DISCHARGE, RAINFALL AND POLLUTION LOAD ON DHALESHWARI RIVER: A STUDY ON TREND ANALYSIS

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ABSTRACT

River flows are changing when hydro-meteorological variables are changing, water resources are losing the natural discharge capacity from upper stream as well as increasing rate of pollution load. This study has been conducted to discharge, rainfall and pollution of the Dhaleshwari river at savar station. 21 years of rainfall and discharge data have been collected. The time period of discharge and rainfall is 1998 to 2018. Mann-Kendall test and sen's slope estimator has been conducted to determine trend. Annual trend of discharge is a decreasing trend. Summer and monsoon discharge are decreasing trend but winter discharge is increasing trend. Annual rainfall is upward trend. Summer rainfall is upward but monsoon and winter both are downward trends. Pearson coefficient of correlation has been used to find the relation between hydro-meteorological variables. The dependency of rainfall on discharge is very low. So there is no strong relationship between rainfall and discharge. According to findings, it seems the discharge condition of Dhaleshwari river is always changing and rainfall at Savar is also changing. P^H, TDS, Salinity, chloride as some pollution loading parameters were studied for several years thus results frequent discharge and improper industrialization at bank of Dhaleshwari river.

Keywords: *Rainfall, Discharge, Dhaleshwari river, Pollution load, Change.*

1. INTRODUCTION

Surface water is an essential element for natural and artificial environment which is carried by rivers and provides the life generating-fuel to civilizations (Islam & Sikder, 2017). River is a large stream that begins from mountain or lake. A large stream consists of many small streams. River generally receives water from rainfall, snowmelt, etc. The river is a large stream of water. If a country is considered a human body then water is the blood of body and river is vein (Ekram et al, 2018). Dhalesshori river is locate in savar. There are 2 stations has been selected for discharge and rainfall which are jagir and savar respectively. Dhaleshwari river is a distributary of Jamuna river. It starts off the Jamuna near the north-western tip off tangail district. It is a meandering river having two branches. The mainstream flows north of manikganj and joins the other branch, the Kaliganga, south of Manikganj. The Kaliganga again joins with the Dhaleshwari. Study about river discharge and rainfall are pertinent to know the river flow conditions, surface water flow, irrigation etc. One of the most important variables used for observing the hydrological cycle over the land surface is the flow of river. River discharge is powerful integrating tools and its monitoring can provide accurate and timely data to response of the land surface to atmospheric forces. It is also one of the accurately measured components of the hydrological cycle (Shiklomanov et al, 2006) and therefore can provide more estimates of water cycle trends and variability. Variability in rainfall characteristics (type, amount, frequency, intensity and duration) is among the important climate change impacts. Rainfall variability affects water resources sustainability which includes the availability, management, and utilization of water resources. This may inversely affect ecosystems, land productivity, agriculture, food security, water quantity and quality, and human health (EPA, 2014). Rainfall is an important variable that underlies both droughts and floods (Coscarelli and Caloiero, 2012). Annual discharge at jagir station is downward and rainfall at savar station is upward. Climatic variability and surface water situation are changing all over the world, Bangladesh is not isolated from this phenomenon. Four assessment report of (IPCC, 2007) showed that, long term trend analysis of precipitation from 1900 to 2005 found drier situation in southern Asia. In this study, Dhalesshori river has been considered as study area. Hydro-meteorological data considered as rainfall at Savar station and river discharge at jagir station. Rainfall and discharge data are conducted for this research. Trend is a General direction in which something is developing of changing. The purpose of trend testing is to determine if values of a random variable generally increase (or decrease) over same period of time in statistical terms (Helsel and Hirsch, 1992). Rainfall and discharge trend have been analyzed here. 21 years of rainfall and discharge data (1998 to 2018) has been considered. Relation between rainfall and discharge has been studied in this research. Annual and seasonal trend and relation have been studied here. Dependency of rainfall on discharge is very low. Trend, relation variability has been discussed in this study, not impacts on human or wildlife.

2. METHODOLOGY

Research methodology is a way to systematically solve the research problem (Kothari, 2004). It may be understood as a science of studying how research is done scientifically. Research methodology is a science of studying how research is done scientifically. In short, methodology is the study or description of methods (Baskervile, 1991).

2.1 Sampling location

Dhalesshori river at Dhaka district is the study area of this project. Because one discharge station and one rainfall station are situated in there. Discharge and rainfall station of jagir and savar respectively are situated in Dhaka district. Rainfall station located near the discharge station of jagir. Both two station are shown in the following map.

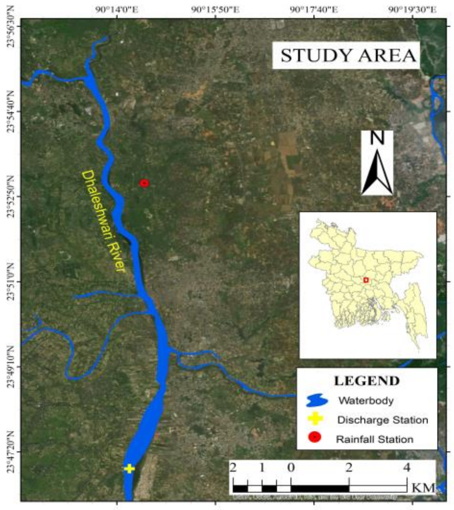

Fig 1: Sampling location

Daily time series data of streamflow or discharge at jagir (1998 to 2018). Total period of discharge data is 21 years at jagir station. In other hand, daily time series data of rainfall at Savar station have been analyzed. Discharge (from 1998 to 2018) of jagir station and rainfall (from 1998 to 2018) of Savar station have been collected from Flood Processing and Forecasting Circle (FPEC) of Bangladesh Water Development Board (BWDB).

2.2 Data processing

Processing implies editing, coding, classification and tabulation of collected data so that they are amenable to analysis (kothari, 2004). Collected discharge and rainfall data from NWRD was daily time series data. Discharge data purveyed for FPFC was observed data and rainfall was daily time series data. There are some missing data in collected time series of data set. All of the missing value was interpolated by some statistical formula. Two statistical formulas have been used for interpolation.

2.2.1 Linear interpolation method

Linear interpolation is often used to fill the gaps in a table. Linear pattern means the points created a straight line. Linear interpolation method use when gap of data is short. It lies between one or two days not more than two days. In case of discharge, the value of stream flow is closely related to previous or following days. Linear interpolation method use to fill up gap before last value and after first value. Formulas of linear interpolation is

$$y = y_1 + \frac{(x - x_1) \times (y_2 - y_1)}{(x_2 - x_1)} \qquad (1)$$

Here, y= new discharge, y_1= previous discharge, y_2= discharge of following days, x= new year, x_1= previous year, x_2= following years.

2.2.2 Interpolation by regression

Interpolation is a method of constructing new data points within the range of a discrete set of known data points. This can be achieved by regression. When gap of data is more than two variables or longer gaps then regression analysis is used to fill up missing data. Formula of regression is

$$y = bx + a \qquad (2)$$

Here, y= discharge, x= time period/year (independent), b= regression coefficient or changing rate for one-unit change in ‘x’, a= intercept.

2.3 Data processing

There are two types of trend test which one is parametric test and another one is non-parametric test. Non-parametric test is conducted to this research. Mann-Kendall Test (MK) and Sen’s Slope Estimator method are used as non-parametric test. Non-parametric data is more reliable for hydrologic data. Pearson’s Coefficient of Correlation is used to show the relationship between variable. Discharge-discharge, discharge-rainfall relation is determined by correlation. Relation is spectacled by percentage. Coefficient of correlation is calculated to determine the dependency rate.

2.3.1 Data analysis methods

I) Mann-Kendall test

The purpose of the Mann-Kendall (MK) test (Mann 1945, Kendall 1975) is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. The hypotheses of Mann and Kendall’s trend test is

H_0: Time series values are independent and identically distributed i.e. there is no trend.

H_A: There is a monotonic (not necessarily linear) trend.

So, it is a teo-tailed test. The test statistic, S (score) is then computed as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}\ (y_j - y_i) \qquad (3)$$

Where, sign (y_j-y_i) is equal to +1, 0, or -1, n is the total number of observations. A positive value of S indicates an ‘upward trend’ and a negative value of S indicates ‘downward trend’.
The variance statistic is given as

$$V(s) = \frac{n(n-1)(2n+5)}{18} \qquad (4)$$

Therefore, the test statistic z is calculated as

$$Z = \begin{cases} \frac{(s-1)}{\sqrt{V(s)}} & \text{where} 0, S = 0 \\ \frac{(s+1)}{\sqrt{V(s)}} & \text{where} S < 0 \end{cases} \qquad (5)$$

Z follows standard normal distribution with mean zero and variance unity. A positive value of test statistic indicates a positive association means upward trend, a negative value of test statistic indicates a negative association means downward trend and test statistic w equal zero means no association(no trend). The null hypothesis of no trend is rejected when S and Z are significantly different from zero. It is highly recommended for general use by World Meteorological Organization (Mitchell et al., 1966).

II) Sen’s Slope estimator test

This test computes both the slope (i.e. linear rate of change) and intercepts according to Sen’s method. First, a set of linear slopes is calculated as follows:

$$T_i = \frac{x_j - x_k}{j - k} \qquad \text{for i} = 1, 2, 3, \dots\dots\dots \text{N} \qquad (6)$$

Where, x_j and x_k are considered as data value at time j and k (j>k) correspondingly. The median of these N values of T_i is represented as Sen's estimator of slope which is guven as:

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

Sen's estimator is computed as $Q_{med} = T_{(N+1)/2}$ if N appears odd, and it is considered as $Q_{med} = [T_{N/2} + T_{(N+2)/2}] /2$ if N appears even. At the end, Q_{med} is computed by a two-sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q_i indicates upward or increasing trend and a negative value of Q_i gives a downward or decreasing trend in the time series.

III) Pearson's Coefficient of Correlation

Coefficient of correlation is a numerical measure of the correlation between two fluctuating series, and is denoted by r. The numerical expression of the degree of correlation existing between two variables. Let, $x_1, x_2, \ldots\ldots x_n$ and $y_1, y_2, \ldots\ldots y_n$ be two data sets. Coefficient of correlation between two data set can be expressed as

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 (y_i - \bar{y})^2}} \quad (8)$$

Major characteristics of "r" are as follows:

1. The value of r lies between -1 to +1
2. When r = +1, there exists perfect positive correlation.
3. When r = -1, there exists a perfect negative correlation.
4. When r = 0, there is no correlation.

2.4 Coefficient of Determination

The coefficient of determination is the square term of coefficient of correlation (r). It is usually denoted by r^2 (or R^2). It expresses the proportion of the total variation of the dependent variable has been explained by the independent variable (Aziz, 2008). The value of Coefficient of Determination is 0 to 1. It is the proportion of the variance in the dependent variable that is predictable from the independent variable(s).

3. ILLUSTRATIONS

3.1 Trends in annual mean discharge

Within 21 years times (1998 to 2018) period of discharge has been calculated. Non-parametric tests have been applied here to detect trend. Mann-Kendall test and Sen's slope estimator has been conducted to find out the trend. Table 1 indicates Mann-Kendall and Sen's slope values and it has been depicted that value of z of discharge at jagir station is -0.94 and -0.164 respectfully. So, it seems that trend of discharge at jagir station is downward.

Table 1: Mann-Kendall test and Sen's slope value of annual discharge.

Station	**Mann-kendalls slope (z)**	**Sen's slope (z)**
Jagir	-0.94	-0.164

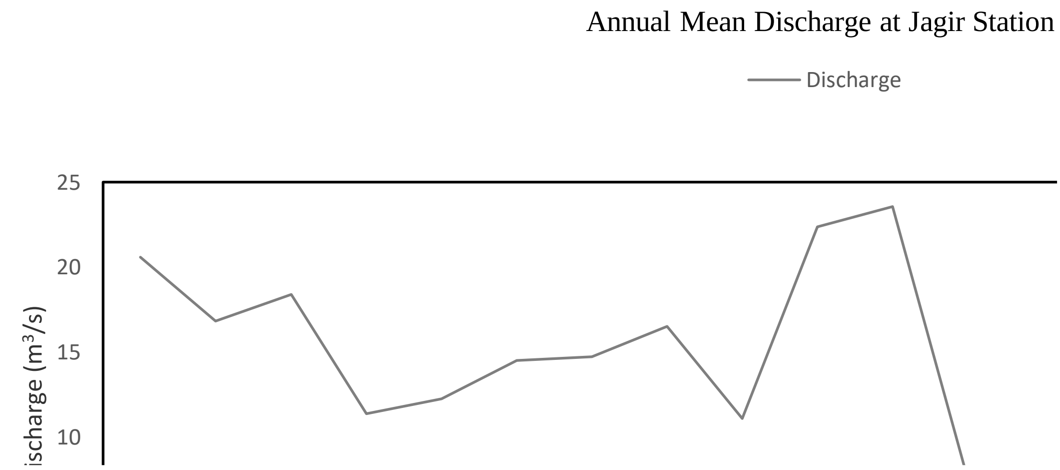

Figure 2: Annual mean discharge at jagir station

3.2 Trend is seasonal mean discharge

The range of months of summer is from March to May and monsoon is from June to October and winter is from November to February. Time period of data considered as from 1998 to 2018 for summer, monsoon and winter. Table 2 indicates that Mann-Kendall test value of summer, monsoon and winter are -0.54, -1.00 and 1.60 respectively. These values clearly indicate that trend of discharge in summer and monsoon is downward. Winter trend is upward. Sen's slope values of summer, monsoon and winter are -0.042, -0.595 and 0.099 respectively.

Table 2: Mann-Kendall and sen's slope values of seasonal mean discharge

Station (jagir)	**Mann-kendalls slope (z)**	**Sen's slope**
Summer	-0.54	-0.042
Monsoon	-1.00	-0.595
Winter	1.60	0.099

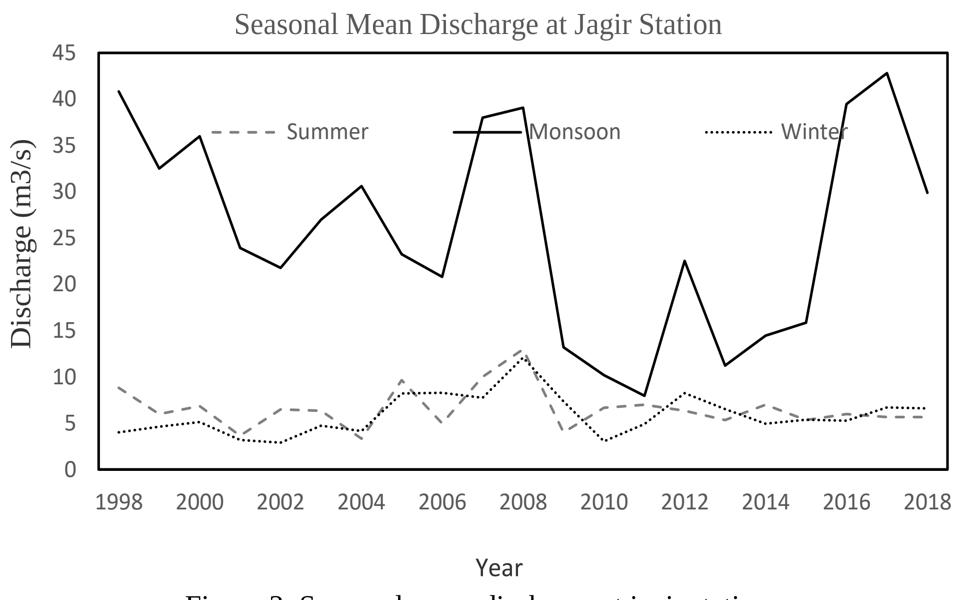

Figure 3: Seasonal mean discharge at jagir station

Graphical representation has been clearly indicated that there is little difference between summer and winter stream flow. Discharge rate in some years are higher in winter than summer. In 2011, very low discharge appeared in monsoon.

3.3 Trends in rainfall at savar station

Rainfall trend is the annual, seasonal, monthly, etc variability of rainfall. Trend of rainfall during time period of rainfall data is from 1998 to 2018 has been studied here. To detect trend, non-parametric test (Mann-Kendall test, sen's slope estimator) has been used in this study.

3.4 Annual rainfall trend at savar station

21 years of rainfall at savar station has been studied here. Trend condition has been determined by non-parametric tests which are Mann-Kendall test and sen's slope estimator. From table 3, it has been showed that annual rainfall is upward or increasing trend. Value of the Mann-Kendall test is 0.27 which is positive value. Sen's slope value of annual rain is 5.258 that mean magnitude of rainfall change is 5.258 per year.

Table 3: Mann-Kendall and sen's slope statistics of trend in rainfall at savar station.

Station	Mann-kendall test, z value	Sen's slope
Savar	0.27	5.258

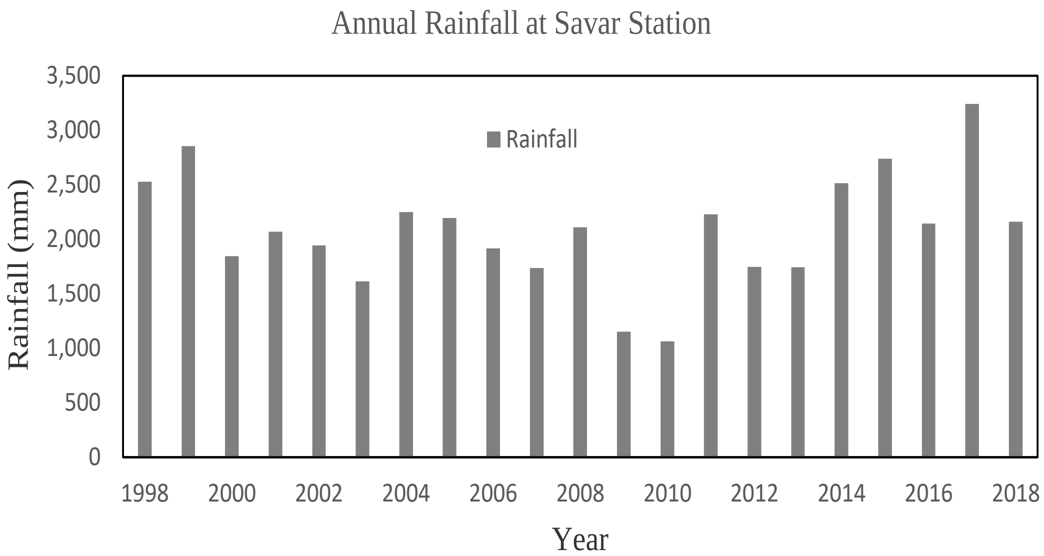

Figure 4: Annual rainfall at savar station

3.5 Seasonal rainfall trend at savar station

There are three seasons in total which are summer, monsoon and winter. Summer consists of March to May and monsoon is June to October and winter is November to February. Monsoon considers as rainy season and summer and winter are considered as dry season.

Seasonal rainfall trend has been analysed here. From table 4, Mann-Kendall test values of summer, monsoon, and winter are 0.96, -0.03 and -0.36 respectively. So, it clearly indicates that summer trend of rainfall is upward. On the other hand, monsoon and winter rainfall trends are downward because their z values are negative. Sen's slope values of summer, monsoon, and winter are 8.907, -4.340 and -1.183 respectively. Downward trend of monsoon rainfall is higher than winter rainfall. Graphical presentation of seasonal rainfall trend has been shown by bar diagram in figure 5.

Table 4: Mann-Kendall And Sen's Slope Test Of Seasonal Trend Of Rainfall At Savar Station

Season	**Z value**	**Sen's slope**
Summer	0.96	8.907
Monsoon	-0.03	-4.34
Winter	-0.36	-1.183

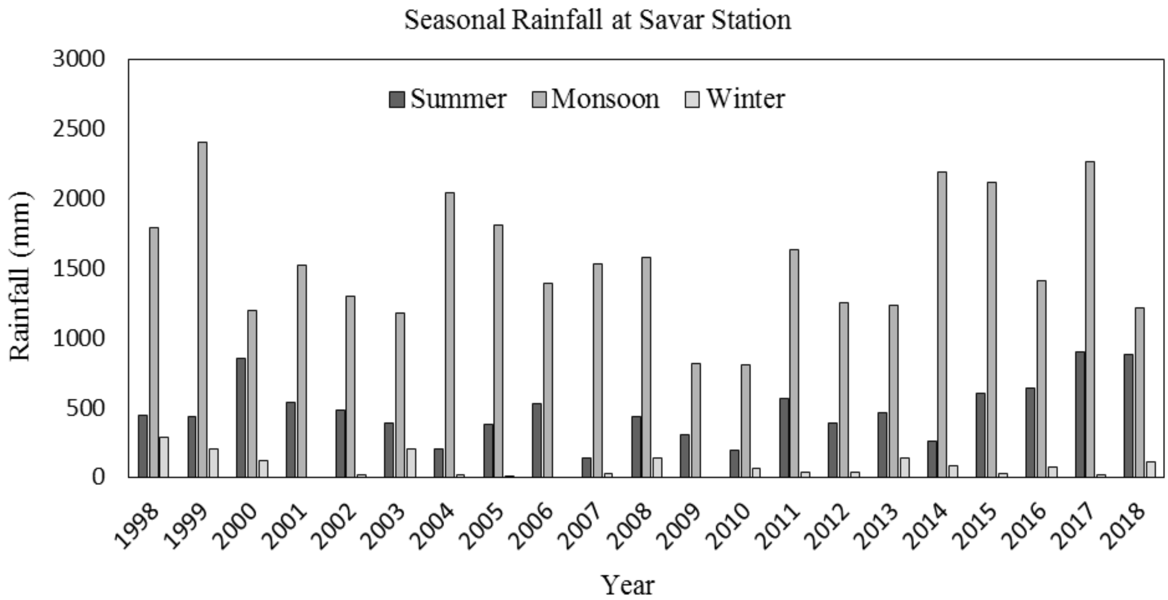

Figure 5: Seasonal rainfall at savar station

3.6 Relation between two stations

In river catchment area, some portions of discharge of river are fed by precipitation. Precipitation considered as rainfall. So, discharge of a river must depend on precipitation (rainfall). In Bangladesh, 75% of rainfall occurs in monsoon region (Islam, et al, 2007). For Pearson's coefficient of correlation, rainfall considered as an independent variable and discharge considered as dependent variable. Table 5 shows the correlation and dependency rate between discharge at jagir station and rainfall at savar station. In this table, it appears that "r" is positive. There was positive correlation between discharge and rainfall. The positive value of "r" indicates positive relationship and negative value of "r" indicates negative relationship. Value of "r" is 0.3776 is close to 0.5 that results significant relationship between two station.

Table 5: Correlation between Rainfall at Savar Station and Discharge at Jagir Station

Independent variable	**Dependent variable**	**r**	**r^2**	**r^2 (%)**
Rainfall	Discharge	0.3776	0.14258	14.2

From table 5, it has been indicated that relationship between annual rainfall and discharge is 14.2%. That means 14.2% of annual discharge is fed by annual rainfall. Rest of discharge is contributed by others sources like runoff, tributaries, etc. Three different seasons have been considered here which are summer (March – May), monsoon (June – October), and winter (November – February). Winter season comprise with November, December, January and February.

Table 6 shows the correlation between rainfall at savar station and discharge at jagir station. Where rainfall is independent variable and discharge is dependent variable. Pearson's coefficient of correlation exhibits the dependence rate of dependent variable on independent variable. From table 6 it seems that "r" value of correlation of summer, monsoon and winter is -0.16855, 0.299655 and -0.11885 respectively. Value of "r" is positive in monsoon. So, there has positive relationship between rainfall at savar station and discharge at jagir station in monsoon time. Negative value of "r" shows negative relation between rainfall and discharge in summer and wintertime.

Dhalesshori river in summer depends on rainfall at savar. The rest of discharge is fed by other sources. In monsoon and winter discharge is contributed by rainfall is 8.97% and 1.41% respectively. Upstream flows are the main contributor to Dhalesshori river's discharge.

Table 6: Correlation between Rainfall at Savar Station and Discharge at Jagir Station at different seation

Duration	**R**	**R^2**	**R^2 (%)**
Summer	-0.16855	0.0284	2.84%
Monsoon	0.299655	0.089793	8.97%
Winter	-0.11885	0.0141	1.41%

4. CONCLUSIONS

Annual discharge within these time periods is 14.2% that means 14.2% of annual discharge is fed by annual rainfall. Rest of discharge is contributed by others sources like runoff, tributaries, etc. In 2011, very low discharge appeared in monsoon. The mean discharge and rainfall during this period are negative whereas recent years' rainfall increasing in summer season and for monsoon opposite trend. There was positive correlation between discharge and rainfall. The positive value of "r" indicates positive relationship and negative value of "r" indicates negative relationship. Value of "r" is 0.3776 is close to 0.5 that results significant relationship between two station.

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