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Seasonal Rainfall Trend Analysis

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ABSTRACT
This study aims to detect the trend in seasonal rainfall of four rainy months i.e. June, July, August and September. To determine the trend of rainfall, non-parametric Mann-Kendall test and non-parametric Sen's Slope estimator for determination of magnitude of trend was used. Linear regression analysis, which is a useful parametric model used to developed functional relationships between variables was also applied to determine trend of rainfall for the study area. From all statistical test results it was indicated that there was some change in the trend of rainfall of the rainy months.
Keywords: Trend analysis, Mann-Kendall test, Sen's estimator.

I. INTRODUCTION

Change in climate and change in rainfall pattern is the most concern issue now days in India. Scientists are studying and trying to mitigate this change occurring in environment by various techniques. Rainfall is an important factor that needs serious attention as Indian agriculture is drastically affected due to change in rainfall pattern. As stated by Jain and Kumar (2012), changes in climate over the Indian region, particularly the SW monsoon, have a significant impact on agricultural production, water resources management and overall economy of the country. Any variation in climatic variables affects the crop growth stages thereby degrading the yield stability and quality. Temperature and rainfall are the two most important climatic parameters that affect the growth, development and yield of the crops. The growth of crops and their yields are dependent on the monsoon rain; even the sowing of crop for winter season is also determined by the soil moisture retained from the later parts of the monsoon. Hence changing rainfall pattern and its impact on agriculture and water resources remains a major climatic problem today. To overcome such constraints, one should have proper planning and management of our resources. Understanding of rainfall trend is an important tool for future of agriculture. Information and knowledge of trend and variability of rainfall is essential to supply supplemental water for crops during their critical growth stages. The trend analysis has helped scientists to find some serious implications of climate change. The purpose of a trend test is to determine whether the values of a series generally increase or decrease. Trend analysis is used to determine the significance of a trend and to estimate the magnitude of that trend. Trend analysis determines whether the measured values of a variable increase or decrease during a time period. There are many parametric and non-parametric methods that have been applied for detection of trends. One of the widely used non-parametric tests for detecting a trend in hydro-climatic time series is the Mann–Kendall (MK) test. The present study is attempt to study the trend of seasonal rainfall using Mann- Kendall and Sen's Slope statistics and regression analysis for the detection of the trend of precipitation. As reported by Guhathakurta and Rajeevan (2006) the Indian monsoon (June to September) rainfall is very crucial for the economic development, disaster management, hydrological planning for the country.

II. METHODOLOGY

Study area: The Allahabad district is located in the north part of India and south-east part of Uttar Pradesh state between 240 47'00'' to 250 47'00'' North Latitude and 810 19'00'' to 820 21'00'' East Longitude. It has an area of 5246 sq km. The Allahabad district receives an annual rainfall of 600 to 800mm. Ganga and Yamuna, which originates respectively, from Himalaya Glacier, are the two major rivers of the Allahabad. Precipitation data required for the study covered daily rainfall data of 15 years for Allahabad.

Trend analysis for hydro-meteorological variables such as precipitation, temperature and streamflow has been of particular interest to hydrologists and researchers for several decades. Recent studies indicate that the most widely used method is the non-parametric Mann-Kendall test (Mann,1945; Kendall,1975). Trend detection for rainfall of the study area covered mainly of three steps; first was to detect increasing or decreasing trend by Mann-Kendall (non-parametric) test in the seasonal rainfall data series, second was estimation of magnitude of trend by using Sen's slope estimator

and third was to develop regression models for the observed rainfall data series.

Mann-Kendall Test (Non- parametric)

The MK statistics (S) is defined as,

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

where N is number of data points. Assuming (x_j-x_i) = θ, the value of *sgn(θ)* is computed as follows;

$$\text{sgn}(\theta) = \begin{cases} 1 & if \quad \theta > 1 \\ 0 & if \quad \theta = 1 \\ -1 & if \quad \theta < 1 \end{cases}$$

This statistics 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

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k (t_k - 1)(2t_k + 5)}{18}$$

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

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & if \quad S < 0 \end{cases}$$

The value of Z is computed and if the value lies within the limits ±1.96, the null hypothesis of having no trend in the series cannot be rejected at 95% level of confidence.

Sen's Estimator

The magnitude of trend in a time series can be determined using non-parametric method known as Sen's estimator (Sen, 1968). This method assumes a linear trend in the time series. In this method, the slopes (T_i) of all data pairs are calculated first by

$$T_i = \frac{x_j - x_k}{j - k}$$

for i = 1,2,……..,N

Where x_j and x_k are data values at time j and k (j>k) respectively. The median of these N values of T_i gives the Sen's estimator of slope (*Q*). A positive value of *Q* indicates an upward trend and a negative value indicates a downward trend in the time series.

$$Q = Q_{N+1_{/2}}, \quad if\ N\ is\ odd$$

Or

$$Q = \left(\frac{1}{2}\right) Q\left[\frac{N}{2}\right] + Q\left[\frac{N+2}{2}\right], \quad if\ N\ is\ even$$

Regression Analysis

This is a parametric test that assumes normally distributed data. It is used to test for linear trend by the linear relationship between time and the variable of interest. The correct application of this method requires the variables to be normally distributed and temporally and spatially independent. The regression analysis can be carried out directly on the time series. Trend in rainfall at a particular station can be examined by applying the regression analysis with time as the independent variable and annual rainfall as the dependent variable. A linear equation, y = mt + c, defined by c (the intercept) and trend m (the slope), which represents the rate of increase or decrease of the variable, can be fitted by regression and t is time in years.

III. RESULTS AND DISCUSSION

Trend analysis of seasonal rainfall data (June - September) has been done in this study. Mann-Kendall, Sen's Slope Estimator and Regression analysis has been used for the determination of the trend and magnitude of trend. The results obtained are given below;

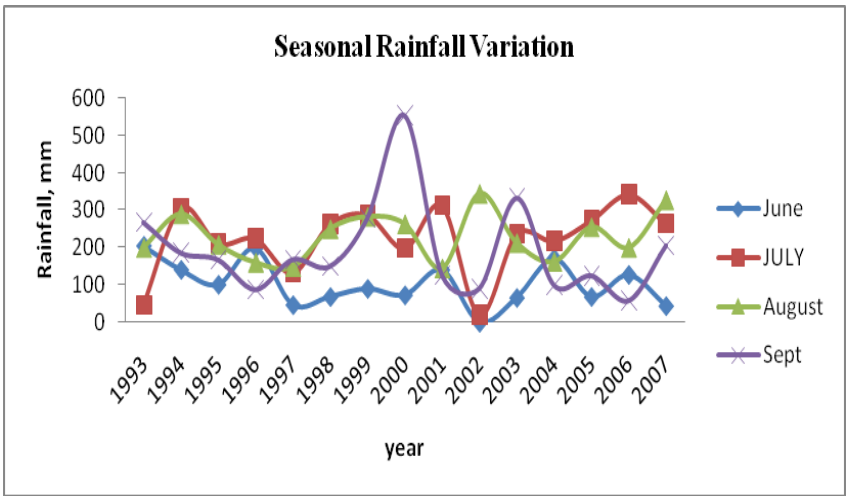

Fig.1 Seasonal Rainfall Variation for June to September**.**

Table. 1 Values of Mann-Kendall test (Z), Sen's Slope estimator and Regression Analysis**.**

	June	**July**	**August**	**September**
Mann-Kendall trend test (Z)	-1.833	1.288	0.545	-1.139
Sen's slope	-28.3	37.1	13.1	-35.2
Regression Analysis				
Slope (m)	-5.389	6.730	3.022	- 4.088
Intercept (c)	10881	13240	5815	8370

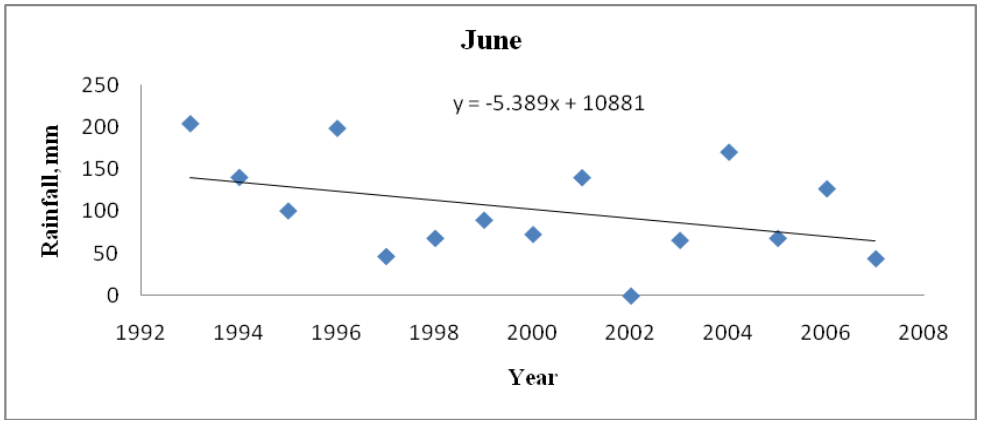

Fig.2 Regression Analysis for June.

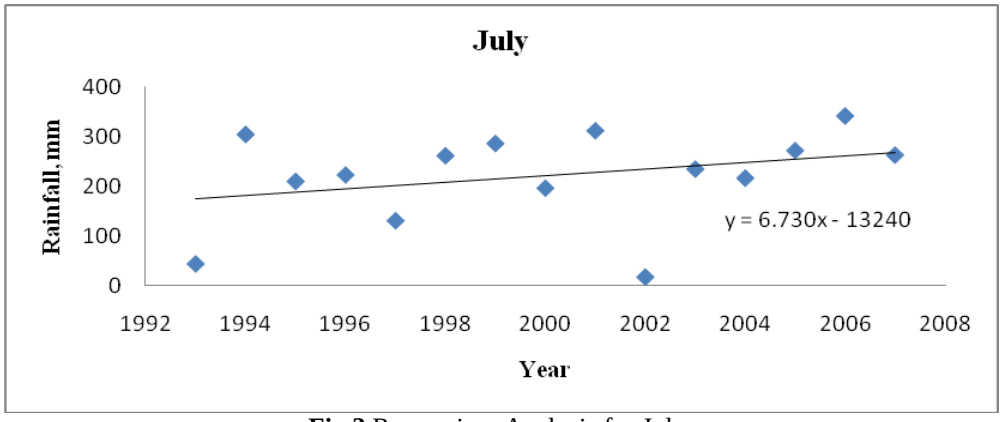

Fig.3 Regression Analysis for July.

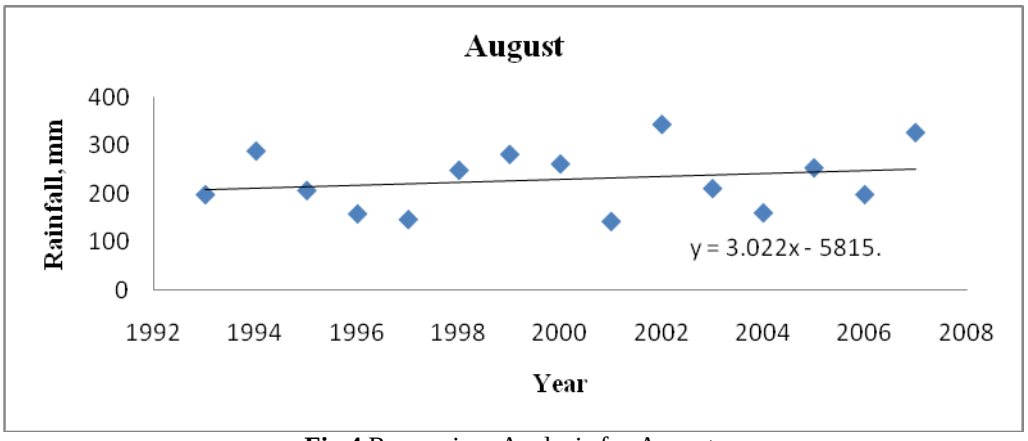

Fig.4 Regression Analysis for August.

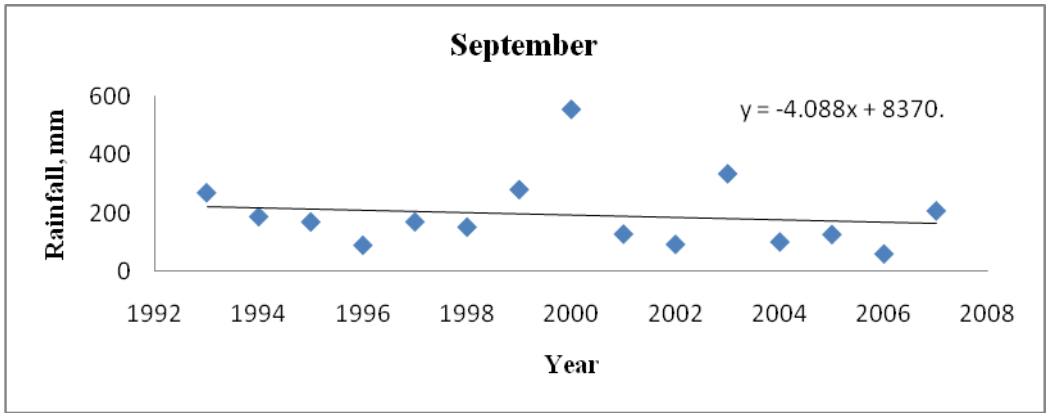

Fig.5 Regression Analysis for September.

Figure 1 gives the scenario of seasonal rainfall variation for the month June, July, August and September. From fig.1 it was observed that for the study area the seasonal rainfall received during month of June was less than the other months for whole of the time period considered. For other months the seasonal rainfall received in the July and August was more than the other months for the whole of the time period considered for the study. The result of the Mann-Kendal analysis to detect the trend and the magnitude of trend determined using Sen's slope estimator for the seasonal rainfall is presented in Table1. This analysis revealed negative (decreasing) trend for June and September whose Z values were -1.833 and -1.139 respectively. For the seasonal rainfall of the month July and August positive (increasing) trend was observed. The Z values for July and August were 1.288 and 0.545 respectively. The magnitude of seasonal rainfall by Sen' estimator for June, July, August and September was -28.3, 37.1, 13.1 and -35.2 respectively.

Regression analysis carried for the seasonal rainfall the month of June, July, August and September are showed in the fig.2, 3, 4,and 5 respectively. The developed functional relationships for the variables is also showed in the figures. Table.1 shows the regression analysis values of the slope and the intercepts for all the four months. The slope coefficient indicates the rate of change in the rainfall characteristic. The sign of the slope defines the direction of the trend of the variable, if sign is positive then it has increasing trend and if sign is negative then it has decreasing trend. The value of slope (m) for June was -5.389 and that for September it was - 4.088, which indicates there was decreasing trend of rainfall for these two months. For the month July and August the values of slope (m) were 6.730 and 3.022 which indicated there was increasing trend in the rainfall of these two months.

IV. CONCLUSION

This study was carried out to detect the decadal seasonal rainfall trend using Mann-Kendall, Sen's Slop Estimator and Regression analysis for the rainy months of June, July, August and September respectively. The Z value of Mann-Kendall test showed positive and negative trend for the rainy months. Among the four rainy months, negative trend was observed for June and September, but for July and August positive trend was observed. Sen's slope values for the four rainy months also showed increasing and decreasing magnitude of trend, which

were corresponding with the Mann-Kendall test values. The developed functional relationships for the variables using regression analysis also showed same trend of rainfall, which was observed for Mann-Kendall test and Sen's Slop Estimator. The trend m (the slope), in the equation y = mt + c of regression analysis showed negative trend for June and September, but for July and August positive trend was observed. Hence, from all statistical test results it is concluded that there was some change in the trend of rainfall of the rainy months of this area in these studied years.

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