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Research Paper

Trend and change point analysis of rainfall of various districts of Bihar

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ABSTRACT : Precipitation trend analysis has been of great concern during the past century because of the attention given to global climate change by the scientific community. The study of precipitation trends is critically important for a country like India whose food security and economy are dependent on the timely availability of water such as 83 per cent water used for agriculture sector, 12 per cent for industry sector and only 5 per cent for domestic sector. So the present study attempted to know the trend of rainfall of five different districts *viz.*, Araria, Kishanganj, Madhubani, Purnia and West Champaran of Bihar for the period (1950-2000). The change point analysis has been critically analyzed for observing any change. For this purpose, rainfall data have been collected from respective meteorological stations.Statistical analysis of trend subjected to Mann-Kendall test, Sen's slope testand change point analysis.

KEY WORDS : Mann-Kendall test, Pettitt change point analysis, Sen's slope

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INTRODUCTION :

Climate of a location provides information about flora, fauna and feasible living conditions of humans. It is broadly governed by different weather parameters like precipitation, temperature, humidity, bright sunshine availability and wind speed on long term basis. Further, rainfall and temperature constitutes major parameters concerning every one.This analysis help us to plan future strategy to overcome any possible abrupt change affecting human being and crops.

Trend analysis helps to indicate whether analytic concentrations are increasing or decreasing over time. In addition, an estimate of the trend's magnitude can help to determine whether a statistically significant trend over a period of time is present or not. It is akey for predicting the rainfall of a particular place on the basis of yearly, monthly rainfall data for planning of the agricultural activities of the area. Several studies relating to changing pattern of rainfall over India observed that there is no clear trend of increase or decrease in average rainfall over the country (Mooley and Parthasarthy, 1984; Thapliyal and Kulshreshtha, 1991; Lal, 2001 and Kumar *et al.*, 2010).

When performing long-term trend analysis on precipitation factors, the trends obtained signify the overall characteristics of the precipitation factors. The intersection where two dissimilar trends meet is called a change point. To determine whether change points exist in the long-term data, Pettitt change point analysis test is commonly used.

MATERIALS AND METHODS :

In the present study monthly rainfall data for the period of 1950-2000 have been taken from the respective meteorological observatory located at their respective districts. In this study, monsoon period has been defined as the months of July, August and September; Pre-monsoon as the months of April, May and June and winter constituted the month of November, December and January.

In this study non-parametric statistical methods have been used to test the trends in the rainfall meteorological data of the study area. Non-parametric tests are more suitable for non-normally distributed data in comparison to parametric statistical tests (Lanzante, 1996 and Jana *et al*., 2015). Change point analysis was also done to know the year from which significant change has been occurred.

The most frequently used non-parametric statistical tool for identifying trends in hydro-meteorological time series variables such as water quality, stream-flow, temperature and precipitation is the Mann-Kendall (MK) test. The statistical significance trend detected using a non-parametric model such as Mann-Kendall (MK) test can be complemented with Sen's slope estimation to determine the magnitude of the trend.

Mann-Kendall trend test:

The non-parametric Mann-Kendall test is commonly employed to detect monotonictrends in series of environmental data, climate data or hydrological data. Since it is a non-parametric test so its main advantage is that the data need not conform to any particular distribution. The Null hypothesis, H_0, is that the data come from a population with independent realizations and are identically distributed. The alternative hypothesis, H_1, is that the data followa monotonic trend.

This test is rank based method for evaluating the presence of trends in time-series data. The initial value of the Mann-Kendall statistic, S is assumed to be 0 (no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. The net result of all such increments and decrements yields the final value of S.

Let 1x, 2x, …, jx,…, nx represent n data points where jx represents the data point at time j. Then the Mann-Kendall statistic (S) is given by:

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

$$\mathrm{Sgn}(x_j - x_i) = \begin{cases} 1; \text{if } (x_j - x_i) > 0 \\ 0; \text{if } (x_j - x_i) = 0 \\ -1; \text{if } (x_j - x_i) < 0 \end{cases}$$

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size n to statistically quantify the significance of the trend.The mean of S is E[S] = 0 and the variance σ^2 is:

$$\sigma^2 = \left\{ n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j-1)(2t_j+5) \right\} / 18$$

where, n is the number of data points, p is the number of tied groups (a tied group is a set of sample data having the same value) and t_j is the number of data points in the j^{th} tied group. The statistic S is approximately normal distributed provided that the following Z-transformation is employed:

$$Z_{MK} = \begin{cases} \dfrac{S-1}{\sigma} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{\sigma} & \text{if } S < 0 \end{cases}$$

Z_{MK} follows the standard normal distribution (Kendall, 1975). The hypothesis of no trend is rejected if $|Z| > Z_{1-\propto/2}$, where, Z is taken from the standard normal distribution table and $\propto$ is level of significance (Barnard, 1947).

Sen's slope estimate :

The magnitude of slope of trend is estimated using the approach described by Sen (1968). The Sen's slope estimator is a non-parametric, linear slope estimator that works most effectively on monotonic data. This test computes both the slope (*i.e.* linear rate of change) and intercept according to Sen's method. First, a set of linear slopes is calculated as follows:

$$d_k = \frac{X_j - X_i}{j - i} \text{ for } 1 \le i < j \le n$$

where, d is the slope, X denotes the variable, n is the number of data and i, j are indices. Sen's slope is then calculated as the median from all slopes b = Median d_k. A positive value of b indicates an upward trend, whereas a negative value represents a downward trend.

Pettitt's change point analysis test :

There are various methods to determine change point analysis of a time series (Chen and Gupta, 2011). In this study, we used the nonparametric approach developed by Pettitt (1979) to detect change points in rainfall time series. The Null hypothesis of the test is H_0: The T variables follow one or more distributions that have the same location parameter (no change point), against the alternative hypothesis H_1: a change point exists. This test uses a modification of Mann-Whiney $U_{t,N}$, that tests whether two sample sets $X_1, X_2, \ldots, X_t$ and $X_{t+1}, X_{t+2}, \ldots, X_N$ are from the same population. The test statistic $U_{t,N}$ is defined as:

$$U_{t,n} = U_{t-1,N} + \sum_{j=1}^{N} \mathrm{sgn}(x_j - x_i) \text{ for } t = 1,2,\ldots,N$$

and

$$\mathrm{Sgn}(x_t - x_j) = \begin{cases} 1; \text{if } (x_t - x_j) > 0 \\ 0; \text{if } (x_t - x_j) = 0 \\ -1; \text{if } (x_t - x_j) < 0 \end{cases}$$

The test statistics counts the number of times an observation of first sample exceeds an observation of the second sample. The test statistics K_N and associated probability (P) used in the test are given as :

$$K_N = \max_{1 \le t \le N} |U_{t,N}|$$

$$P \cong 2\exp\{-6(K_N)^2/(N^3 + N^2)\}$$

RESULTS AND DATA ANALYSIS :

The mean, co-efficient of variation (%) and its percentage contribution of monthly rainfall of five different districts of Bihar for the period of 1950 - 2000 has been delineated in Table 1.

Monsoon rainfall accounts for 64.71, 65.56, 65.70, 69.39 and 72.52 per cent of the annual rainfall of the district Kishanganj, Araria, Purnia, Madhubani and West Champaran. So here we can conclude that West Champaran is the rainiest district during Monsoon among all the five districts.This study reveals that if intensity of rainfall is increasing during Premonsoon months (*viz.*, April, May and June), then it can be concluded that month of July will receives highest intensity of rainfall, which will help the farmers to decide their time of sowing (early, timely or late).

The standard deviation (SD) and co-efficient of variation (CV) of the monthly rainfall indicate high degree of variability associated in the monthly rainfall. In case of monthly rainfall the co-efficient of variation is less significant in the months of May, June, July, August and September (CV <75%). Monsoon rainfall has minimum co-efficient of variation and winter rainfall has highest co-efficient of variation. It can be inferred that rains during South-west monsoon are more reliable. In South-west monsoon, July and August are generally the active monsoon months. June is the onset month which witnesses an outburst of rain while September is the withdrawal month, receiving more of the sporadic rain.

Trend analysis of monthly rainfall:

The rainfall data set of different five districts of Bihar for the period of 1950 – 2000 have been analysed separately.

From Table 2 it can be seen that during May and June there is insignificant trend in all the five districts. Besides Madhubani and West Champaran show insignificant trend during the month of July also. In Kishanganj there is very little but significant negative trend during the months of March, July and October and remaining months show positive trend. In Araria there is very little but significant negative trend during the months of March, July, August and September and remaining months show positive trend. In Purnia there is very little but significant negative trend during the months of March, July, August, September and October and remaining months show positive trend. In Modhubani there is very little but significant negative trend during the months of August, September and October and remaining months show positive trend. Similarly in West Champaran there is very little but significant negative trend during the months of March, August, October and November and remaining months show positive trend.

The results from Mann-Kendall trend test is re-established by Sen's slope estimate. here we can see that negative value of Sen's slope shows decreasing trend and positive value of the slope shows increasing trend that justified the results obtained from Mann-Kendall trend test.

It can be seen from Fig. 1 that there is sudden decreasing trend during 1960-1970 and increasing trend during 1980-1990.

Monthly anomaly clearly depicts that how rainfall has changed over time (anomaly is that which shows dispersion from mean). Anomaly plot for rainfall (mm) showing monthly anomaly of five district (Fig. 2 to 6) indicate that the month of July has maximum positive monthly anomaly which means July month receives rainfall more than their mean rainfall of all the studied districts. On the other hand December month has maximum negative annual anomaly which mean December month receives rainfall less than mean rainfall.

Change point analysis:

The Pettitt test was used to detect changes in annual rainfall for the period 1950-2000. For annual rainfall of different districts of Bihar, It has been seen that true

Table 1: Monthly rainfall statistics for the period (1950-2000)

Months/ period	Kishanganj			Araria		
	Mean(mm)	CV (%)	% Contribution	Mean(Nos)	CV(%)	%Contribution
Jan.	13.7	96.07	0.87	15.6	93.03	1.17
Feb.	9.3	96.18	0.59	10.1	99.54	0.76
Mar.	15.0	89.09	0.95	14.1	94.46	1.06
Apr.	39.3	68.87	2.49	27.1	73.79	2.03
May	114.6	51.08	7.26	85.1	56.89	6.37
Jun.	260.5	39.69	16.51	209.6	43.62	15.69
Jul.	423.1	30.80	26.82	354.8	33.78	26.58
Aug.	317.4	36.55	20.12	280.3	41.29	20.99
Sep.	280.2	39.21	17.76	240.1	45.38	17.99
Oct.	91.7	83.62	5.81	86.0	91.73	6.44
Nov.	8.9	117.99	0.56	9.0	123.22	0.68
Dec.	4.0	199.73	0.25	3.1	204.88	0.23
Annual	1577.6	948.90	100.00	1334.8	1001.6	100.00
Monsoon	1020.7	19.18	64.71	875.1	21.45	65.56
Premonsoon	414.4	28.47	26.27	321.7	31.98	24.11
Winter	26.5	71.75	1.68	27.7	70.96	2.08
		Purnia			Madhubani	
Jan.	15.1	85.47	1.22	16.0	98.15	1.38
Feb.	10.2	93.96	0.83	10.3	90.74	0.89
Mar.	12.1	91.71	0.98	12.1	100.11	1.05
Apr.	24.3	78.13	1.97	15.8	71.83	1.37
May	71.4	54.39	5.77	57.4	73.43	4.96
Jun.	195.7	43.34	15.81	150.9	54.78	13.06
Jul.	314.8	30.26	25.42	318.8	38.14	27.58
Aug	265.8	34.54	21.47	272.7	30.95	23.59
Sep.	232.9	38.39	18.81	210.4	43.93	18.20
Oct.	84.6	78.76	6.83	80.3	82.08	6.95
Nov.	7.6	115.40	0.61	8.0	143.68	0.69
Dec.	3.4	183.56	0.28	2.9	169.40	0.25
Annual	1238.0	927.90	100.00	1334.8	1001.6	100.00
Monsoon	813.4	17.48	65.70	801.8	19.08	69.39
Premonsoon	291.5	32.48	23.55	224.1	41.77	19.39
Winter	26.1	67.28	2.11	26.9	74.37	2.33

Table 1 : Contd…………

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Months/ period	West Champaran		
	Mean (mm)	CV (%)	% Contribution
Jan.	16.5	83.84	1.29
Feb.	10.1	78.02	0.79
Mar.	10.2	92.12	0.80
Apr.	18.0	70.96	1.42
May	45.1	80.47	3.54
Jun.	180.4	53.40	14.17
Jul.	359.6	36.33	28.26
Aug.	333.7	24.89	26.23
Sep.	229.3	36.66	18.02
Oct.	59.4	95.62	4.66
Nov.	5.1	152.10	0.40
Dec.	4.9	135.93	0.38
Annual	1272.4	940.4	100.00
Monsoon	922.7	18.98	72.51
Premonsoon	243.5	42.34	19.14
Winter	26.5	63.00	2.09

Table 2: Trend analysis of monthly rainfall (1950-2000)

Months/ period	Kishanganj		Araria		Purnia		Madhubani		West Champaran	
	MK	p-value	MK	p-value	MK	p-value	MK	p-value	MK	p-value
Jan.	0.03	0.77	0.57	0.56	0.06	0.55	0.06	0.54	0.09	0.31
Feb.	0.25	0.01	0.24	0.02	0.19	0.08	0.18	0.06	0.21	0.03
Mar.	-0.06	0.57	-0.06	0.55	-0.07	0.47	0.02	0.82	-0.07	0.51
Apr.	0.11	0.28	0.08	0.43	0.07	0.46	0.01	0.96	0.12	0.23
May	0.32	0.00	0.32	0.00	0.34	0.00	0.34	0.00	0.35	0.00
Jun.	-0.22	0.02	-0.29	0.00	-0.28	0.00	-0.34	0.00	-0.3	0.00
Jul.	-0.12	0.21	-0.17	0.08	-0.15	0.13	-0.24	0.01	-0.24	0.01
Aug.	0.03	0.78	-0.01	0.89	-0.02	0.81	-0.06	0.52	-0.16	0.09
Sep.	0.05	0.59	-0.02	0.86	-0.02	0.84	-0.04	0.72	0.05	0.58
Oct.	-0.06	0.51	-0.08	0.43	-0.06	0.56	-0.05	0.61	-0.04	0.71
Nov.	0.07	0.47	0.06	0.55	0.05	0.59	0.03	0.76	-0.02	0.84
Dec.	0.12	0.31	0.07	0.49	0.11	0.27	0.12	0.23	0.08	0.39

(MK: Mann Kendall)

Table 3: Sen's slope estimate of monthly rainfall data

Months/period	Kishanganj	Araria	Purnia	Madhubani	West Champaran
Jan.	0.01	0.05	0.07	0.06	0.09
Feb.	0.16	0.15	0.12	0.13	0.11
Mar.	-0.05	-0.06	-0.06	0.02	-0.03
Apr.	0.31	0.15	0.16	0.01	0.12
May	2.08	1.51	1.22	1.23	0.89
Jun.	-2.47	-2.54	-2.17	-2.71	-2.73
Jul.	-1.49	-1.72	-1.23	-2.55	-3.30
Aug.	0.29	-0.12	-0.22	-0.43	-1.36
Sep.	0.36	-0.12	-0.19	-0.27	0.43
Oct.	-0.31	-0.45	-0.31	-0.24	-0.09
Nov.	0.01	0.01	0.02	0.01	0.00
Dec.	0.00	0.00	0.01	0.01	0.01

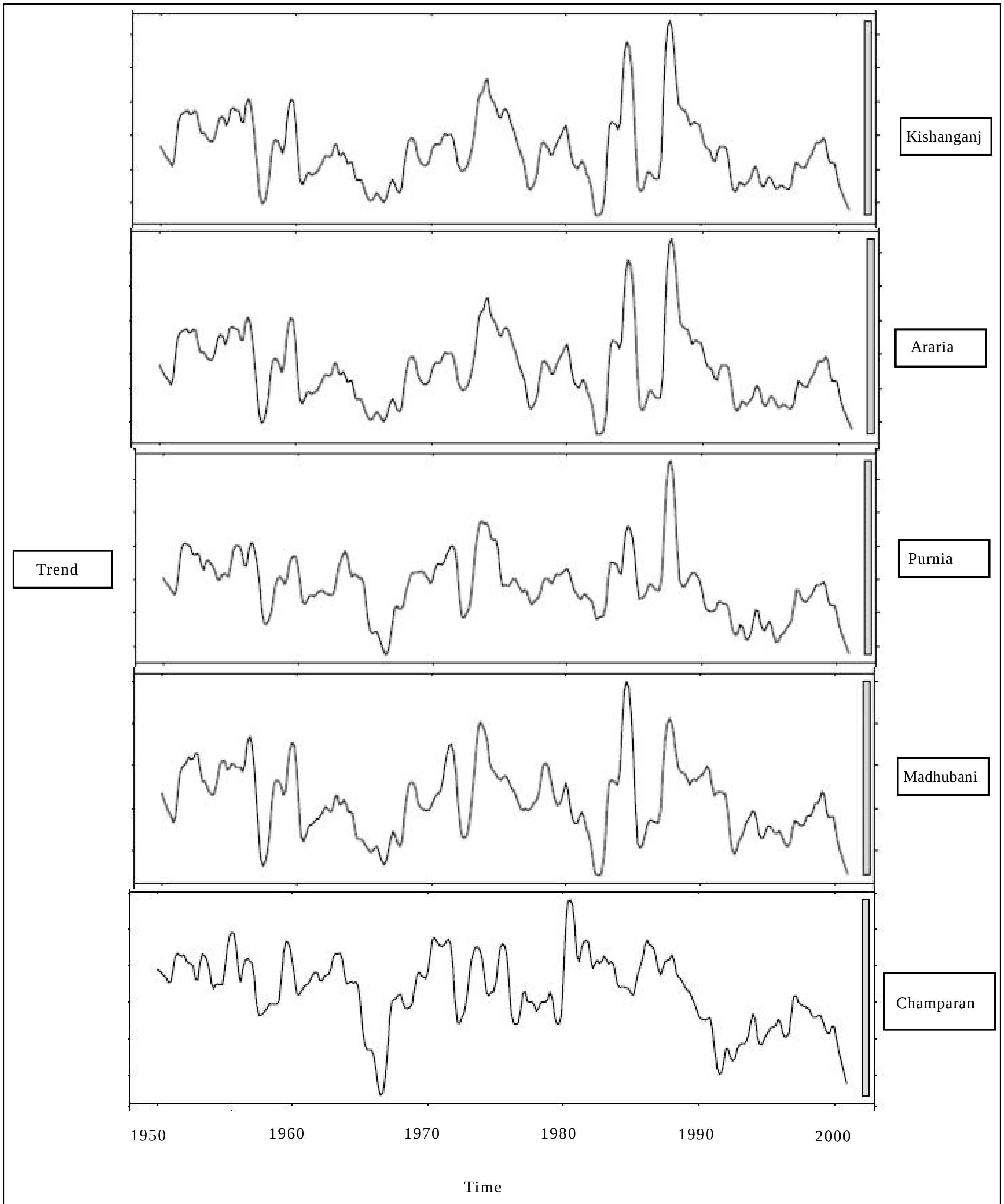

Fig. 1 : Trend analysis for rainfall (mm) of five districts of Bihar

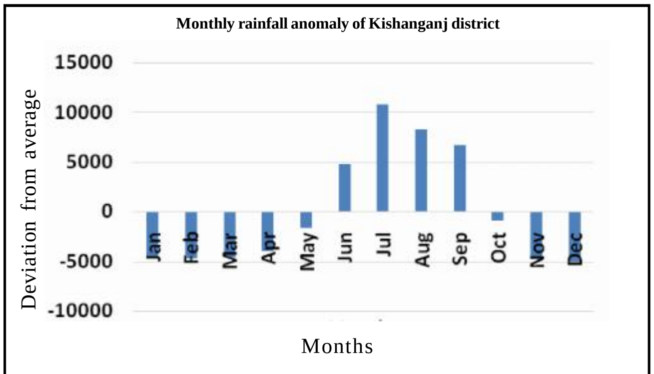

Fig. 2 : Monthly anomaly plot for rainfall (mm) of Kishanaganj district

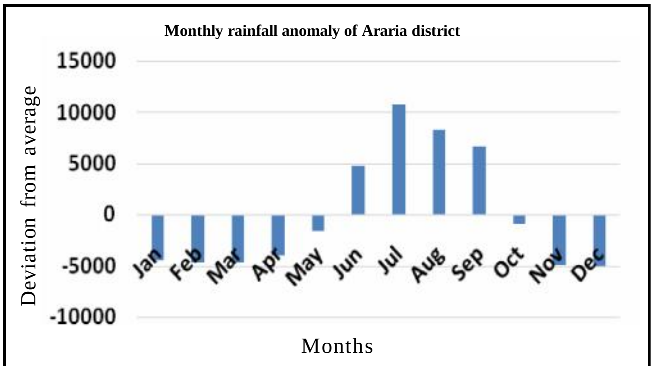

Fig. 3 : Monthly anomaly plot for rainfall (mm) of Araria district

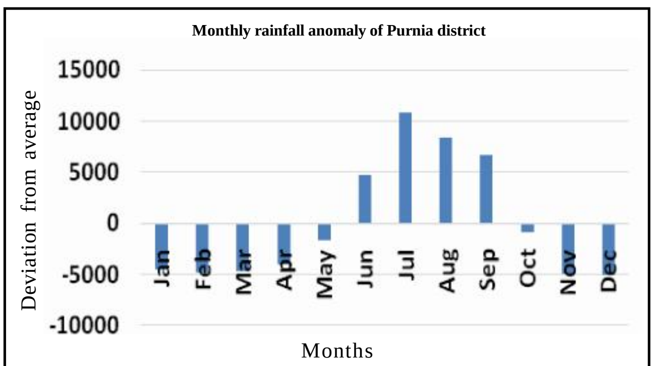

Fig. 4 : Monthly anomaly plot for rainfall (mm) of Purnia district

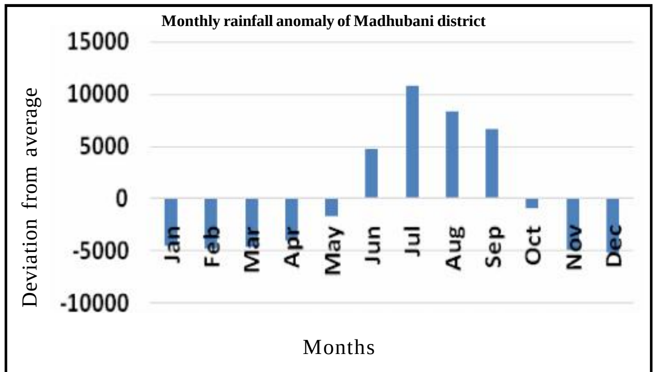

Fig. 5 : Monthly anomaly plot for rainfall (mm) of Madhubani district

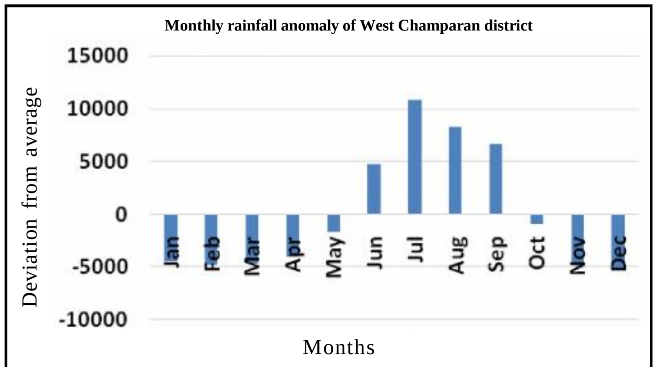

Fig. 6 : Monthly anomaly plot for rainfall (mm) of West Champaran district

change point is present in the series and details has been given in Table 4.

Conclusion:

Historical meteorological data of five districts of Bihar on rainfall have been analyzed with Mann Kendall Z statistic, Sen's slope test. The study reveals that in general during May and June there is insignificant trendin all the five districts. However, March, July, August, September and October show very little but significant negative trend in all the five districts. Also, if intensity of rainfall is increasing during Premonsoon months (*viz.*,

Table 4 : Change point analysis of different district of Bihar

District	K_T	p-value	Change point (present or not)	Change point present at tau value
Kishanganj	4399	1.206	yes	221
Araria	5145	1.001	yes	280
Purnia	4910	1.065	yes	221
Madhubani	5925	0.7991	yes	221
West Champaran	5808	0.8283	yes	244

April, May and June), then it can be concluded that month of July will receives highest intensity of rainfall, which will help the farmers to decide their time of sowing (early, timely or late).

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