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RAINFALL VARIABILITY OVER SOUTHERN BIHAR, INDIA

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ABSTRACT

In the present study Mann-Kendall (MK)/Modified Mann-Kendall (MMK) test, and Sen's slope test were used to determine the trend over the Southern part of Bihar at seasonal and annual time scales for 11 stations using 110 years data (1901-2010). In MMK test all stations in annual and monsoon season showed a significant decrease in rainfall trend at the 10% significance level. The maximum decrease in the magnitude of rainfall observed for the annual season was - 2.861 mm/year followed by monsoon rainfall - 2.792 mm/year, and for winter rainfall - 0.085mm/year respectively. On the other hand, the maximum increase in rainfall observed for Post monsoon season was 0.225 mm/year and for summer season it was 0.138mm/year during the study period. Spatial trend depicted the Nalanda and Jamui has the greatest reduction of rainfall from the last 110 years. This study will be very helpful for policymakers, agriculturists, and framers to take a decision on water management, crop scheduling and patterns over this region.

Keywords: Trend analysis; MMK; Sens's slope; Innovative Trend Method.

INTRODUCTION

Rainfall, being the prime source of water on the surface of the Earth, studies of rainfall is very essential for the deeper understanding of the hydrological cycle and its importance for the existence of all lives on the earth. Global warming directly affects the rainfall quantity, intensity and frequency, hence trend analysis plays crucial role in identifying long term changes in rainfall at various temporal and spatial scales. IPCC (2007) reported global surface temperature variation was 0.74 ± 0.18 °C from 1906 to 2005, glaciers, freshwater availability, living being may get affected by variation of future climate change. Most susceptible (climate change) area is agriculture as it is highly dependent on rainfall and temperature variation (Philip et al., 2014). In developing countries like India, agriculture is the main sources of income and any noticeable changes in the monsoon rainfall (pattern, intensity and frequency) directly affect the livelihood of major population (Kumar et al., 2010).

For assessing the spatial and temporal variation of annual and seasonal rainfall trend over India, several studies were conducted (Basistha et al., 2009; Kumar et al., 2010; Joshi and Pandey, 2011; Kundu et al., 2015; Gajbhiye et al., 2016; Sanikhani et al., 2018; Namitha et al., 2019).There have been attempts also made to study rainfall trend of Bihar. Warwade et al. (2018) analyzed spatio-temporal variation of annual and seasonal rainfall over Bihar for the period between 1901 and 2002. They found that annual and monsoon rainfall trends decreased significantly over the area and no significant trends in pre-monsoon, post-monsoon and winter rainfall. The average decline in rainfall rate was -2.17mm/year and -2.13mm/year for annual and monsoon periods.

Trend analysis of a time series is done to check its statistical significance and get the magnitude of trend. Many parametric and non-parametric methods can be applied for long-term rainfall trend analysis. In case of a parametric test the data should be followed to a particular distribution .While in a non-parametric trend analysis, the time series data used should be independent and allows the outliers present in the data (Lanzante, 1996). Therefore, in the present study various non-parametric statistical techniques namely the Mann Kendall (MK)/ Modified Mann–Kendall (MMK) test (Hamed and Rao, 1998) was used to analyze the statistical significance of the trend and Sen's slope estimator (Sen, 1968) was used to determine the magnitude of trend in the rainfall series.

It is generally seen that Northern part of Bihar is affected by flood whereas Southern part is affected by drought. Many studies covered the Northern part due to the flood of Kosi River but there is lack of study in the Southern part of Bihar. Therefore, the present study has been carried with the main objectives as: (i) to detect the magnitude and direction of rainfall trend of Southern Bihar over a period of 110 years (1901 to 2010) and (ii) to identify the spatial distribution of Rainfall trend over the study area.

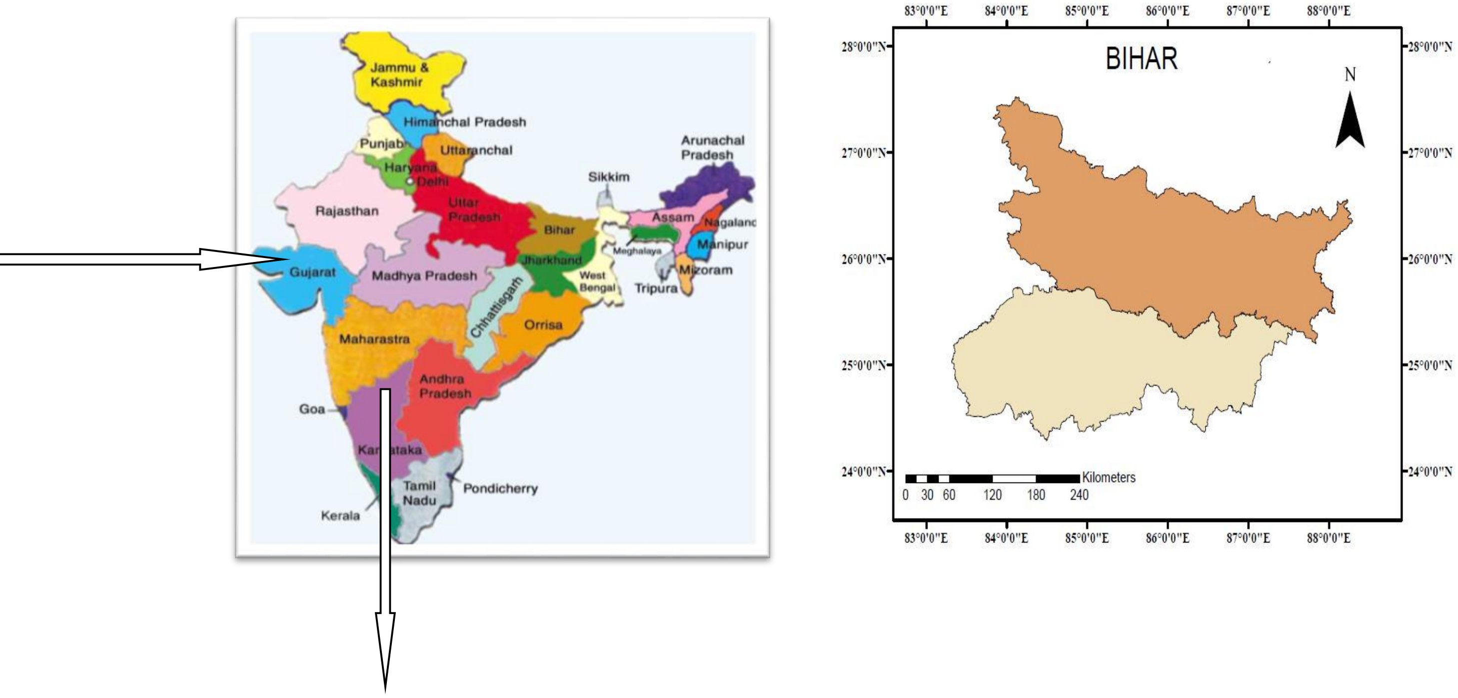
MATERIALS AND METHODS

Study Area

The study area is southern part of Bihar state in India with an area of 41,255 km^2 and lies between 83^0 19’50”E to 88^0 17’40”E and 24^0 20’10”N to 26^0 31’15”E. Location of the study area and considered stations were shown in Fig1. The average rainfall in the area is 990-1300 mm. The average minimum temperature is between 7.56°C to 10.56°C and maximum temperature of about 35ºC to 42ºC.

Data Used

Monthly rainfall data from 1901 to 2010 (110 years) for eleven stations of southern Bihar were used for present study obtained from India Meteorological Department (IMD). The whole rainfall time series classified into four seasons as summer (March to May), monsoon (June to September), post monsoon (October and November) and winter (December to February) as defined by IMD.



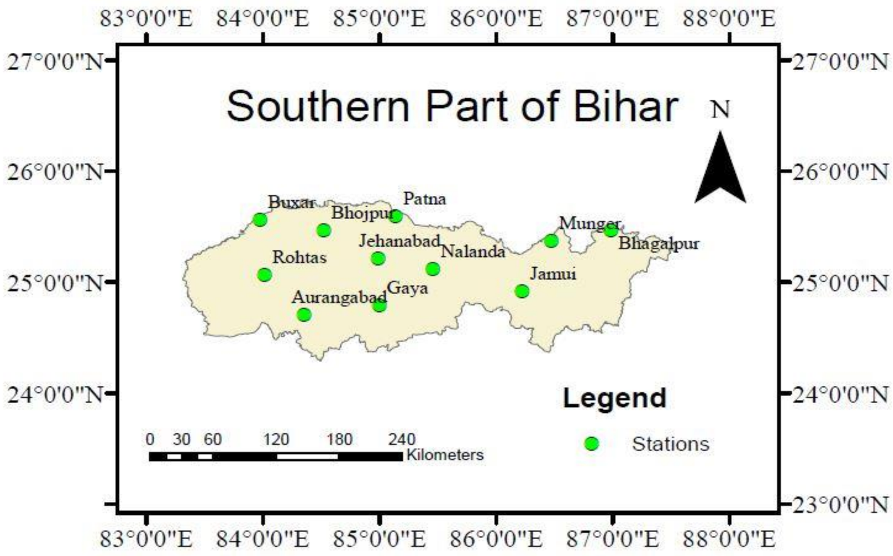


Fig1. Location map of the study area and considered stations

Magnitude of the Trend

For determining the magnitude of trend in a time series Sen's estimator were widely used by the various researchers in a hydro-meteorological time series. In this method, the slopes(T_i) of all data pairs are first calculated by the given eqn (1)

$$T_i = \frac{x_j - x_i}{j-i} \text{ for } i = 1, 2, 3 \ldots\ldots N \qquad \ldots(1)$$

where x_j and x_i are data values at the time j and i (j>i) respectively. The median of these values of T_i is Sen's estimator of slopes which is calculated as eqn (2)

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

If N is Odd, the Sen's estimator is computed as $\beta = T_{(N+1)/2}$ but in case of N is even, $\beta = [T_{N/2} + T_{(N+2)/2}]/2$. Finally β is computed by two sided test at 100 (1-α) % confidence interval and then true slope can be computed by using the non-parametric test. A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

Significance of the Trend

Nonparametric MK/MMK test were used for trend detection in annual and seasonal rainfall series (Mann, 1945; Kendall, 1975). Various researchers applied MK test to examine trend in hydro meteorological series (Yu et al., 1993; Douglas et al., 2000; Yue et al., 2003; Burn et al., 2004; Singh et al., 2008). It is essential to check the significance of autocorrelation in time series as a preliminary examination in MK test. For auto-correlated series, Hamed and Rao (1998) provided Modified Mann Kendall (MMK) to remove the effect of auto correlation.

RESULT AND DISCUSSIONS

Statistical Characteristics of Annual Rainfall

Table 1 depicted the geographical location, mean, minimum (min), maximum (max), standard deviation (SD), coefficient of variation (CV) and Skewness Coefficient (SC) of all the stations. Basic statistics were analyzed for annual rainfall from 1901-2010. Mean min, max and SD varied from 1007.53 to 1203.68 mm, 366.30 to

765.20 mm, 1428.64 to 1961.87 and 194.06 to 240.74mm respectively. Coefficient of variation varied from 0.17 to 0.22 and skewness coefficient from -0.40 to 0.40 respectively.

Annual and Seasonal Trend of Rainfall Series Using MK Test

The MK MMK test and Sen's slope estimator test were used for identifying possible trends in seasonal and annual rainfall data obtained from 11 stations in Southern part of Bihar, India for the period 1901-2010. A summary of the MMK test results is provided in Table 2 for the annual and seasonal rainfall data of 11 stations. At annual and monsoon season time scale all stations showed significant decreasing trend at significance level of 10%. In summer season 6 stations (Bhagalpur, Bhojpur, Buxar, Gaya, Patna and Rohtas) showed significant increasing trend .In winter season 4 stations showed significant decreasing trend and1 station (Jamui) showed significant increasing trend. In Post Monsoon season significant increasing trend were observed in 3 stations and significant decreasing trend in 1 station.

Table 1 Annual Rainfall (1901–2010) statistics of various stations considered for present study.

Stations	Latitude °N	Longitude °E	Mean (mm)	Minimum (mm)	Maximum (mm)	Standard Deviation	CV	SC
Aurangabad	24.7	84.3	1083.29	492.62	1691.99	240.74	0.22	-0.13
Bhagalpur	25.5	86.9	1200.64	765.20	1664.64	200.04	0.17	0.09
Bhojpur	25.5	84.5	1022.40	439.89	1464.84	211.54	0.21	-0.6
Buxar	25.6	83.9	1007.53	460.50	1428.64	194.06	0.19	-0.40
Gaya	24.8	85.0	1125.79	551.42	1771.52	238.16	0.21	0.03
Jamui	24.9	86.2	1203.68	749.92	1892.44	216.55	0.18	0.38
Jehanabad	25.2	84.9	1065.751	537.70	1548.48	207.99	0.20	-0.22
Munger	25.3	86.5	1166.36	695.00	1961.87	229.09	0.20	0.40
Nalanda	25.1	85.4	1083.85	366.30	1655.38	223.45	0.21	-0.29
Patna	25.6	85.1	1092.04	589.92	1761.20	213.02	0.20	0.30
Rohtas	25.1	84.0	1053.61	500.95	1599.00	207.86	0.20	-0.15

#CV variation coefficient, SC skewness coefficient

Table 2 Values of Z statistics for seasonal and annual rainfall using MK/ MMK for study region.

Stations	Annual	Summer	Winter	Monsoon	Post Monsoon
Aurangabad	-3.693	-0.983	-0.421	-3.494	-1.084
Bhagalpur	-4.480	2.472	-3.372	-4.903	5.022
Bhojpur	-3.694	1.873	-0.225	-3.511	-2.193
Buxar	-3.740	1.786	-0.793	-3.521	-0.692
Gaya	-4.084	1.680	-1.754	-3.765	-0.536
Jamui	-4.805	1.621	2.861	-4.921	3.378
Jehanabad	-4.058	1.103	-0.025	-3.866	-0.698
Munger	-4.085	1.118	-3.167	-4.691	3.627
Nalanda	-4.019	0.094	-1.163	-4.178	1.353
Patna	-4.369	2.703	-1.254	-4.696	-1.183
Rohtas	-3.369	1.884	-2.395	-3.281	-0.861

#Numbers in bold indicate significant values at the 10% level ($Z_{10\%} = \pm 1.645$)

Magnitude of Annual and Seasonal Trend Slope

The magnitude of the Annual and seasonal rainfall trends for the study period was calculated from Sen's slope estimator and presented in Table 3. Annual and monsoon rainfall clearly showed a decreasing rate of rainfall in all stations, while in summer all stations showed rising rate of rainfall except Aurangabad. The maximum decrease in the magnitude of rainfall was observed for annual rainfall (− 2.861 mm/year) and monsoon rainfall showed (- 2.792 mm/year) decrease in rainfall, while the maximum decrease of winter rainfall was (-0.085mm/year).Maximum increase in Post monsoon rainfall was observed as (0.225 mm/year) and summer rainfall was increased by (0.138mm/year) during the study period. The central part of the study area has experienced greater decreasing rate in annual rainfall than the eastern and western part (Fig.2). Figure 2 illustrates significant and non-significant increasing and decreasing trend with different symbols. The monsoon season also almost shown same decreasing pattern over the area as annual rainfall, and the condition is not good as it contributes to maximum rainfall to that region. For summer season, south-western part of the study area showed minimum decreasing rate while the maximum increase in the magnitude of rainfall in eastern part, however eastern part experienced maximum decrease in winter rainfall .The post-monsoon seasons showed maximum decreasing slope in western part and increasing rate in eastern part.

Results of present study has by Sharma and Singh (2017) as they found decreasing rainfall trends for winter, monsoon and annual rainfall series during the time period of 102 years over a neighboring state of Bihar i,e; Jharkhand while an increasing trend in pre-monsoon and post-monsoon rainfall. They also found that annual and monsoon rainfall trends decreased significantly over the state, however no significance trends were observed in pre-monsoon, post-monsoon and winter rainfall.

Agricultural production, water resource availability, urban water supply, water uses in industrial, residential, and agricultural purposes are directly affected by rainfall pattern. From the present study, it was observed that most of the considered stations have significant decreasing trend in annual, monsoon and winter season (few stations) and increasing trend in summer (all) and post monsoon season (very few). About 80% of the rainfall is contributed by monsoon season to the total rainfall hence this reduction of rainfall in such a manner may imbalance the water availability on the region. This imbalance of water causes greater extraction of ground water for irrigating crops and decreasing of groundwater level, facing drought problems, and reducing soil moisture (Mirabbasi and Eslamian, 2010). This study is very important to mitigate drought and may helpful to enhance the agriculture production in the study area.

Table 3 Values of Sen's slope for seasonal and annual rainfall (1901–2010).

Stations	Annual	Summer	Winter	Monsoon	Post Monsoon
Aurangabad	-2.135	-0.027	-0.007	-2.003	-0.048
Bhagalpur	-1.779	0.138	-0.085	-1.936	0.225
Bhojpur	-2.389	0.050	-0.006	-2.269	-0.111
Buxar	-2.209	0.041	- 0.015	-2.132	-0.026
Gaya	-2.250	0.051	-0.040	-2.180	-0.028
Jamui	-2.516	0.048	0.074	-2.470	0.220
Jehanabad	-2.137	0.029	0	-2.092	- 0.029
Munger	-2.134	0.037	-0.071	-2.288	0.150
Nalanda	-2.861	0.004	-0.036	-2.792	0.056
Patna	-2.149	0.112	-0.033	-1.952	-0.064
Rohtas	-1.769	0.054	-0.078	-1.71	-0.026

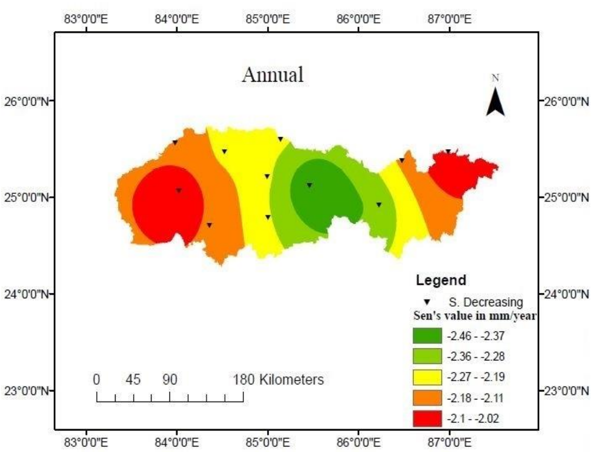


Fig. (a)

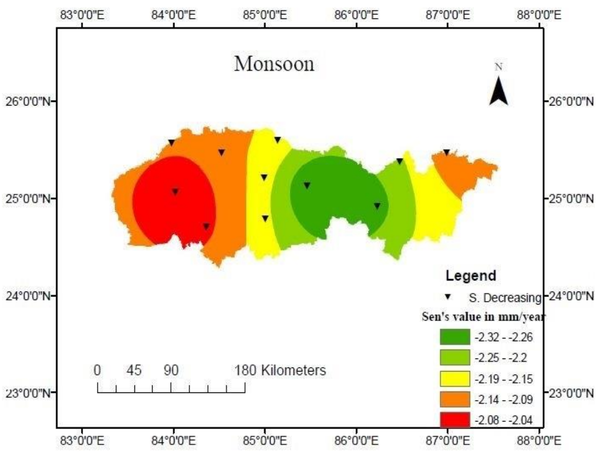


Fig. (b)

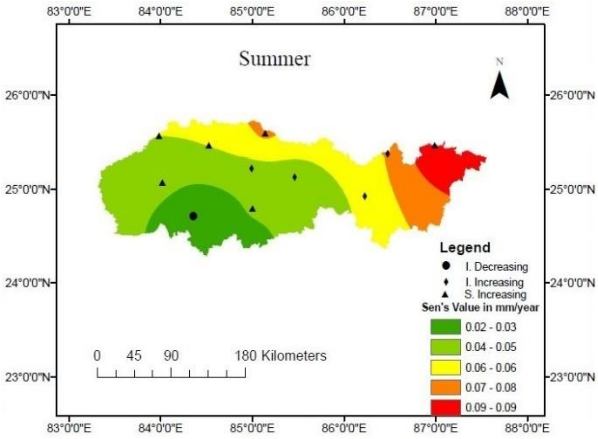


Fig. (c)

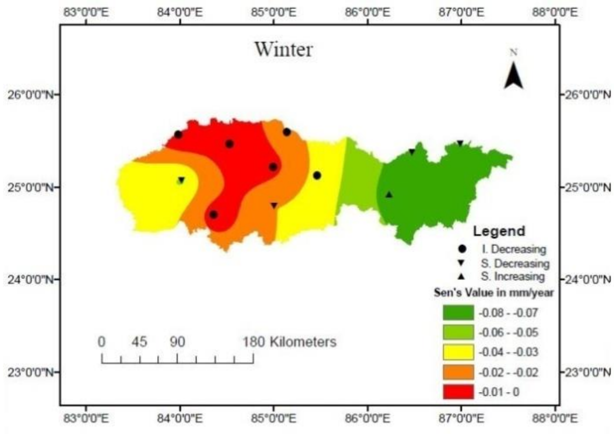


Fig. (d)

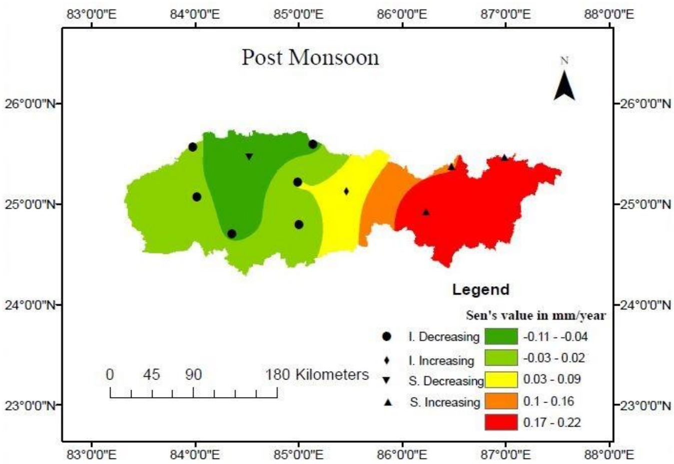


Fig.2 (a-e). Spatial Distribution of magnitude of Annual and Seasonal rainfall trend determined by Sen's slope test.

CONCLUSIONS

In this study, the trends of rainfall over the Southern Bihar using 110-year data were evaluated by MK/MMK, and Sen's slope estimator. All stations in annual and monsoon season showed significant decrease in rainfall. The maximum decrease in the magnitude of rainfall was observed for annual rainfall (− 2.861 mm/year) and monsoon rainfall showed (- 2.792 mm/year) decrease in rainfall. In summer season both significant and non significant increasing trend were observed. Post Monsoon season also showed significant increasing in some of the stations while some stations showed insignificant decreasing trend. Winter season also showed clear decreasing trend. Therefore present study of trend analysis provided researchers very interesting and informative findings which will be very useful for climate change experts and policymakers to take decision for adaptation of water management practice.

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