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APPLICATION OF NON PARAMETRIC TEST FOR TREND DETECTION OF RAINFALL IN THE LARGEST ISLAND OF BANGLADESH

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ABSTRACT

This study aims to determine trends of rainfall of largest island Bhola in Bangladesh. This is an effort to analyze one of the most important climatic variable i.e., precipitation, for analyzing the rainfall trend in the area. Rainfall data from 1966 to 2011 has been processed in the study to find out the monthly variability of rainfall for which Mann-Kendall test and Sen's Slope Estimator for the determination of trend and slope magnitude. Monthly precipitation trend has been identified here to achieve the objective which has been shown with 46 years of data. The application of a trend detection framework resulted in the identification of insignificant trends from January to December. There are rising rates of precipitation in some months and decreasing trend in some other months obtained by these statistical tests suggesting overall insignificant changes in the area.

Keywords: rainfall, trend analysis, Mann-Kendall test, Sen's slope estimates.

INTRODUCTION

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer more intense events. This could lead to longer dry spells and a higher risk of floods. Precipitation, especially rain, has a dramatic effect on agriculture. All plants need at least some water to survive; therefore rain is important to agriculture. A regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, even devastating to crops. Drought can kill crops and increase erosion, while overly wet weather can cause harmful fungus growth. Plants need varying amounts of rainfall to survive. Primary effects of rainfall are physical damage like as damage to structures, including bridges, buildings, sewerage systems, roadways, and canals. In addition, secondary effects such as Water supplies - contamination of water. Clean drinking water will become scarce, Diseases - unhygienic conditions. Spread of water-borne diseases, Crops and food supplies - Shortage of food crops can be caused due to loss of entire harvest. However, lowlands near rivers depend upon river silt deposited by floods in order to add nutrients to the local soil, Trees - Non-tolerant species can die from suffocation, Transport - Transport links destroyed, so hard to get emergency aid to those who need it. Relevant reviews on trend analysis in precipitation time series or relevant field include the studies of Bani-Domi (2005), D, Ercan Kahya *et al*. (2006), K karpouzos *et al*. (2010), K. Drápela *et al*. (2011), Mondal *et al*. (2012). The purpose of this study is to investigate the variability of rainfall trend in Bhola for 46 years in order to contribute to a better interpretation of its hydrological status. The study consists of four sections. The first section introduces the paper and explains the motive of this work. The second section describes the study area, the data employed and the statistical techniques applied for trend and step change detection. The third section discusses the result while the fourth one outlines the major findings.

METHODOLOGY

Study area

Bhola is an administrative district in south-western Bangladesh, which includes Bhola Island, the largest island in the country. It is located in the Barisal Division and has an area of 3, 737.21 km². It is bounded by Lakshmipur and Barisal Districts to the north, the Bay of Bengal to the south, by Lakshmipur and Noakhali districts, the (lower) Meghna river and Shahbazpur Channel to the east, and by Patuakhali District and the Tentulia river to the west. About 400 mmcf natural gas has been found at Kachia in Bhola which is being used to run a power station. It is situated at 22.68° latitude and 90.64° longitude and amount of rainfall occurs during monsoon period i.e., May to September. The economy of the study area is comprised of agriculture and more than 90 per cent population is practicing agriculture here.

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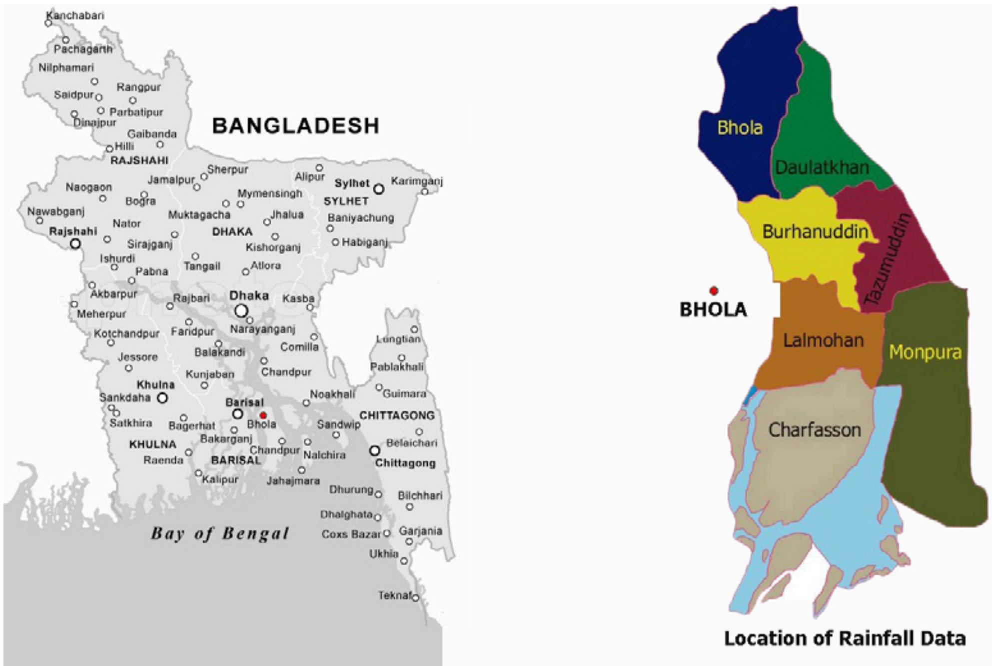

Figure-1. Study area.

Serial correlation

One of the problems in detecting and interpreting trends in hydrologic data is the confounding effect of serial dependence. 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 and Navarra (1995) suggest that the time series should be 'pre-whitened' to eliminate the effect of serial correlation before applying the Mann-Kendall test. This study incorporates this suggestion, and thus possible statistically significant trends in a precipitation observations (x_1, x_2. . . x_n) are examined using the following procedures:

a) Compute the lag-1 serial correlation coefficient (designated by r_1).
b) If the calculated r_1 is not significant at the 5% level, then the Mann-Kendall test is applied to original values of the time series.
c) If the calculated r_1 is significant, prior to application of the Mann-Kendall test, then the 'pre-whitened' time series may be obtained as $\mathbf{x_2 - r_1x_1, x_3 - r_1x_2, \ldots, x_n - r_1x_{n-1}}$.

Mann-Kendall test

By Mann-Kendall test, we want 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 are evaluated as an ordered time series. Each data value is 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. The net result of all such increments and decrements yields the final value of S. The M-K test statistic S is calculated using the formula:

The Mann-Kendall statistic *S* is given as

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

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

$$\mathbf{Sgn}(\mathbf{x_j} - \mathbf{x_i}) = \begin{cases} +1, > (\mathbf{x_j} - \mathbf{x_i}) \\ 0, = (\mathbf{x_j} - \mathbf{x_i}) \\ -1, > (\mathbf{x_j} - \mathbf{x_i}) \end{cases} \tag{2}$$

It has been documented that when n ≥ 8, the statistic S is approximately normally distributed with the mean. E(S) = 0

The variance statistic is given as

$$\mathrm{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{t=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18} \tag{3}$$

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Where t_i is considered as the number of ties up to sample i. The test statistics Zc is computed as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{\mathrm{Var}(S)}}, S > 0 \\ 0, S = 0 \\ \frac{S+1}{\sqrt{\mathrm{Var}(S)}}, S < 0 \end{cases} \quad (4)$$

Z_C here follows a standard normal distribution. A positive (negative) value of Z signifies an upward (downward) trend. A significance level α is 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 is considered as significant.

Sen's slope estimator test

The magnitude of trend is predicted by the Sen's estimator. Here, the slope (T_i) of all data pairs is computed as (Sen, 1968).

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for } i = 1,2,\ldots\ldots,N \quad (5)$$

where x_j and x_k are considered as data values at time j and k (j>k) correspondingly. The median of these N values of Ti is represented as Sen's estimator of slope which is given as:

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \quad (6)$$

Sen's estimator is computed as Qmed=$T_{(N+1)/2}$ if N appears odd, and it is considered as

Qmed= $[T_{N/2}+T_{(N+2)/2}]/2$ if N appears even. At the end, Qmed 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 an upward or increasing trend and a negative value of Qi gives a downward or decreasing trend in the time series.

RESULTS AND DISCUSSIONS

Trend analysis of Bhola has been done in the present study with of precipitation data. The majority of the monthly series in the data set appear to have no significant lag-1 serial correlation coefficient so there was no need to prewhite the data and all the statistical tests described above are applied to the original time series. Mann-Kendall and Sen's Slope Estimator has been used for the determination of the trend. Figure-2 represents the annual with maximum rainfall occurrence in the years 1971 with the total precipitation of 3521 mm approximately and minimum rainfall has occurred in the year 1966 with the total of around 1471 mm. Average rainfall for this time interval is 2316.23.

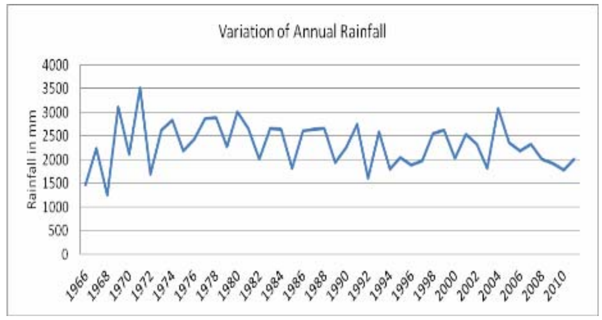

Figure-2. Annual rainfall.

Annual average is least for the month of January for all these 46 years (7.28 mm) followed by December (8.90 mm) and February (25.34 mm) while maximum rainfall occurs in the month of July (471.13 mm) followed by June (435.10 mm) and August (391.12 mm). Figures 3, 4 and 5 show the rainfall distribution of 46 years of individual months.

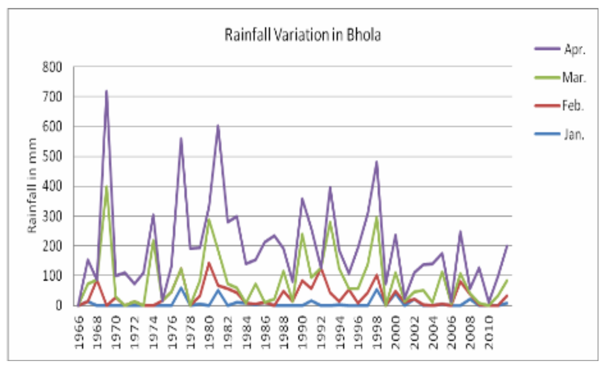

Figure-3. Rainfall of January to April months from 1966-2011.

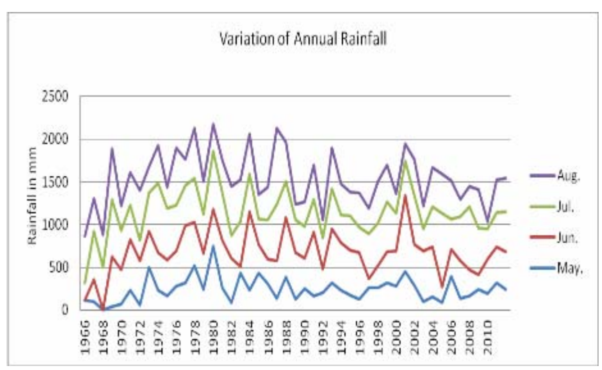

Figure 4. Rainfall of May to August months from 1966-2011.

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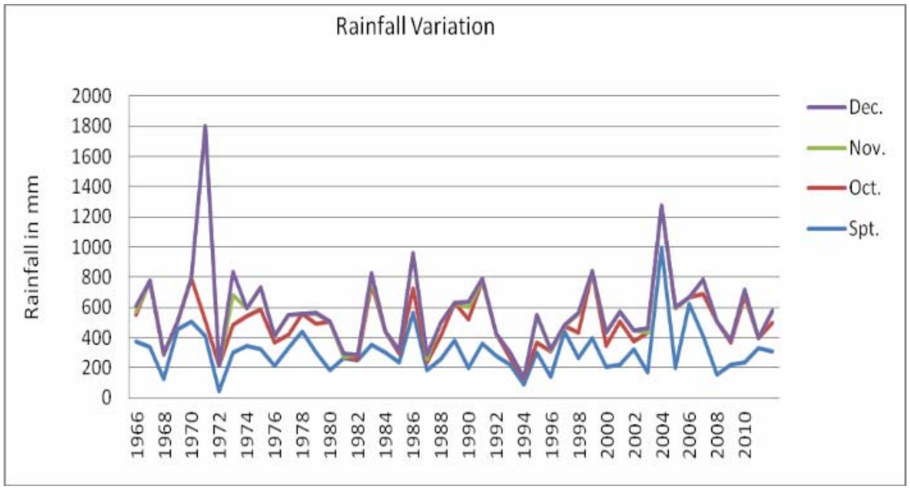

Figure 5. Rainfall of September to December months from 1966-2011.

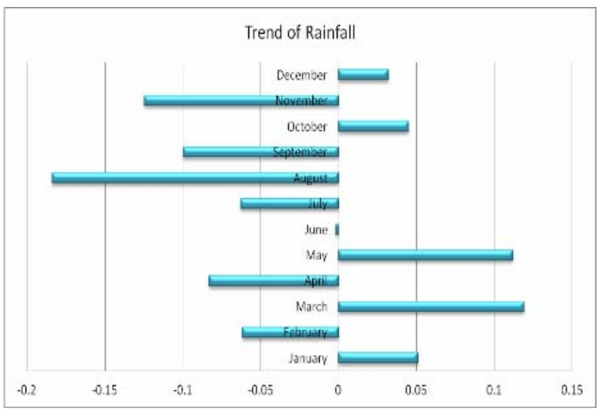

Figure-6. Trend for individual months by Mann-Kendall test.

In the non parametric Mann-Kendall test, trend of rainfall for 46 years from January to December has been calculated for each month individually together with the Sen's magnitude of slope. In the Mann-Kendall test describes the trend of the series for individual 12 months from January to December which are 0.051, -0.062, 0.119, -0.083, 0.112, -0.002, -0.063, -0.184, -0.100, 0.045, -0.125, 0.032, respectively. For January, March, May, October and December there is an evidence of rising trend while test value is showing negative trend in February, April, June, July, August, September, November. Thus test values for five months show a positive trend and for other seven months it shows negative trend representing almost non-significant condition (Table-2).

Table-1. Basic statistics of rainfall data in bhola from 1966 to 2011.

Month	Minimum	Maximum	Mean	Std. deviation
January	0.000	60.000	7.285	15.155
February	0.000	144.000	25.344	34.564
March	0.000	399.000	52.064	80.904
April	0.000	436.000	113.968	97.338
May	0.000	749.000	242.907	144.451
June	0.000	919.000	435.101	199.673
July	194.000	860.000	471.133	143.206
August	91.000	893.000	391.126	146.097
September	42.000	993.000	308.943	157.850
October	4.000	442.000	189.288	127.811
November	0.000	1283.000	70.167	192.156
December	0.000	151.000	8.907	24.116

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Table-2. Estimated non parametric results and significance test.

Month	Mann-Kendall trend test	P value	Sen's slope
January	0.051	0.655	0
February	-0.062	0.566	0
March	0.119	0.260	0.1
April	-.083	0.426	-.714
May	0.112	0.276	1.44
June	-.002	0.992	0
July	-0.063	0.545	-0.846
August	-0.184	0.073	-3
September	-0.100	0.334	-1.781
October	0.045	0.670	0.6
November	-0.125	0.241	-.007
December	0.032	0.789	0

The estimated Sen's slope has been calculated for January to December showing rising slope magnitude March, May, October although non-significant. Only the month April, July, August, September and November shows non-significant decreasing trend but the months of January, February, June and December show no change in the Sen's Slope while others are depicting either increasing or decreasing trend. This result is quite significant as the months where Mann-Kendall trend analysis has shown negative trend, similar negative slope has been observed for the Sen's Slope and vice versa.

CONCLUSIONS

The application of this trend analysis frame work revealed an overall upward and downward trend even though no statistically significant. Furthermore, Bhola is a rural area and thus represents more of agricultural land and cultivation zones. The Mann-Kendall Test represents both positive and negative trend in the area although not much significant. Individually months of January, March, May, October and December are showing positive trend and months of February, April, June, July, August, September, November and December are depicting negative trend. Rainfall varies in different months for different years which are evident in the graphs. Sen's Slope is also indicating increasing and decreasing magnitude of slope in correspondence with the Mann-Kendall Test values. There are three months with increasing trend value along with the increasing slope magnitude, and five months with decreasing or negative value and Sen's Slope and four month shows no trend. However, study of the area may reveal other aspects which will be helpful in controlling flood causing havoc in this particular area.

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