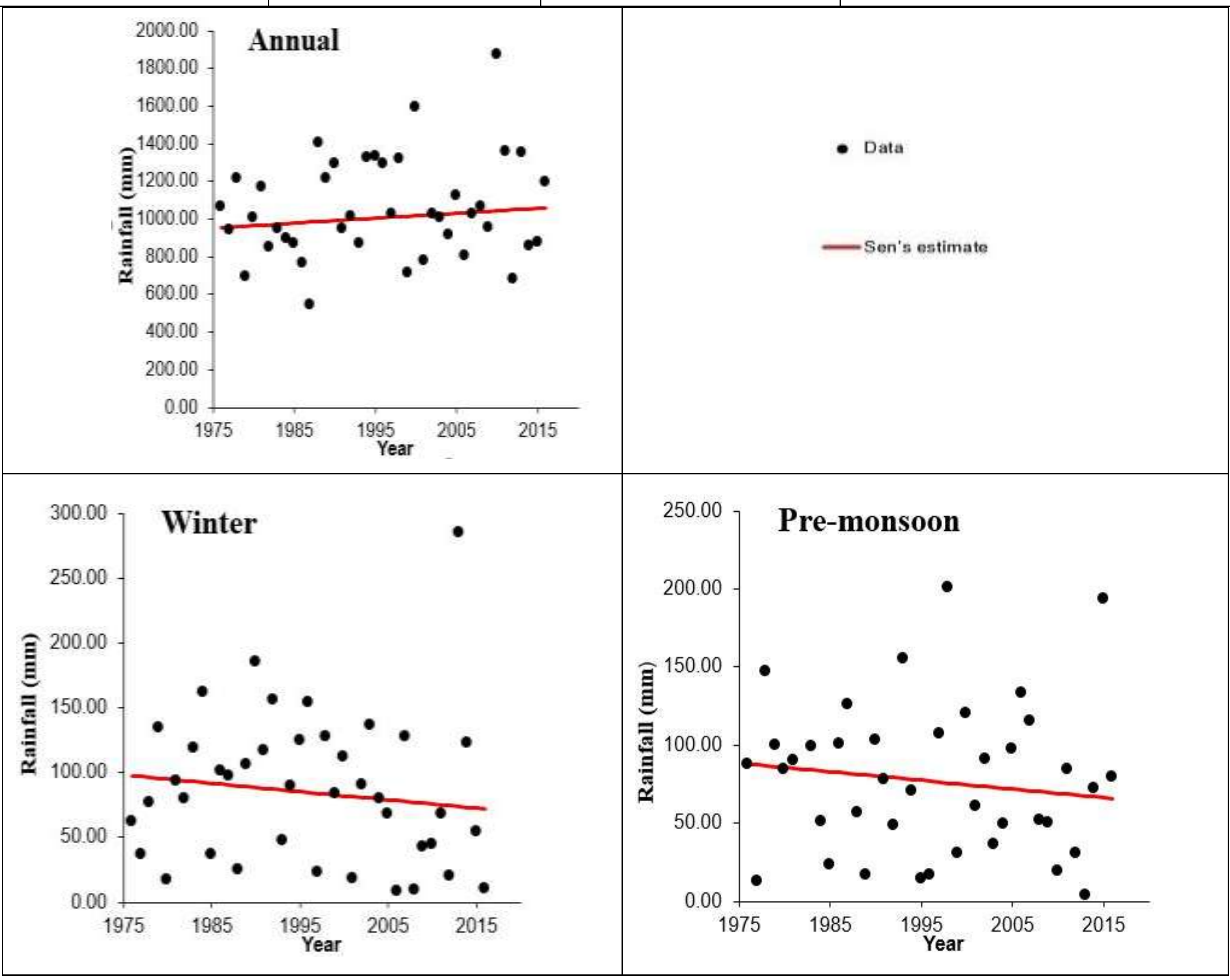
of annual rainfall, So trend nature of annual rainfall is same as of monsoon rainfall. Rainfall decreased in winter, pre-monsoon & post-monsoon season.

Table 1: Trend analysis for observed annual & seasonal rainfall at Roorkee station

Time Series	Mann Kendall Z-statistics	Sen's slope estimate (mm/year)	Trend (At 95% confidence level)
Annual	0.842	2.638	Insignificant increasing
Winter	-0.932	-0.646	Insignificant decreasing
Pre-monsoon	-0.753	-0.554	Insignificant decreasing
Monsoon	0.730	3.394	Insignificant increasing
Post-monsoon	-0.879	-0.176	Insignificant decreasing



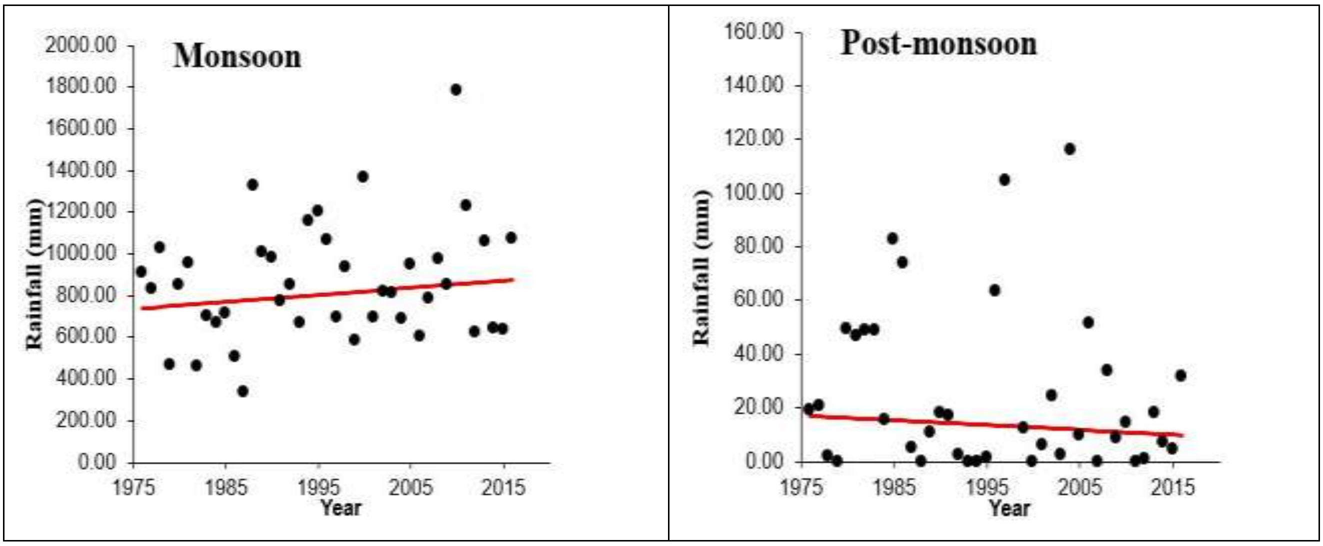


Figure 2: Trend analysis for observed rainfall at Roorkee station during 1976 to 2016

V. CONCLUSION

It is quite clear from results that temporal extent of rainfall throughout the year is being limited to only monsoon season. Non-monsoon rainfall is decreasing which causes very unhealthy impact on agriculture, economy & many subsistent sector. It may lead to huge cost of irrigation and scarcity of water during non-monsoon season. There will be more cost in growing perennial crops. So It is better to stand up now for local community for conservation of water so that availability of water can be secured in non-monsoon season. Some traditional methods like rainwater harvesting, step wells should be implemented to conserve water. An efficient strategy should be planned in order to secure the water availability in non-monsoon period for agriculture, domestic, industrial etc. purposes.

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