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# TREND ANALYSIS OF RAINFALL DATA IN DIVISIONAL METEOROLOGICAL STATIONS OF BANGLADESH

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## Abstract

Sixty four years, 1952-2016, rainfall data (monthly rainfall and annual total rainfall) were analyzed using non-parametric methods like Mann-Kendall and Sen's T test to detect the recent trends in rainfall pattern over seven divisions of Bangladesh. Sen's non-parametric estimator of slope was frequently used to estimate the magnitude of trend, whose statistical significance was assessed by the Mann–Kendall test. Station basis trend analysis was performed for rainfall data. For rainfall of Bangladesh most of the stations, viz. Dhaka, Sylhet, Rangpur, Khulna showed significant upward trend. There were rising rates of rainfall in some months such as April in Rangpur and September in Khulna and a decreasing trend in some other months as in January in Sylhet were obtained by these statistical tests suggested overall significant changes in rainfall trend in these areas. Monthly rainfall and annual total rainfall were found to decrease at the rates of 4.94 mm/year and 16.11 mm/year, respectively, where the downward trend of monthly total rainfall was insignificant but the trend of annual total rainfall was significant with 5% level of significance.

**Keywords:** Mann-Kendall, Sen's T, rainfall pattern, weather station, downword trend.

## Introduction

Bangladesh is located in the tropical monsoon region and its climate is characterized by high temperature, heavy rainfall, often-excessive humidity, and fairly marked seasonal variations. (Banglapedia, 2014). Rainfall is the most important natural factor that determines the agricultural production in Bangladesh. The variability of rainfall and the pattern of extreme high or low precipitation are very important factor for the agriculture as well as the economy of our country. It is well established that the rainfall is changing on both the global (Hulme *et al.,* 1998; Lambert *et al.,* 2003; Dore, 2005) and the regional scales (Rodriguez-Puebla *et al.,* 1998; Gemmer *et al.,* 2004; Kayano and Sans´ıgolo, 2008) due to global warming. The implications of these changes are particularly significant for Bangladesh where hydrological disasters of one kind or another is a common phenomenon (Shahid and Behrawan, 2008).

Global warming has already induced changes in precipitation in different geographical regions. During the 21st century, global warming was projected to continue and climate change impacts were likely to intensify (Noorunnahar *et al.,* 2013). In Bangladesh, we are already experiencing climate related hazards like floods, draughts and cyclones. Heavy rainfall is characteristic of Bangladesh causing it to flood almost every year. With the exception of the relatively dry western region of Rajshahi, where the annual rainfall

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is about 1,600 mm (63. in), most parts of the country receive at least 2,300 mm (90.6 in) of rainfall per year. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the region of Sylhet in north eastern Bangladesh receives the greatest average precipitation.

The study of rainfall variability and the trends of wet and dry events are therefore important for long-term water resources planning, agricultural development and disaster management in Bangladesh in the context of global climatic change. A number of comprehensive and research works have so far been conducted on Trend Analysis. Tesemma conducted a study in 2010 by using Mann-Kendal and Sen's T non-parametric test to detect significant trends in the selected years in combination with the Trend Free Pre-Whitening (TFPW) method for correcting time series data from serial correlation.

Yun-Sheng used Non-parametric analysis in 1993 to determine trend of water quality data of rivers in Kansas. Kumar *et al.* (2010) analyzed monthly, seasonal and annual trends of rainfall using monthly data series of 135 years (1871-2005) for 30 sub-divisions (sub-regions) in India. Basistha *et al.,* 2009 attempted to explore changes in rainfall pattern in the Indian Himalayas during 20th century using 80-year data from 30 rain gauge stations maintained by the India Meteorological Department (IMD). Modified Mann-Kendall test (MMK) was applied to detect trend. Bonaccorso conducted a study using Student's t test and the Mann-Kendall test to assess the presence of linear and non-linear trends in annual maximum rainfall series of different durations observed in Sicily. Although a number of studies have been carried out on rainfall patterns (Ahmed and Karmakar, 1993; Hussain and Sultana, 1996; Kripalini *et al.,* 1996; Rahman *et al.,* 1997; Ahmed and Kim, 2003; Shahid *et al.,* (2005); Islam and Uyeda, 2008; Shahid, (2008), only very few works have been found on rainfall trends and extremes in Bangladesh. Shahid *et al.* assessed spatial patterns of annual and seasonal rainfall trends of Bangladesh over the time period (1958-2007) using rainfall data recorded at 17 stations distributed over the country in 2010. Rahman *et al.* (1997) used trend analysis to study the changes in monsoon rainfall of Bangladesh and found no significant changes. Ahmed (1989) estimated the probabilistic rainfall extremes in Bangladesh during pre-monsoon (1995) season. Karmakar and Khatun (1995) repeated a similar study on rainfall extremes during the southwest monsoon season. However, both the studies were focused only on the maximum rainfall events for a limited period. May in 2004 reported that the frequency of wet days has noticeably increased over the tropical Indian Ocean and predicted that intensity of heavy rainfall events in Bangladesh will be increased in the future.

The Inter-Governmental Panel of Climate Change (IPCC) predicted the temperature and rainfall in Bangladesh will increase steadily till the end of this century. Islam in his study projected by 2018; annual rainfall in Bangladesh will increase at least 5.3%.

In the context of climate change and disaster management, it is, therefore important to understand the rainfall trends. In this study, a trend analysis was conducted for monthly and annual data of Rainfall of seven divisional stations. Mann-Kendall test was used to detect the trend and the Sen.'s slope method was used to determine the magnitude of change in climate time series. The main objective of this research was to determine whether there is evidence of long term trends in rainfall. This research will provide updated information on the effect of climate change and climate variability on hydro meteorological data in Bangladesh. The aim of this study was to investigate the possible trends in the parameters of rainfall from the stations individually.

## Materials and Methods

All types of climatic data in daily scale or monthly scale are available at Bangladesh Meteorological Department (BMD) which is situated at Agargaon, Dhaka, Bangladesh. For this study, monthly and annual rainfall data over the period maximum ranges from 1952 to 2016 of the seven divisional weather stations of Bangladesh was obtained from the Bangladesh Meteorological Department (BMD). Figure 1 and Table 1 showed the specific locations of the seven weather stations and data period of rainfall used in this study. We divided the seasons of Bangladesh into four categories as suggested by Islam and Uyeda (2007)

At first Monthly total Rainfall was calculated from daily precipitation data. The annual and seasonal rainfalls were calculated from monthly total rainfall. Figure 2 summarized stepwise methodology of the study. Then Homogeneity analysis of data was performed by removing serial correlation effect.

### Serial correlation

One of the problems in detecting and interpreting trends in hydrologic data is the confounding effect of serial dependence. Serial correlation structure in the data is accounted for determining the significance level of the results of the Mann-Kendall test. Specifically, if there is a positive serial correlation (persistence) in the time series, then the non-parametric test will suggest a significant trend in a time series that is, in fact, random more often than specified by the significance level (Kulkarni and Van Storch, 1995). For this, Von Storch (1995) suggested that the time series should be 'pre-whitened' to eliminate the effect of serial correlation before applying the Mann–Kendall test.

### Mann-Kendall Test

First of all, test for the trend in annual series was made so as to get an overall view of the possible changes in data processes. To determine if the trends found were significant, the Mann-Kendall trend test was used (Mann, 1945 and Kendall, 1970). This test was chosen over other trend detection tests based on the following factors:

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic and in hydrologic time series. The test has low sensitivity to abrupt breaks due to inhomogeneous time series. Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set (Samad *et al.,* 2017). The non-parametric method Mann-Kendall test was applied to calculate the seasonal and the annual rainfall series to investigate the rainfall trends and

**Table 1. Rainfall data period and name of the divisional weather stations**

| General Location | Station name | Period of record used |
|---|---|---|
| | Dhaka | 1954-2016 |
| | Barishal | 1953-2016 |
| | Rajshahi | 1965-2016 |
| Seven Division of Bangladesh | Sylhet | 1956-2016 |
| | Rangpur | 1952-2016 |
| | Khulna | 1952-2016 |
| | Chittagong | 1999-2016 |

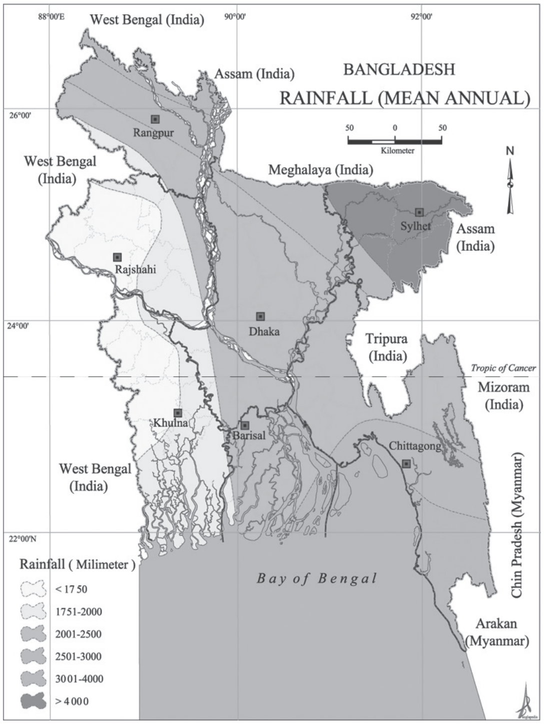


**Fig. 1. Locations of the seven Divisional Rainfall stations used in this study.**

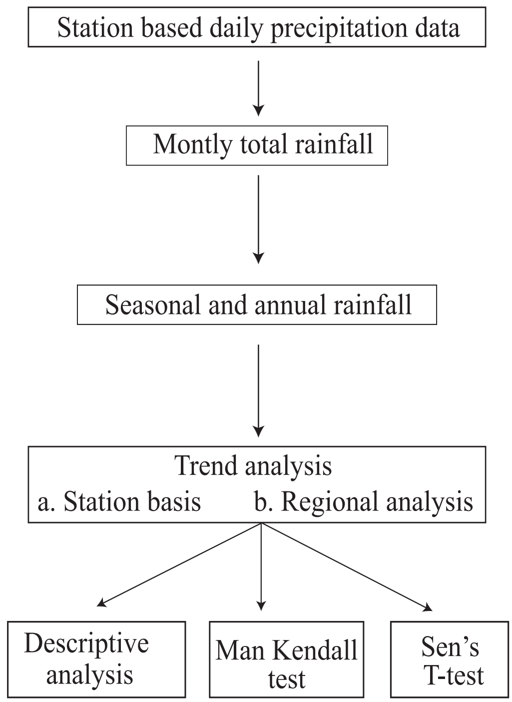


**Fig. 2. Stepwise Data organization and analytical tools used in this study.**

the Sen's test method was used to investigate magnitude of the rainfall changes.

By Mann-Kendall test, we wanted to test the null hypothesis $H_0$ of no trend, i.e. the observations $x_i$ are randomly ordered in time, against the alternative hypothesis, $H_1$, where there is an increasing or decreasing monotonic trend. The data values were evaluated as an ordered time series. Each data value was compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic $S$ 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.

**Table 2. Monsoon Seasons of Bangladesh including different months**

| Seasons | Months |
|---|---|
| Dry Winter Season | December, January, February |
| Pre-Monsoon Season | March, April, May |
| Rainy Monsoon Season | June, July, August, September |
| Post-Monsoon Season | October, November, December |

The net result of all such increments and decrements yields the final value of S. The Mann-Kendall statistic *S* is given as

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

The application of trend test was done to a time series $x_i$ that was ranked from i = 1, 2… n-1 and $x_j$, Which was ranked from j = i+1,2,…, n. Each of the data point $x_i$ was taken as a reference point which was compared with the rest of the data point's $x_j$ so that,

$$Sgn(xj-xi)=\begin{cases}+1,>(x_j-x_i)\\ 0,=(x_j-x_i)\\ -1,<(x_j-x_i)\end{cases}$$

The variance statistic was given as Var (S)

$$\frac{n(n-1)(2n+5)-\sum\frac{m}{i=1}t_i(i)(i-1)(2i+5)}{18}$$

Where $t_i$ was considered as the number of ti'es up to sample i. The test statistics $Z_c$ was computed as

$$Z_c=\begin{cases}\frac{s-1}{\sqrt{Var(S)}},S>0\\ O,S=0\\ \frac{s+1}{\sqrt{Var(S)}},S<0\end{cases}$$

$Z_c$ here followed a standard normal distribution. A positive or negative value of Z signified an upward or downward trend. A significance level α was also utilized for testing either an upward or downward monotone trend (a two-tailed test). If $Z_c$ appears greater than $Z\alpha_{/2}$ where α depicts the significance level, then the trend was considered as significant.

**Sen's T Test**: This technique is an aligned rank method having procedures that first remove the block (season) effect from each datum, then sum the data over blocks, and finally produce a statistic from these sums. The aligned rank test is more powerful than its counterpart. It is distribution free and not affected by seasonal fluctuations (Sen 1968; Van Belle and Hughes, 1984).

**Sen's Slope Estimator**

The magnitude of trend was predicted by the Sen's estimator. For linear trend, the slope was usually estimated by computing the least squares estimate using linear regression.

**Results and Discussion**

The analysis of rainfall trends revealed changes in rainfall of divisional stations over the time period maximum from 1952–2016. Variables related to rainfall, viz. monthly total rainfall and annual total rainfall were considered to analyze. Results of trend analysis of these variables at seven stations were given in the Table as well as in the Figures bellow. The values in the table were obtained by Sen's slope method represented the changes of rainfall in mm/month Mann-Kendall trend test.

**Table 3. Descriptive statistics of annual rainfall of seven divisional stations of Bangladesh**

| Station | Mean Rainfall (mm) | Std. Dev. Rainfall (mm) |
|---|---|---|
| Dhaka | 1958.35 | 404.81 |
| Barishal | 1991.25 | 430.80 |
| Rajshahi | 1439.19 | 307.00 |
| Sylhet | 3691.62 | 743.13 |
| Rangpur | 2065.66 | 520.61 |
| Khulna | 1571.89 | 426.11 |
| Chittagong | 2935.62 | 565.16 |

Table 3 showed that the annual mean amount of rainfall varied by location. The highest and lowest amount of rainfall was recorded in Sylhet and Rajshahi division respectively. Mean annual rainfall during different time period varied from 1439.19 mm to 3691.62 mm. Again it was noticed that rainfall amount increased gradually from North to South. Table 4 showed that the Mann-Kendall test results revealed upward trend in annual rainfall in six out of seven weather stations say Dhaka, Barishal, Khulna, Rangpur, Sylhet and Chittagong and a downward trend of annual rainfall in Rajshahi. Annual rainfall changed significantly in five stations whether rainfall found insignificant as well decreased trend was noticed in Rajshahi station. Again Highest estimate of Sen's slope was observed in Sylhet rainfall Station. Figure 3 showed seasonal trend of mean rainfall of seven divisional station of Bangladesh. Lowest amount of rainfall occurred during winter season say December, January, and February and the highest during rainy monsoon seasons say June, July, August, and September. Again it was proved that during rainy monsoon season Mean rainfall in Sylhet was 3 times higher than mean rainfall in Rajshahi. Table 5 concluded that none of the months of Dhaka Station showed significant trend although annual rainfall showed significant results at 5% level of significance. The slope estimates showed positive rates of change for all of the months of Dhaka Station. Annual rainfall of Dhaka, Sylhet, Rangpur and Khulna stations was increasing as well as showed significant

**Table 4. Mann-Kendall and Sen's test results of annual rainfall trends in the seven Stations**

| Station | MK test (Test Z) | Trend | Result | Sen's Slope of estimate change in Rainfall (mm/y) |
|---|---|---|---|---|
| Dhaka | 0.27 | ↑ | Sig. | 6.87 |
| Barishal | 0.14 | ↑ | NS | 3.29 |
| Rajshahi | -0.02 | ↓ | NS | 0 |
| Sylhet | 0.25 | ↑ | Sig. | 13.95 |
| Rangpur | 0.29 | ↑ | Sig. | 9.95 |
| Khulna | 0.35 | ↑ | Sig. | 9.87 |
| Chittagong | 0.00 | ↑ | NS | 1.79 |

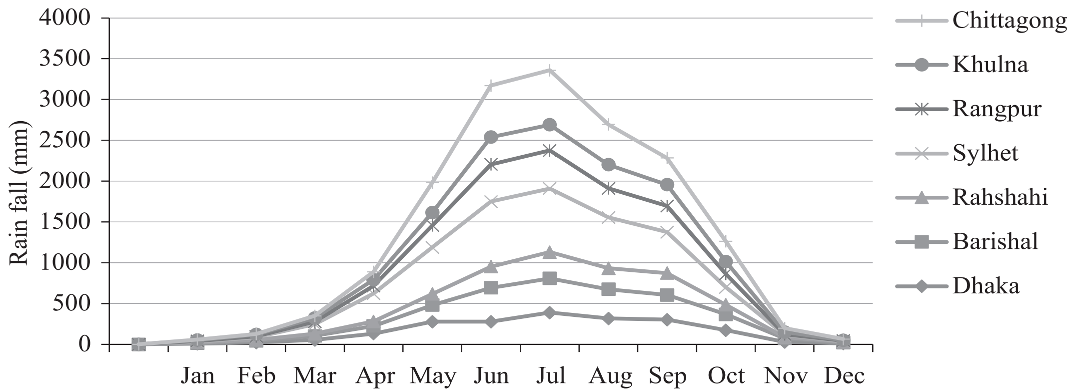


**Fig. 3. Seasonal trend of mean rainfall of seven divisional stations of Bangladesh.**

**Table 5. Seasonal trend analysis of Dhaka station**

| Period (1954-2016) | Mean | SD | Mann-kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 7.07 | 12.38 | -0.05 | 0.61 | 0 | | |
| Feb | 20.74 | 22.35 | 0.05 | 0.60 | 0.02 | 0.16 | 11.00 |
| Mar | 54.48 | 54.13 | 0.09 | 0.29 | 0.27 | 0.17 | 13.00 |
| Apr | 130.81 | 76.84 | 0.01 | 0.98 | 0.02 | -0.06 | -4.00 |
| May | 277.41 | 138.01 | 0.01 | 0.08 | 0.32 | 0.16 | 12.00 |
| June | 277.41 | 138.01 | 0.01 | 0.89 | 0.32 | 0.16 | 12.00 |
| July | 388.42 | 155.46 | -0.00 | 1.00 | 0 | -0.11 | -8.00 |
| Aug | 316.21 | 123.56 | 0.01 | 0.89 | 0.12 | -0.02 | -2.00 |
| Sep | 301.44 | 150.71 | 0.07 | 0.46 | 0.64 | 0.25 | 18.00 |
| Oct | 172.47 | 117.08 | 0.10 | 0.26 | 0.90 | 0.14 | 10.00 |
| Nov | 29.41 | 43.97 | -0.04 | 0.66 | 0 | 0.12 | 9.00 |
| Dec | 10.46 | 22.26 | -0.04 | 0.73 | 0 | | |

trend. However, the trend was not statistically significant for Barishal, Rajshahi and Chittagong although Barishal and Chittagong showed upward trend. Only Rajshahi station revealed downward trend. From figure 4 we got some ideas about the monthly significant trend as well as their direction. Again figure 5 provided view of annual trend of the stations followed significant trend. The sequential Mann-Kendall test revealed periodic fluctuations for seasonal rainfall at majority of the stations.

## Conclusion

This study has shown that Rainfall varies in different months for different years which were evident in the graphs. Monsoon rainfall was decreased non-significantly in most of the northern Bangladesh (Rajshahi and Rangpur Station). Rainfall during winter was decreased in all the areas over Bangladesh. Mean Annual Rainfall values indicated highest rainfall occurs in Sylhet divison on the other hand lowest rainfall occurs in Rajshahi

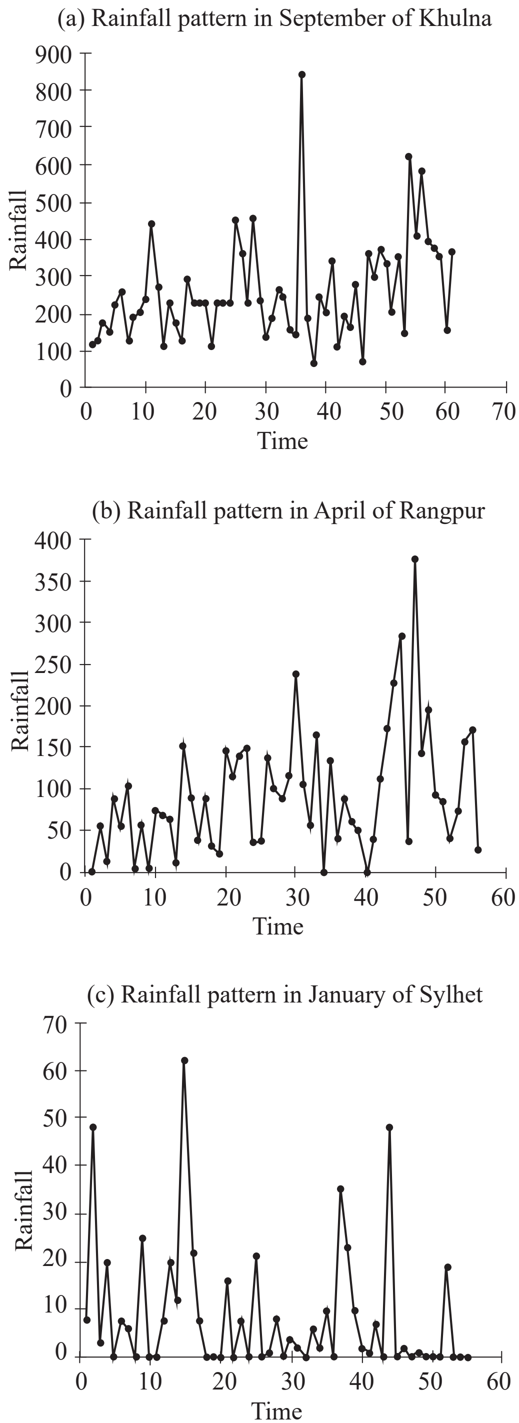


**Fig. 4. Time plot of monthly rainfall which follow significant trend.**

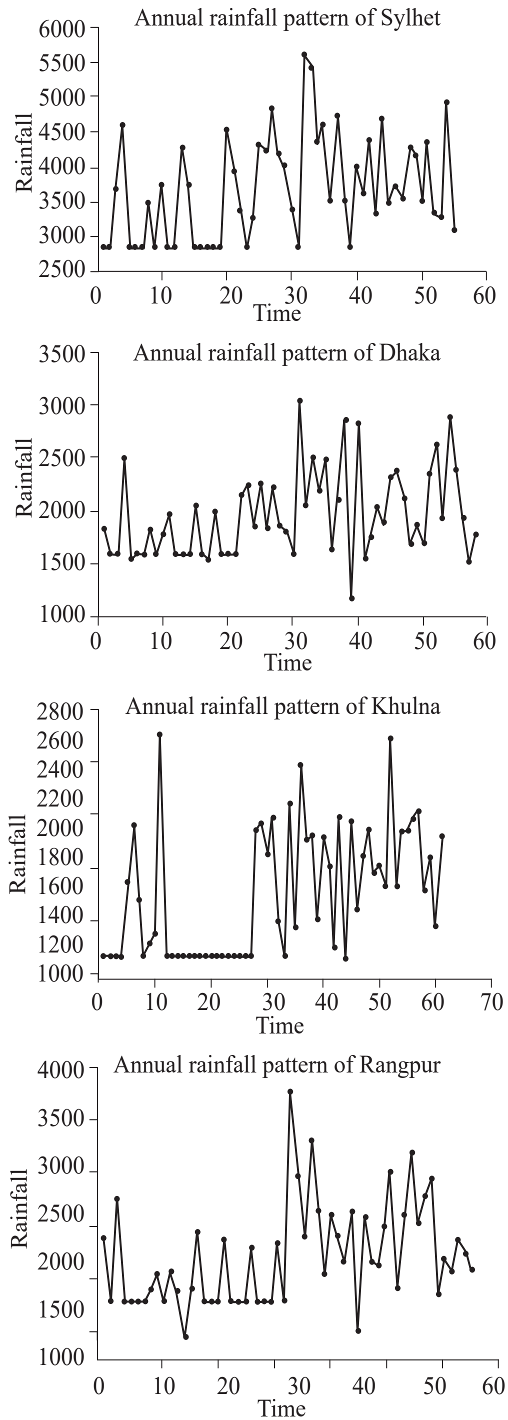


**Fig. 5. Time plot of annual rainfall of the stations which follow significant trend.**

**Table 6. Seasonal trend analysis of Barishal station**

| Period (1953-2016) | Mean | SD | Mann-kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 7.56 | 20.38 | 0.00 | 1.00 | 0 | 0.04 | 2.00 |
| Feb | 20.97 | 24.81 | 0.03 | 0.77 | 0 | 0.00 | 0.00 |
| Mar | 50.39 | 62.92 | -0.02 | 0.87 | 0 | -0.01 | -1.00 |
| Apr | 93.85 | 78.02 | 0.05 | 0.54 | 0.24 | 0.08 | 10.00 |
| May | 202.47 | 102.88 | -0.04 | 0.66 | -0.21 | -0.08 | -10.00 |
| June | 415.43 | 1758.64 | -0.05 | 0.58 | -0.71 | -0.07 | -8.00 |
| July | 420.06 | 136.97 | 0.01 | 0.94 | 0.031 | 0.03 | 4.00 |
| Aug | 359.38 | 143.85 | -0.03 | 0.78 | -0.29 | -0.11 | 13.00 |
| Sep | 303.82 | 164.73 | -0.08 | 0.37 | -0.78 | -0.05 | -6.00 |
| Oct | 194.14 | 120.31 | -0.04 | 0.67 | -0.49 | 0.02 | 2.00 |
| Nov | 44.80 | 65.42 | 0.00 | 0.99 | 0 | -0.01 | 0.00 |
| Dec | 9.22 | 27.16 | 0.05 | 0.61 | 0 | | |

**Table 7. Seasonal trend analysis of Rajshahi station**

| Period (1965-2016) | Mean | SD | Mann- kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 9.50 | 14.28 | -0.07 | 0.52 | 0 | | |
| Feb | 13.11 | 14.48 | -0.07 | 0.49 | -0.03 | 0.16 | 6.00 |
| Mar | 24.97 | 27.74 | -0.00 | 0.99 | 0 | 0.00 | 0.00 |
| Apr | 56.25 | 54.47 | -0.05 | 0.61 | -0.17 | 0.08 | 3.00 |
| May | 137.57 | 64.42 | 0.08 | 0.40 | 0.50 | -0.06 | -2.00 |
| Jun | 258.57 | 121.42 | -0.00 | 0.97 | 0 | 0.06 | 2.00 |
| Jul | 322.06 | 140.87 | -0.19 | 0.06 | -3.10 | -0.38 | -14.00 |
| Aug | 256.54 | 103.79 | -0.05 | 0.57 | -0.64 | -0.16 | -6.00 |
| Sep | 268.08 | 134.84 | 0.03 | 0.71 | 0.47 | 0.16 | 6.00 |
| Oct | 117.91 | 79.40 | -0.02 | 0.79 | -0.16 | 0.11 | 4.00 |
| Nov | 12.63 | 19.11 | -0.09 | 0.37 | 0 | | |
| Dec | 8.75 | 20.25 | -0.17 | 0.12 | 0 | | |

**Table 8. Seasonal trend analysis of Sylhet station**

| Period (1956-2016) | Mean | SD | Mann- kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 8.64 | 13.57 | -0.20 | 0.04 | -0.03 | 0.01 | -1.00 |
| Feb | 32.48 | 35.05 | 0.05 | 0.59 | 0.04 | -0.06 | -5.00 |
| Mar | 117.47 | 101.21 | 0.14 | 0.11 | 1.05 | 0.27 | 20.00 |
| Apr | 341.92 | 172.01 | 0.12 | 0.18 | 2.08 | 0.21 | 15.00 |
| May | 570.43 | 214.41 | -0.03 | 0.75 | -0.34 | -0.19 | -14.00 |
| Jun | 798.19 | 238.29 | -0.12 | 0.18 | -2.93 | -0.21 | -15.00 |
| Jul | 778.20 | 280.71 | 0.01 | 0.91 | 0.26 | 0.22 | 16.00 |
| Aug | 623.14 | 194.26 | 0.02 | 0.78 | 0.43 | 0.14 | 10.00 |
| Sep | 501.09 | 222.70 | 0.03 | 0.75 | 0.50 | 0.13 | 9.00 |
| Oct | 213.81 | 135.68 | -0.06 | 0.47 | -0.73 | -0.03 | -2.00 |
| Nov | 27.87 | 38.37 | -0.02 | 0.84 | 0.00 | 0.01 | 1.00 |
| Dec | 9.29 | 17.53 | -0.03 | 0.79 | 0 | | |

** indicates significant at 5% level of probability.

**Table 9. Seasonal trend analysis of Chittagong station**

| Period (1999-2016) | Mean | SD | Mann- kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 7.38 | 17.34 | -0.14 | 0.70 | 0 | | |
| Feb | 6.76 | 13.55 | 0.03 | 0.47 | 0 | | |
| Mar | 26.61 | 25.66 | -0.02 | 0.57 | -0.28 | -0.20 | -1.00 |
| Apr | 96.92 | 67.51 | 0.11 | 0.31 | 1.05 | 0.61 | 3.00 |
| May | 368.69 | 368.69 | -0.17 | 0.82 | -6.75 | -0.20 | -1.00 |
| Jun | 631.53 | 290.63 | -0.10 | 0.70 | -14.98 | -0.60 | -3.00 |
| Jul | 668.38 | 265.02 | 0.15 | 0.26 | 14.62 | 0.60 | 3.00 |
| Aug | 493.23 | 243.44 | 0.06 | 0.40 | 7.53 | 0.20 | 1.00 |
| Sep | 328.38 | 192.79 | 0.23 | 0.15 | 15.78 | 1.00 | 5.00 |
| Oct | 247.92 | 162.11 | -0.10 | 0.70 | -5.33 | -0.20 | -1.00 |
| Nov | 45.33 | 55.15 | 0.12 | 9.00 | 1.81 | 0.20 | 1.00 |
| Dec | 14.38 | 27.19 | -0.25 | 0.85 | 0 | | |

**Table 10. Seasonal trend analysis of Rangpur station**

| Period (1952-2016) | Mean | SD | Mann- kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 8.80 | 11.28 | -0.13 | 0.16 | -0.00 | -0.00 | 0.00 |
| Feb | 9.50 | 13.06 | 0.13 | 0.15 | 0.02 | 0.14 | 9.00 |
| Mar | 30.03 | 42.62 | -0.04 | 0.64 | -0.05 | 0.16 | -11.00 |
| Apr | 94.01 | 74.55 | 0.23 | 0.01** | 1.45 | 0.36 | 26.00 |
| May | 269.08 | 94.61 | 0.02 | 0.78 | 0.22 | 0.03 | 2.00 |
| Jun | 455.12 | 183.37 | -0.03 | 0.74 | -0.33 | -0.08 | -6.00 |
| Jul | 467.22 | 203.92 | -0.01 | 0.87 | -0.15 | -0.03 | -2.00 |
| Aug | 355.90 | 168.14 | 0.02 | 0.82 | 0.27 | 0.19 | 14.00 |
| Sep | 320.62 | 171.05 | 0.24 | 0.01 | 3.51 | 0.58 | 42.00 |
| Oct | 163.16 | 145.84 | 0.12 | 0.18 | 1.40 | 0.06 | 5.00 |
| Nov | 8.19 | 17.32 | -0.04 | 0.64 | 0 | 0.08 | 5.00 |
| Dec | 7.29 | 16.63 | -0.02 | 0.85 | 0 | | |

** indicates significant at 5% level of probability.

**Table 11. Seasonal trend analysis of Khulna station**

| Period (1952-2016) | Mean | SD | Mann- kendall test value | P-value | Sen's slope | Sequential MK | Sequential St |
|---|---|---|---|---|---|---|---|
| Jan | 10.12 | 19.02 | 0.06 | 0.47 | 0 | 0.03 | 2.00 |
| Feb | 23.71 | 35.54 | 0.12 | 0.18 | 0.02 | 0.09 | 12.00 |
| Mar | 45.30 | 60.36 | 0.01 | 0.88 | 0 | 0.04 | 5.00 |
| Apr | 75.90 | 68.12 | -0.08 | 0.36 | -0.31 | -0.10 | -12.00 |
| May | 156.80 | 88.24 | 0.13 | 0.13 | 0.95 | 0.13 | 16.00 |
| Jun | 335.56 | 141.21 | -0.08 | 0.34 | -0.59 | -0.11 | -13.00 |
| Jul | 314.16 | 175.91 | 0.03 | 0.71 | 0.41 | 0.00 | 0.00 |
| Aug | 290.18 | 134.04 | 0.15 | 0.08 | 1.51 | 0.16 | 20.00 |
| Sep | 261.12 | 138.90 | 0.27 | 0.003** | 2.45 | 0.20 | 24.00 |
| Oct | 151.70 | 27.88 | 0.04 | 0.63 | 0.17 | 0.17 | 20.00 |
| Nov | 28.83 | 47.34 | -0.01 | 0.85 | 0 | -0.04 | -4.0 |
| Dec | 4.73 | 11.22 | -0.03 | 0.76 | 0 | -0.02 | -1.00 |

**indicates significant at 5% level of probability.

Division. Therefore it can be concluded that there was evidence of some changes in the trend of precipitation of the station in different months. Majority of the stations showed upward trend for rainfall. Some of the months showed no trend or not changeable by the value of the slope estimator. The study, therefore, offers remarkable insights and new perspective for policy makers and planners in helping them taking proactive measures in the context of climate change. Timely measures and institutional changes can certainly help in reducing the irreparable damages that can be caused by climate change.

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