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TREND ANALYSIS OF RAINFALL AND RUNOFF DATA OF PUNPUN RIVER BASIN

Keshav Kumar[1*], Mani Bhushan[2]
[1*]Assistant Professor, Dept. of Civil Engineering Nalanda College of Engineering Chandi, Science and Technology Department Gov. of Bihar (India)
[2] Principal Government Engineering College Khagaria Science and Technology Department Gov. of Bihar

ABSTRACT
The current work is primarily focused with analyzing the shifting rainfall pattern and discharge of a Punpun river basin in Bihar at several raingauge stations, including Patna, Goh, Gurua, Jahanabad, and Nabinagar, using non-parametric statistics. The primary goal is to examine climatic variables, namely precipitation and outflow, in order to examine the rainfall and runoff trends in the basin. The research analysed monthly rainfall and discharge data from 1990 to 2010 to determine the monthly and yearly variance of rainfall and discharge. The same data was then examined to determine the monthly and seasonal variability of rainfall and monthly variability of discharge, for which the Mann-Kendall Test and Sen's slope Estimator were used to determine trend. Monthly and seasonal rainfall and monthly discharge trends have been established here to meet the goal, which has been shown using data from 1990 to 2010. Although trends were detected at several raingauge and discharge stations, the majority of these trends were not statistically significant since p-values were larger than 0.05. It was advised that the availability of data for a longer period of time (more than 21 years) be studied in order to assess trends at raingauge and discharge stations that might provide statistically meaningful findings.
Keywords: Mann-Kendall Test, Trends of Rainfall & Runoff, Non-parametric statistics, Rain gauge, Sen’s slope Estimator, P value.

1. INTRODUCTION

Trend analysis is the activity of gathering data and trying to identify a pattern, or trend, in the data. Because trends occur in a rising or decreasing fashion, trend analysis is one of the most essential topics in any climate change problem. Trend analysis is critical for developing and updating climate variables. This is important for constructing many sorts of hydraulic structures using pre-assessment of discharge and fluid intensity. Knowing the trend for a specific variable of interest might aid in forecasting future realizations and designing future scenarios. Various time series data studies have shown that the trend in temperature and rainfall is either declining or rising.

Water resource management, including food production, flood control, and efficient water resource management, has become a top priority for any growth and planning. According to studies, warming of the Earth's surface has occurred at a pace of 0.74 0.18°C between 1906 and 2005. (IPCC, 2007). According to IPCC assessments, the future impact of climate change will be rather severe, with a decrease in freshwater supplies as a result of climate change. This has also

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shown that by the middle of the twenty-first century, yearly average runoff and water availability will have decreased by 10%-30%. (IPCC, 2007). Various scholars have given long-term data to the study of climate change. Various time series data studies have shown that the trend in temperature and rainfall is either declining or rising. If more episodic rainfall is recorded, it has ramifications for groundwater recharging because variations in rainfall intensity features may result in changes in runoff and infiltration partitioning.

Several research on precipitation trend have also been carried out in South Asia. According to Marco et al. (2003), there is a growing precipitation trend in Jammu-Kashmir, which is southwest of Tibet, and in the southwest of Xinjiang, which is close to the northern part of Pakistan.

2. STUDY AREA

In the research region, there are several raingauge stations. Five raingauge sites (indicated in red in Figure 1) were chosen based on an equitably dispersed region for data collection. Patna, Jahanabad, Goh, Gurua, and Nabinagar are the raingauge stations. The Punpun river basin's average annual rainfall ranges from 99 cm at the Ganga's confluence (Patna district) to 134 cm in the uppermost stretch. (Palamu district). The monsoon season, which lasts from June to September, accounts for 85 to 87 percent of the annual rainfall. The greatest value of 24 hours rainfall with a 50-year frequency is 32 cm, which occurs in the upper watershed of the Morhar River, a Punpun sub-tributary, while it ranges between 24 and 28 cm in other areas. (NIH 1994).

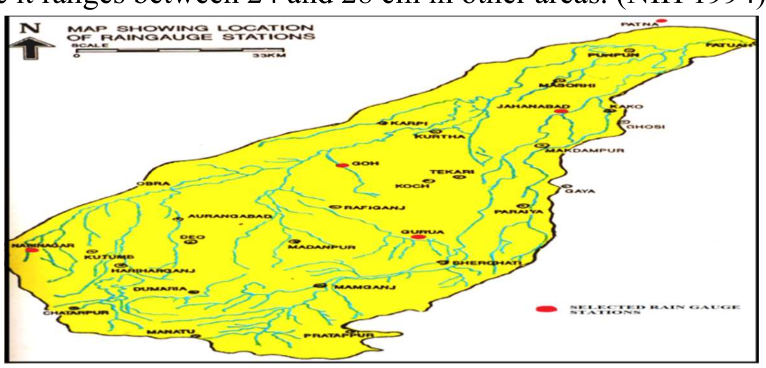

Fig. 1 Map showing the location of selected raingauge stations.

Rainfall Data

The Punpun sub-basin was chosen for the research, with a total catchment area of 8530 km2. The basin has five raingauge stations that are equally dispersed. Patna, Jahanabad, Goh, Gurua, and Nabinagar are among the stations. Monthly rainfall data for all stations were acquired from the India Meteorological Department (IMD) from 1990 to 2010, a period of 21 years. The mean monthly and yearly rainfall statistics for all raingauge stations have been calculated. Figure 2 shows the average monthly rainfall at each of the five raingauge sites. Except for Nabinagar, it can be noted that more than 70% of the annual rainfall occurs from June to September, with the highest value in July. Except for a few sites, Figure 3 indicates that the yearly rainfall of all raingauge

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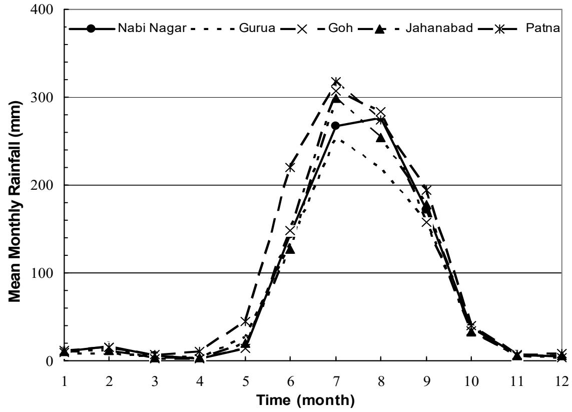
stations follows the same trend. Patna raingauge station's extreme values in 1997 and 2007 are noteworthy in this time period.



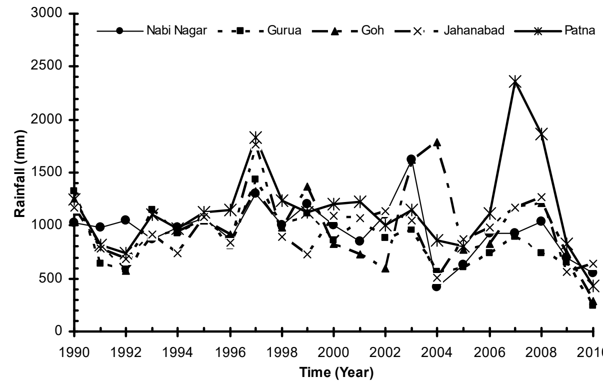
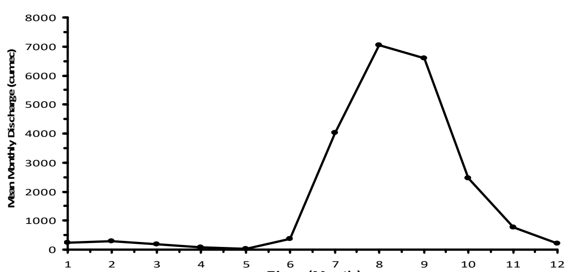


Fig. 2 Mean monthly rainfall data of all raingauge stations Fig. 3Annual rainfall data of all raingauge stations

Runoff Data

Monthly runoff data from the Shripalpur gauging station, which is on the downstream side near Patna, were acquired from the Central Water Commission (CWC), Patna, from 1990 to 2010, a period of 21 years. The average monthly and yearly discharge statistics have also been calculated and are shown in Figures 4 and 5, respectively.

Figure 4 depicts the influence of monsoon rainfall (June to September) on the runoff hydrograph (July to October). It signifies that the rainfall and runoff hydrograph has a lag period of about one month. The majority of the catchment's runoff occurs from July through October, with the highest value in August. Figure 5 indicates that the yearly discharge value pattern is the same as the annual rainfall pattern. The yearly discharge curve also reflects the greatest magnitude of rainfall in 2007.



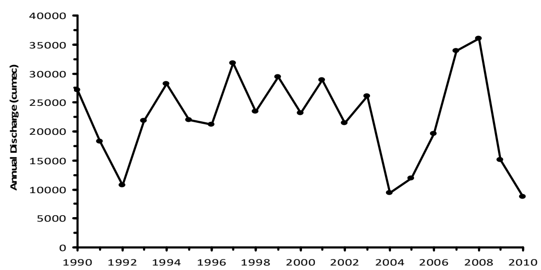


Fig. 4 Mean monthly discharge data at Shripalpur gauging site Fig. 5 Annual discharge data at Shripalpur gauging site

3. METHODOLOGY

Calculation of the Mann-Kendall statistics (S)

A well-liked non-parametric method for identifying patterns in hydro-meteorological time series is the Mann-Kendall test. Instead of looking at actual data values, the test looks at sample data relative magnitudes. This test has the benefit of not requiring the data to support any certain distribution. The values of the data are evaluated as an ordered time series. All following data values are compared to each individual data value.

Let x represent the data point at j while x_1, x_2,... x_n represent the remaining n data points. The Mann-Kendall statistics (S) are then provided by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign\ (x_j - x_k)$$

Where

$$\boldsymbol{sign(x_j - x_k) = -1\ if(x_j - x_k) < 0}$$
$$\boldsymbol{sign(x_j - x_k) = 0\ \ if(x_j - x_k) = 0}$$
$$\boldsymbol{sign(x_j - x_k) = 1\ \ if(x_j - x_k) > 0}$$

S > 0 that's means an increasing trend and S < 0 that's means a decreasing trend.

Calculation of the Mann-Kendall statistics

This is how the Mann-Kendall test is defined:

Step 1: Perform the S calculation as given previously.

Step 2 - Using the following equation, calculate the variance of S, VAR(S).

$$VAR\ (S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p (t_p - 1)(2t_p + 5) \right]$$

Step 3 - As follows, Z is the normalized test statistic.

$$Z = 0\ if\ \ S = 0$$

$$Z = \frac{S - 1}{[VAR\ \ (S)]^{1/2}}\ \ if\ \ S \rangle\ 0$$
$$Z = \frac{S + 1}{[VAR\ \ (S)]^{1/2}}\ \ if\ \ S \langle\ 0$$

Step 4 - Calculating the likelihood of these normalized test statistics. The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1 is given by the equation below.

$$f\ (z) = \frac{1}{\sqrt{2\pi}} e^{\frac{z^{-2}}{2}}$$

Step 5 - The trend is regarded as declining if Z is negative and the calculated probability exceeds the threshold of significance. The trend is deemed to be increasing if the Z is positive and the predicted probability exceeds the threshold of significance. If the calculated probability is below the significance level, there is no trend.

Sen's slope Estimator

Sen's estimator is a non-parametric method for estimating the magnitude of a time series' trend. With this method, a linear trend in the time series is assumed. In the first step of this approach, the slope (Ti) of each pair of data is calculated by

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$$T_i = \frac{X_j - X_k}{j - k} \quad for \quad i = 1, 2, \ldots\ldots\ldots .N$$

Where, X_j and X_k are data values at time j and k, respectively (j > k). The median of these N, T_i values yields Sen's slope estimate (). While a negative number denotes a decreasing tendency in the time series, a positive value of indicates an ascending trend. (Mondall et al, 2012). The level of significance reached by Sen's slope estimator is the same as that obtained by the Mann-Kendall test.

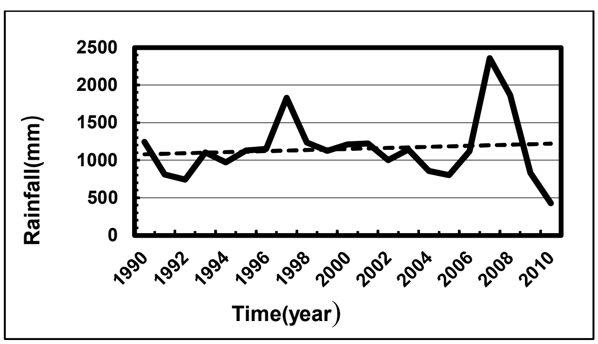
4. RESULTS AND DISCUSSION

4.1 Variation of Rainfall

4.1.1 Variation of Annual Rainfall

IMD Patna gathered rainfall data from different raingauge stations in the Punpun river basin, including Patna, Jahanabad, Goh, Gurua, and Nabinagar, from 1990 to 2010. Figure 6 depicts yearly rainfall time data for the aforementioned raingauge sites. The solid line represents the yearly rainfall variance, while the dotted line indicates the annual rainfall data trend line.

The data was evaluated, and it was discovered that the highest yearly rainfall occurred in the years 2008, 1997, 2004, 1997, and 2003 in Patna, Jahanabad, Goh, Gurua, and Nabinagar, respectively. Also, the minimal annual rainfall in the years 2010, 2004, 2010, 2010, and 2004 was recorded at Patna, Jahanabad, Goh, Gurua, and Nabinagar, respectively. Furthermore, the pattern of yearly rainfall is falling at all raingauge sites except Patna, where it was growing.



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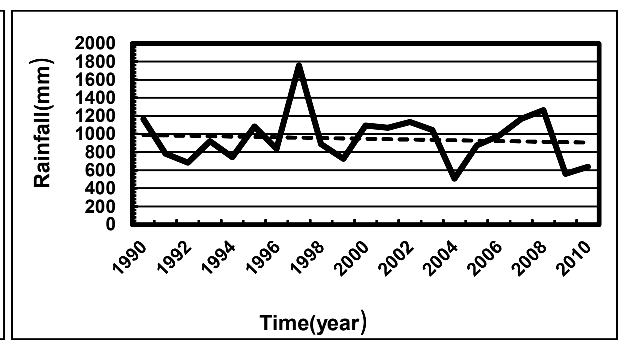

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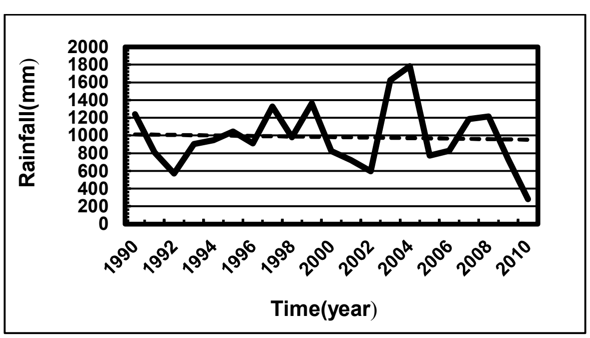

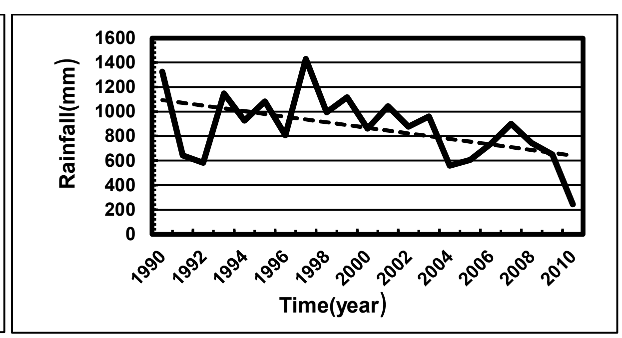

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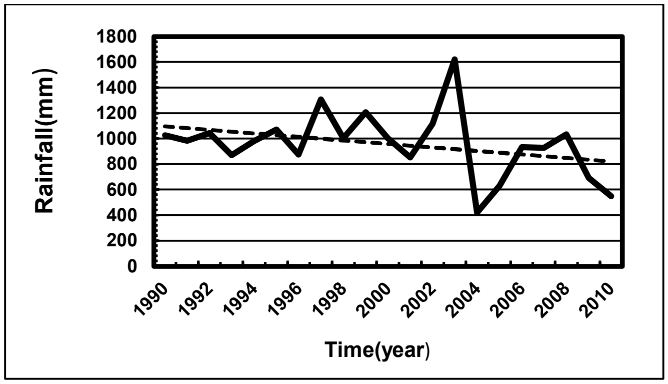
(C) (D)



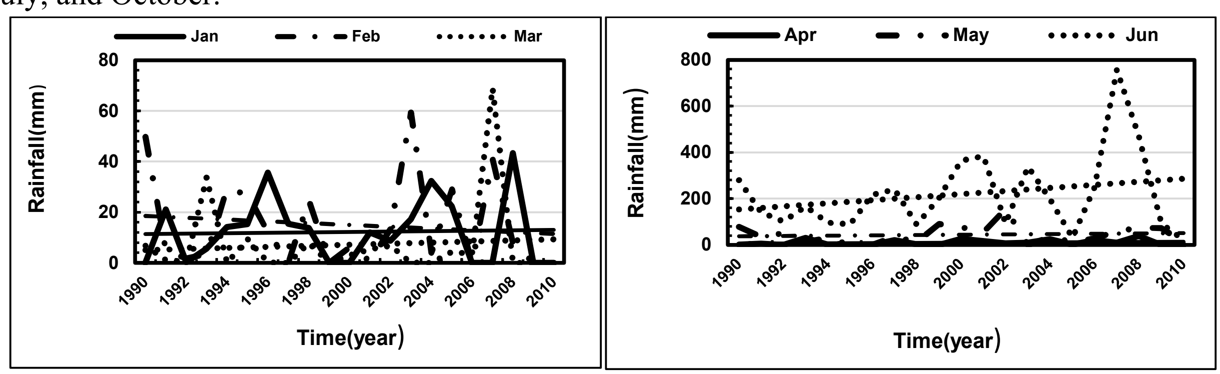
(E)

Figure 6: Time Series of Annual Rainfall at (A) Patna, (B)Jahanabad, (C) Goh, (D) Gurua, (E)Nabinagar

4.1.2 Monthly variation of Rainfall

4.1.2.1 Monthly variation of Rainfall data at Patna

The monthly fluctuation of rainfall data in Patna, Jahanabad, Goh, Gurua, and Nabinagar from 1990 to 2010 is shown in figures 7 to 11. It includes a trend line and variance in rainfall for each quarter of the year. The dashed-dot line represents February, May, August, and November, the dotted line represents March, June, September, and December, and the solid line represents the months of January, April, July, and October. Figures 7, 8, 9, 10, and 11 show that the months of March, June, July, and October have the highest average monthly rainfall, followed by January, June, July, and October, and then February, June, August, and October, followed by January, June, July, and October.



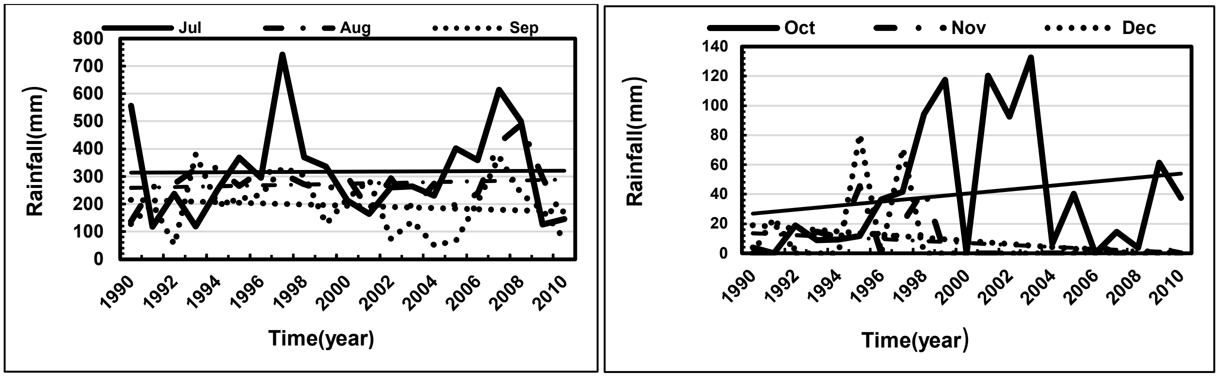


Figure 7: Variation of Monthly Rainfall and its Trend at Patna

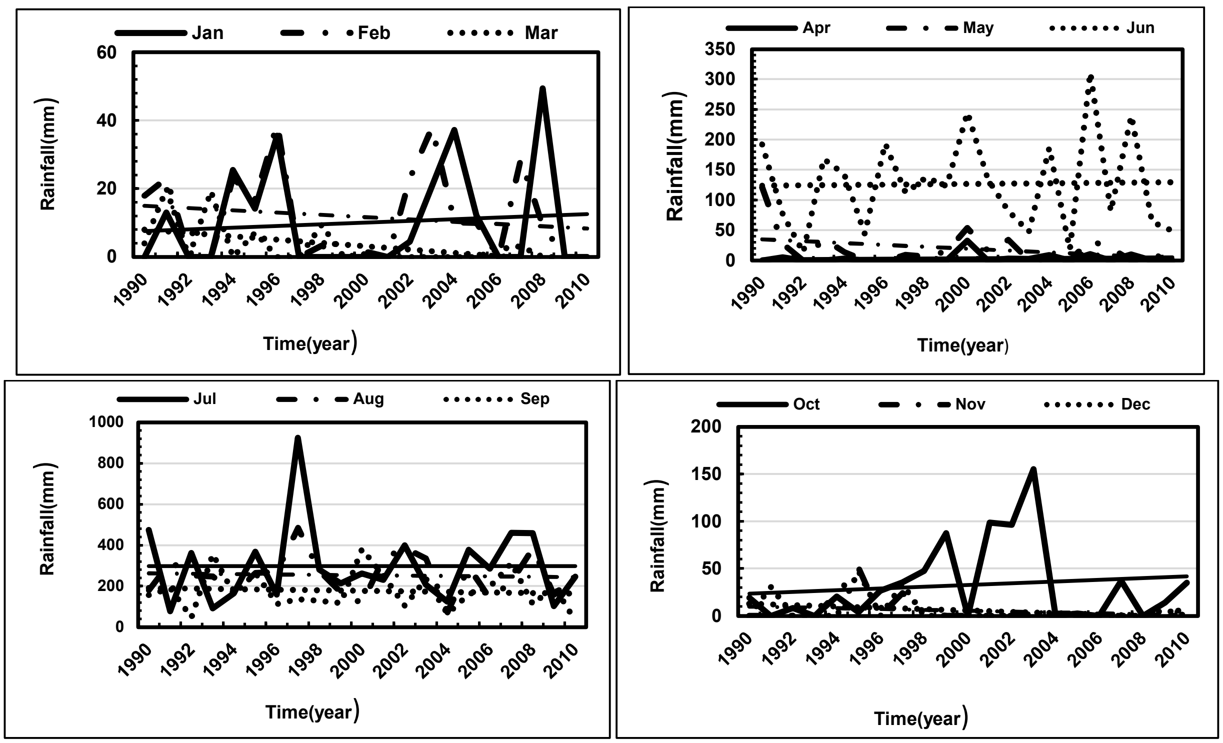
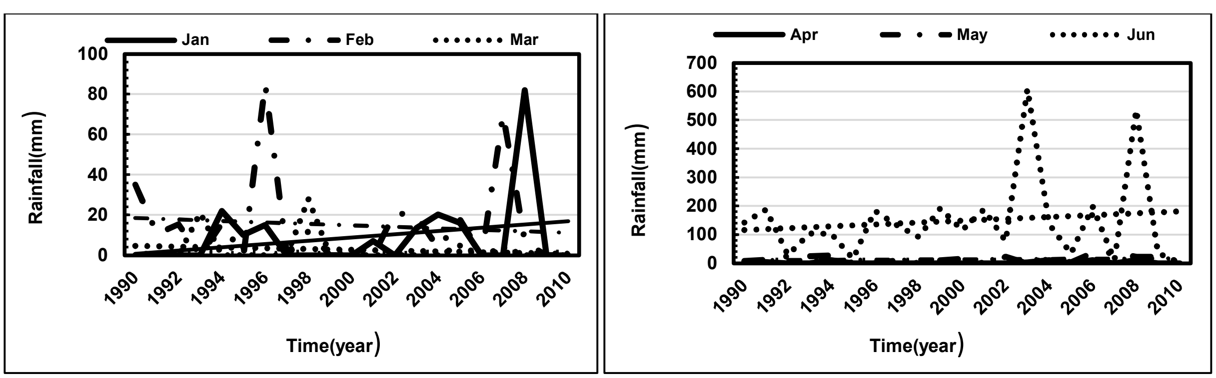


Figure 81: Variation of Monthly Rainfall and its Trend at Jahanabad



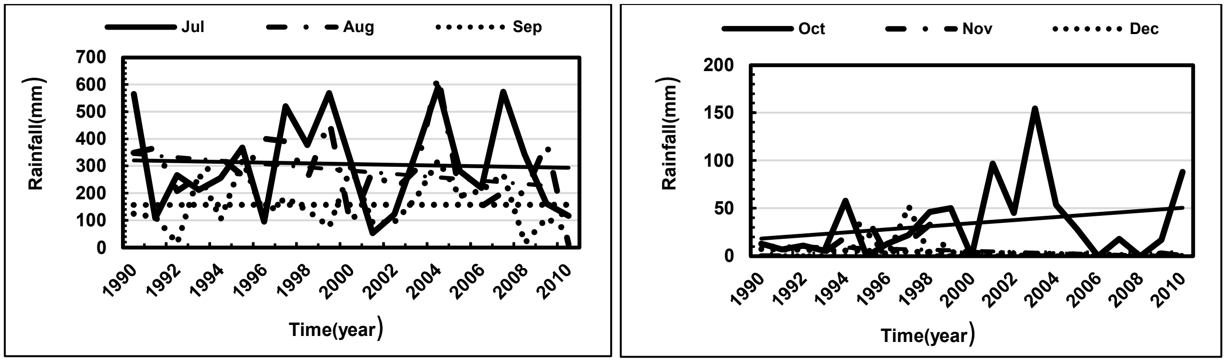


Figure 9: Variation of Monthly Rainfall and its Trend at Goh

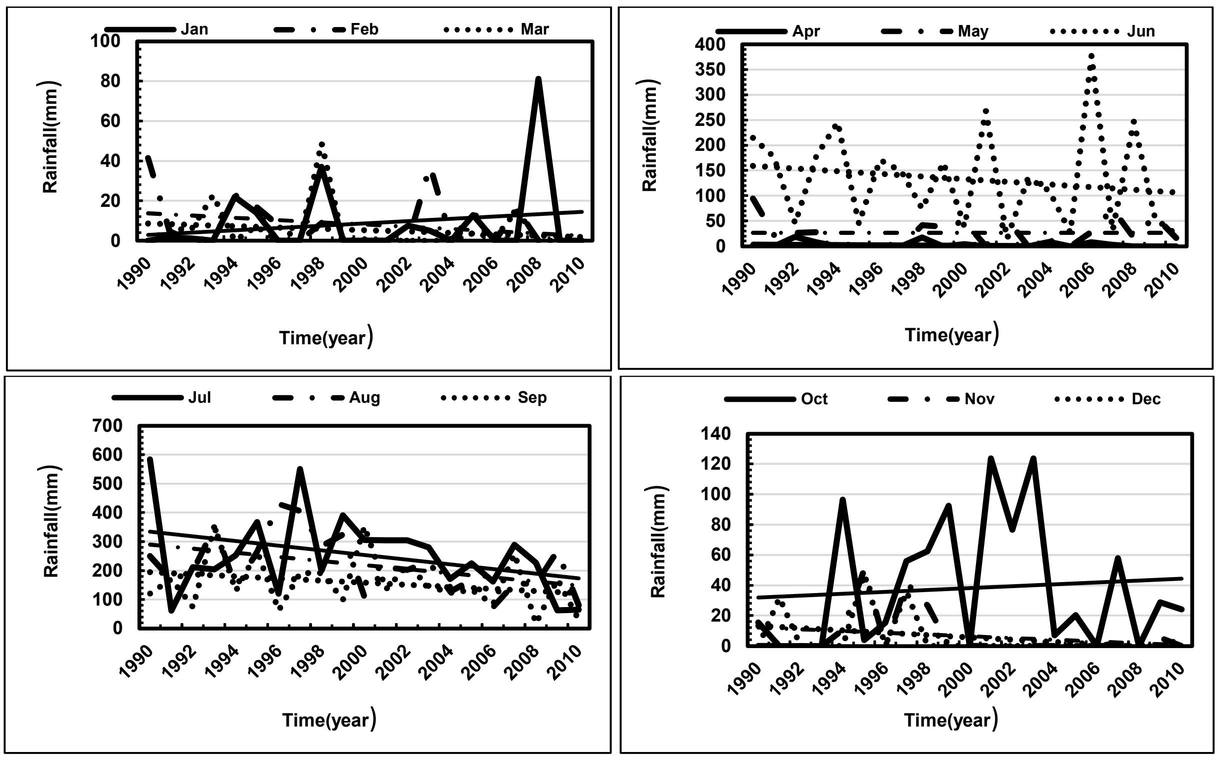
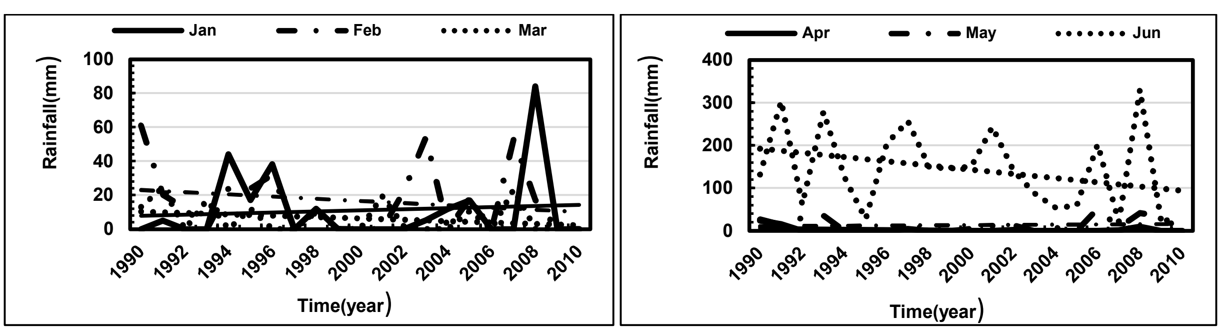


Figure 10: Variation of Monthly Rainfall and its Trend at Gurua



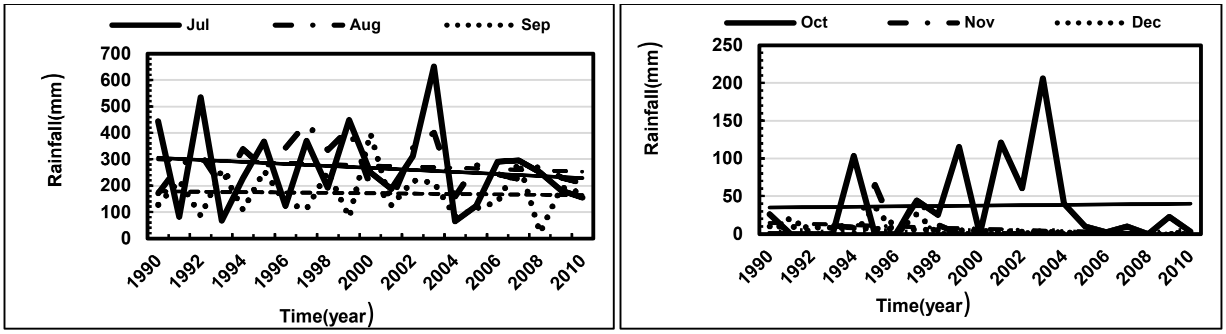


Figure 11: Variation of Monthly Rainfall and its Trend at Nabinagar

4.2 Variation of Discharge

4.2.1 Variation of Annual Discharge

CWC Patna provided discharge statistics for the Sripalpur gauging station. The discharge statistics recorded at Sripalpur range from 1990 to 2010. Figure 12 depicts a time history of yearly discharge at the Sripalpur gauging site. The dashed line shows the annual discharge data trend line, while the solid line shows the yearly discharge variation.

The largest yearly discharge was recorded in 2008, while the lowest annual discharge was recorded in 2004. Furthermore, it can be observed that the yearly discharge trend is diminishing.

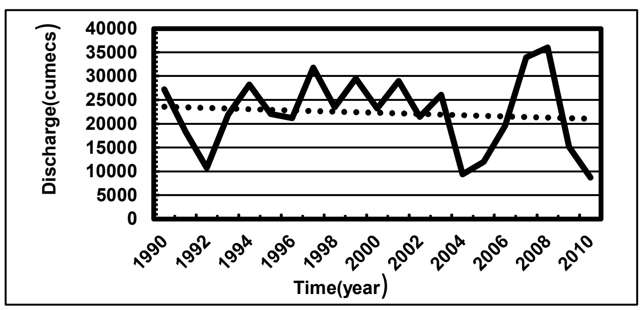


Figure12: Time Series and Trend of Annual Discharge data at Sripalpur

These statistics show that the yearly rainfall pattern in Patna and Goh is growing, whereas it is dropping in Jahanabad, Gurua, and Nabinagar. The annual flow trend at the Sripalpur site is likewise dropping, indicating the influence of decreasing yearly rainfall at Major raingauge sites. It may also be noted that the Patna raingauge station takes into account a minimum area. As a result, the growing trend has no influence on the discharge site.

4.2.2 Monthly variation of Discharge data at Sripalpur

Figure 13 shows the monthly fluctuation of Discharge data at Sripalpur from 1990 to 2010. It shows the variance and trend line of discharge variation for each quarter of the year. The solid line represents the months of January, April, July, and October, the dashed-dot line represents February, May, August, and November, and the dotted line shows monthly discharge variation in March, June, September, and December. It is also studied quarterly throughout the year and discovers that the highest value of monthly discharge occurs in the months of February, June, July, and October.

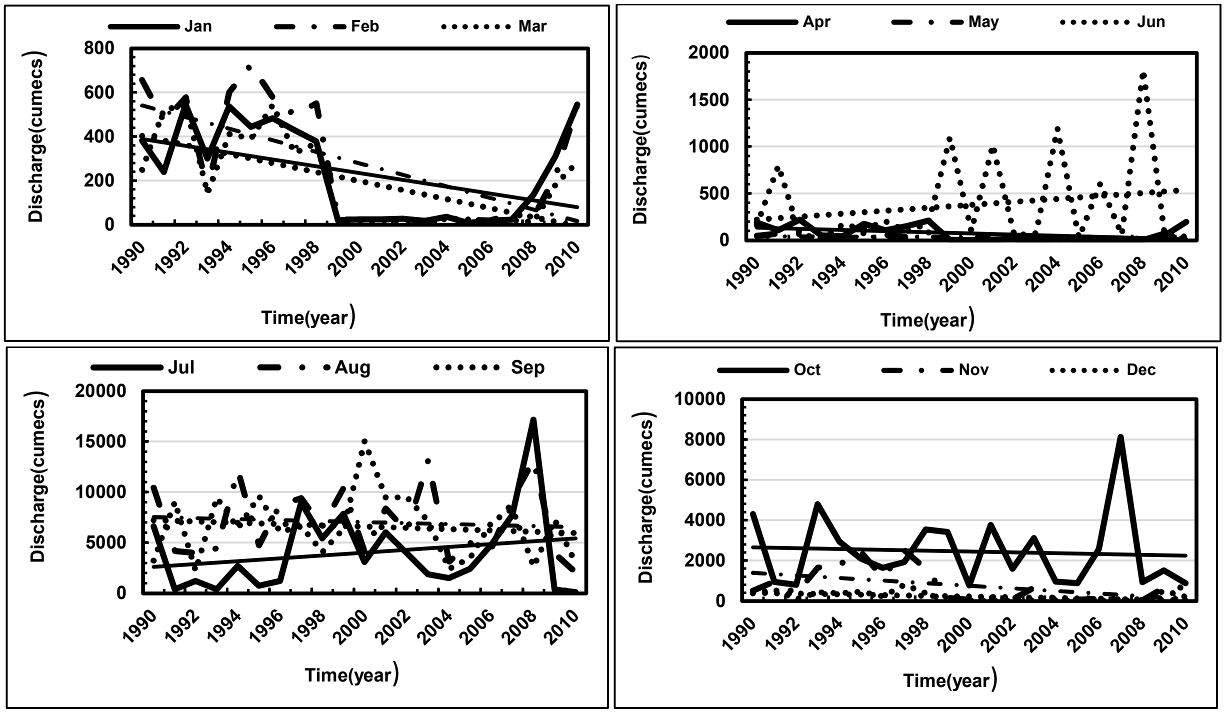


Figure 13: Variation of Monthly Discharge and its Trend at Sripalpur

4.3 Trend analysis by Mann-Kendall Method

Tables 1–11 show the Mann–Kendall trend and estimated Sen's slope for monthly rainfall, discharge, and seasonal rainfall data from 1990 to 2010 for all raingauge stations and discharge sites. The calculated trends are statistically significant if the estimated probability(p) is less than 0.05, suggesting a degree of significance of 95%, regardless of whether the Sen's slope is increasing or decreasing. The estimated trends are not statistically significant if the calculated probability(p) is greater than 0.05, indicating that the threshold of significance is not at 95%.

Table 1: Mann-Kendall Trend Results for Monthly Rainfall and estimated Sen's slope at Patna

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	0	0	0.805	-9	1052.33	-0.2466	Increasing	Insignificant
FEB	-0.235	-1.569	0.288	-36	1088	-1.0611	Decreasing	Insignificant
MAR	-0.030	-0.419	0.206	-42	1051.33	-1.2645	Decreasing	Insignificant
APR	0.083	0.827	0.560	20	1067.33	0.5815	Increasing	Insignificant
MAY	0.125	0.281	0.832	8	1092	0.2118	Increasing	Insignificant
JUN	1.015	0.461	0.785	10	1096.67	0.2717	Increasing	Insignificant
JUL	1.514	0.477	0.694	14	1096.67	0.3925	Increasing	Insignificant

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
AUG	-0.75	-0.274	0.903	-5	1095.67	-0.1208	Decreasing	Insignificant
SEP	-1.525	-0.784	0.650	-16	1096.67	-0.453	Decreasing	Insignificant
OCT	1.620	3.995	0.250	39	1093	1.1494	Increasing	Insignificant
NOV	0	0	0.251	-34	828	-1.1468	Increasing	Insignificant
DEC	0	0	0.775	-8	603.333	-0.285	Increasing	Insignificant

Table 2: Mann-Kendall Trend Results for Monthly Rainfall and estimated Sen's slope at Jahanabad

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	0	0	0.866	6	884	0.1681	No trend	Insignificant
FEB	-0.138	-1.181	0.388	-29	1052.33	-0.8631	Decreasing	Insignificant
MAR	0	0	0.076	-52	828	-1.7723	No trend	Insignificant
APR	0	0	0.486	21	827	0.6954	No trend	Insignificant
MAY	-0.274	-1.403	0.422	-27	1052.33	-0.8014	Decreasing	Insignificant
JUN	-1.226	-0.967	0.739	-12	1096.67	-0.3321	Decreasing	Insignificant
JUL	3.311	1.109	0.607	18	1096.67	0.5133	Increasing	Insignificant
AUG	-0.225	-0.089	0.975	-2	1096.67	-0.0302	Decreasing	Insignificant
SEP	-2.340	-1.317	0.650	-16	1096.67	-0.4529	Decreasing	Insignificant
OCT	0.437	1.338	0.462	25	1068.33	0.7342	Increasing	Insignificant
NOV	0	0	0.488	-18	603.33	-0.6921	No trend	Insignificant
DEC	0	0	0.596	-14	603.33	-0.5292	No trend	Insignificant

Table 3: Mann-Kendall Trend Results for Monthly Rainfall and estimated Sen's slope at Goh

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	0	0	0.5090	20	828	0.660	No trend	Insignificant
FEB	0	0	0.4680	-24	1004.67	-0.725	No trend	Insignificant
MAR	0	0	0.9645	2	507.333	0.044	No trend	Insignificant
APR	0	0	0.8893	5	827	0.139	No trend	Insignificant
MAY	0.345	2.457	0.5628	20	1078	0.578	Increasing	Insignificant
JUN	-1.253	-0.843	0.7169	-13	1095.67	-0.362	Decreasing	Insignificant

JUL	-1.286	-0.418	0.9759	-2	1096.67	-0.030	Decreasing	Insignificant
AUG	-6.754	-2.384	0.1235	-52	1096.67	-1.54	Decreasing	Insignificant
SEP	0.020	0.012	1	0	1096.67	0	Increasing	Insignificant
OCT	0.762	2.203	0.3957	29	1087	0.849	Increasing	Insignificant
NOV	0	0	0.2858	-29	688.333	-1.067	No trend	Insignificant
DEC	0	0	0.6169	-11	399.667	-0.500	No trend	Insignificant

Table 4: Mann-Kendall Trend Results for Monthly Rainfall and estimated Sen's slope at Gurua

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	0	0	0.711	-12	884	-0.37	No trend	Insignificant
FEB	0	0	0.148	-44	884	-1.446	No trend	Insignificant
MAR	0	0	0.346	-29	883	-0.942	No trend	Insignificant
APR	0	0	0.403	-25	827	-0.834	No trend	Insignificant
MAY	0	0	0.621	17	1052.33	0.493	No trend	Insignificant
JUN	-4.264	-3.204	0.123	-52	1096.67	-1.54	Decreasing	Insignificant
JUL	-8.2	-3.224	0.155	-48	1096.67	-1.419	Decreasing	Insignificant
AUG	-7.441	-3.392	0.057	-64	1096.67	-1.902	Decreasing	Insignificant
SEP	-3.184	-2.007	0.381	-30	1096.67	-0.875	Decreasing	Insignificant
OCT	0.556	1.452	0.462	25	1068.33	0.734	Decreasing	Insignificant
NOV	0	0	0.488	-18	603.33	-0.692	No trend	Insignificant
DEC	0	0	0.505	-16	507.33	-0.666	No trend	Insignificant

Table 5: Mann-Kendall Trend Results for Monthly Rainfall and estimated Sen's slope at Nabinagar

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	0	0	0.813	-8	884	-0.2354	No trend	Insignificant

FEB	-0.201	-1.212	0.184	-43	1003.66	-1.3257	Decreasing	Insignificant
MAR	0	0	0.167	-42	884	-1.3789	No trend	Insignificant
APR	0	0	0.492	-19	688.33	-0.6860	No trend	Insignificant
MAY	0	0	0.666	15	1052.33	0.4315	No trend	Insignificant
JUN	-6.7	-4.674	0.061	-63	1095.66	-1.8730	Decreasing	Insignificant
JUL	-4.75	-1.775	0.525	-22	1094.66	-0.6347	Decreasing	Insignificant
AUG	-2.593	-0.936	0.545	-21	1095.66	-0.6042	Decreasing	Insignificant
SEP	-0.535	-0.312	0.879	-6	1096.66	-0.1509	Decreasing	Insignificant
OCT	0	0	0.643	16	1051.33	0.4626	No trend	Insignificant
NOV	0	0	0.252	-31	688.33	-1.1434	No trend	Insignificant
DEC	0	0	0.197	-30	507.33	-1.2875	No trend	Insignificant

Table 6: Mann-Kendall Trend Results for Monthly Discharge and estimated Sen's slope at Sripalpur

Month	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
JAN	-13.56	-5.784	0.0852	-58	1096.66	-1.721	Decreasing	Insignificant
FEB	-13.77	-4.938	0.0320	-72	1096.66	-2.143	Decreasing	Significant
MAR	-13.98	-7.051	0.0072	-90	1096.66	-2.687	Decreasing	Significant
APR	-3.56	-4.724	0.0654	-62	1096.66	-1.842	Decreasing	Insignificant
MAY	-0.93	-2.545	0.2767	-37	1095.66	-1.087	Decreasing	Insignificant
JUN	-2.77	-0.729	0.6946	-14	1096.66	-0.392	Decreasing	Insignificant
JUL	87.87	2.180	0.6505	16	1096.66	0.452	Increasing	Insignificant
AUG	-56.93	-0.807	0.5661	-20	1096.66	-0.573	Decreasing	Insignificant
SEP	-38.06	-0.576	0.7858	-10	1096.66	-0.271	Decreasing	Insignificant
OCT	-66.77	-2.724	0.2638	-38	1096.66	-1.117	Decreasing	Insignificant
NOV	-29.73	-3.930	0.0320	-72	1096.66	-2.143	Decreasing	Significant
DEC	-9.78	-4.382	0.0200	-78	1096.66	-2.325	Decreasing	Significant

Table 7: Mann-Kendall Trend Results for Seasonal Rainfall and estimated Sen's slope at Patna

Season	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
Winter	-0.322	-1.183	0.5646	-20	1088	-0.017	Decreasing	Insignificant

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PreMonsoon	0.867	1.405	0.5661	20	1096.66	0.017	Increasing	Insignificant
Monsoon	-2.406	-0.239	0.7625	-11	1095.66	-0.009	Decreasing	Insignificant
PostMonsoon	-0.363	-0.646	0.8324	-8	1094.66	-0.006	Decreasing	Insignificant

Table 8: Mann-Kendall Trend Results for Seasonal Rainfall and estimated Sen's slope at Goh

Season	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
Winter	0	0	1	-1	1052.33	0	No Trend	Insignificant
PreMonsoon	0.302	1.564	0.7853	10	1092	0.008	Increasing	Insignificant
Monsoon	-4.527	-0.504	0.7857	-10	1096.66	-0.008	Decreasing	Insignificant
PostMonsoon	0.460	1.049	0.7392	12	1092	0.010	Increasing	Insignificant

Table 9: Mann-Kendall Trend Results for Seasonal Rainfall and estimated Sen's slope at Gurua

Season	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
Winter	0	0	0.468	-24	1004.66	-0.022	No Trend	Insignificant
PreMonsoon	0	0	0.879	-6	1080	-0.004	No Trend	Insignificant
Monsoon	-25.44	-3.324	0.012	-84	1096.66	-0.075	Decreasing	Significant
PostMonsoon	-0.11	-0.223	0.714	-13	1079	-0.011	Decreasing	Insignificant

Table 10: Mann-Kendall Trend Results for Seasonal Rainfall and estimated Sen's slope at Jahanabad

Season	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
Winter	0	0	0.666	-15	1052.33	-0.013	No Trend	Insignificant
PreMonsoon	-0.616	-2.34	0.362	-31	1087	-0.027	Decreasing	Insignificant
Monsoon	1.568	0.183	0.927	4	1096.66	0.002	Increasing	Insignificant

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PostMonsoon	0	0	0.927	-4	1080	-0.002	No Trend	Insignificant

Table 11: Mann-Kendall Trend Results for Seasonal Rainfall and estimated Sen's slope at Nabinagar

Season	*sen.slope*	*sen.slope.pct*	*p.value*	*S*	*varS*	*Z*	*sen.slope*	*Trend*
Winter	0	0	0.473	-24	1031.33	-0.022	No Trend	Insignificant
PreMonsoon	-0.097	-0.427	0.761	-11	1087	-0.009	Decreasing	Insignificant
Monsoon	-11.3	-1.314	0.238	-40	1096.66	-0.035	Decreasing	Insignificant
PostMonsoon	-0.780	-1.6	0.544	-21	1087	-0.018	Decreasing	Insignificant

CONCLUSION

Rainfall and discharge from several raingauge stations (Patna, Goh, Gurua, Jahanabad, and Nabinagar) and discharge sites (Sripalpur) have been examined in the Punpun river basin. A non-parametric statistical analysis was performed on the available data to determine the variation of monthly and yearly rainfall and discharge data.

The data acquired for the variation in rainfall and discharge was used to derive the monthly variation in rainfall and discharge. The monthly variation of rainfall and discharge for the Punpun river basin at different raingauge stations and discharge sites was provided. When the variance in rainfall and discharge at all stations was compared for 21 years from 1990 to 2010, it was determined that the fluctuations were statistically insignificant.

For trend analysis, the non-parametric Mann-Kendall test was used using rainfall and discharge data. This test found statistically negligible changes in rainfall, but statistically significant declining trends in discharge (February, March, November, and December). When the same test was applied to the seasonal data (winter, pre-monsoon, monsoon, and post-monsoon) at all the stations, the test indicated statistically insignificant trends except for one station at Gurua, which indicated a statistically significant decreasing trend in one season (Monsoon) and statistically insignificant trends in the other three.

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