Characterizing rainfall trend in Bangladesh by temporal statistics analysis

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ABSTRACT: Climate is changing. Global warming has already induced changes in precipitation in different geographical regions. In Bangladesh, we are already experiencing climate related hazards like floods, draughts and cyclones. A climate variable like rainfall is the most important parameter for agricultural aspects. The analysis is based on the rainfall variation in Bangladesh over fifty years from 1950 to 1999 to study the rainfall trend over this period. Rainfall data from 24 Bangladesh Meteorological Department (BMD) stations and relevant maps have been collected. These data have been analyzed for both annual and seasonal variation. To compare seasonal variations, four seasons of pre-monsoon, monsoon, post-monsoon and winter have been considered. Linear trend lines have been followed in estimation of future rainfall to determine any significant change of trends for selected parameter (rainfall) of different stations. The statistical analysis includes temporal trend study of different districts and over the country which provide the information about variation of standard deviation, mean and co-efficient of variation of rainfall in different seasons at different locations of Bangladesh. The sets of analysis that are carried out for the rainfall data series are intuitively focused towards examining any discernable trends in these time series. When it comes to countrywide mean rainfall over time, it can be speculated that as the year increases the monsoon rainfall will be increased and at the same time it will become more uncertain and unpredictable. The reverse is true for winter season. As far as regional analysis is concerned the mean rainfall increases sharply in Rangamati, Rangpur,Sandip,Feni and Dinajpur due to an increase of rainfall in premonsoon season. It can be said that the mean rainfall shifts towards premonsoon season from monsoon. More need based analysis can be carried out based on the outcomes of this paper to investigate rainfall pattern in drought prone areas for mitigation of drought or crop areas for adjustment of crop period. The analysis result will help the planners and policy makers to counter act the adverse effect of environmental parameter (rainfall) in different sectors like agriculture, drought mitigation, flood control etc.

1 INTRODUCTION

The objective of this study was to identify the trend of temporal statistics (standard deviation, mean and co-efficient of variation) district wise and countrywide with respect to year to predict that how much the rainfall deviates from mean in a particular district with the increase of years, and to identify the probability of uncertainties in term of depth of rainfall. The trend of beginning, ending and duration of rainfall with respect to year is analyzed because these characteristics of rainfall have great effect on crop pattern, crop seeding and harvesting. The deviation of predicted duration from the actual duration is evaluated to identify the probability of uncertainties in terms of duration of rainfall.

2 METHODOLOGY

2.1 Study Area

The study area is 68007 km^2, which covers 22 districts among 64 districts of Bangladesh. Its position is between latitude 20° 34′ - 26° 38′ N, longitude 88° 01′ - 92° 41′ E. For the convenience of analysis the study is based on available data of 24 BMD (Bangladesh Meteorological Department) stations among 34 BMD (Bangladesh Meteorological Department) stations for measuring rainfall pattern. These stations have their respective longitude and latitude. The available rainfall data are, daily rainfall record at 24 BMD stations for 50

years (1951-2000) and monthly rainfall record at 24 BMD stations for 10 years (1996-2005). Figure 1 shows study area for the current study.

Figure 1. Location of 34 BMD stations

2.2 Categorizing Available Data

Each year rainfall and temperature data has been categorized for two different seasons as follows:

- Pre-monsoon (March – May)
- Monsoon (June – September)
- Post-monsoon (October – November)
- Winter (December – February)

2.3 Analyzing Available Data

Statistical analysis has been undertaken to predict trend of temporal variation countrywide. Standard deviation, mean and co-efficient of variation of rainfall has been calculated for the entire country. Similar analysis is undertaken to predict standard deviation, mean and co-efficient of variation of rainfall district wise. Data have been organized in terms of annual and four seasons as pre-monsoon, monsoon, post-monsoon and winter. Data series have been applied for linear trend, so that data should be consistent for fifty years period and to determine any significant change of trends for selected parameter (rainfall) of different stations. The sets of analysis that are carried out for the rainfall data series are intuitively focused towards examining any discernable trends in these time series. Due to unequal length of records, comparison of result with respect to different stations and seasons are difficult. In Bangladesh, information on data quality is very sparse. There are lots of missing data, which would affect the result related to the trend analysis substantially.

3 RESULTS AND DISCUSSION

3.1 *Trend of countrywide temporal statistics*

Standard deviation, mean and co-efficient of variation of rainfall is represented with respect to year in 10 years interval from 1956 to 2005 in premonsoon,monsoon, postmonsoon and winter countrywide of Bangladesh(27 stations) in the following graphs.The analysis performed over the country is summarized in the following Figure 2 to Figure 4.

From Figure 2 the standard deviation of rainfall is increasing with the increase of years except in winter. In winter the slope is downward which means the possibility of deviation of rainfall with respect to mean is low. As the year increases the occurrence of rainfall becomes close to mean and is more certain and predictable. In case of premonsoon, monsoon and post monsoon it is vice versa.

In Figue 3 the trend of mean of rainfall is upward except in season of winter. In premonsoon, monsoon, postmonsoon the mean of rainfall increases with the increase of years.

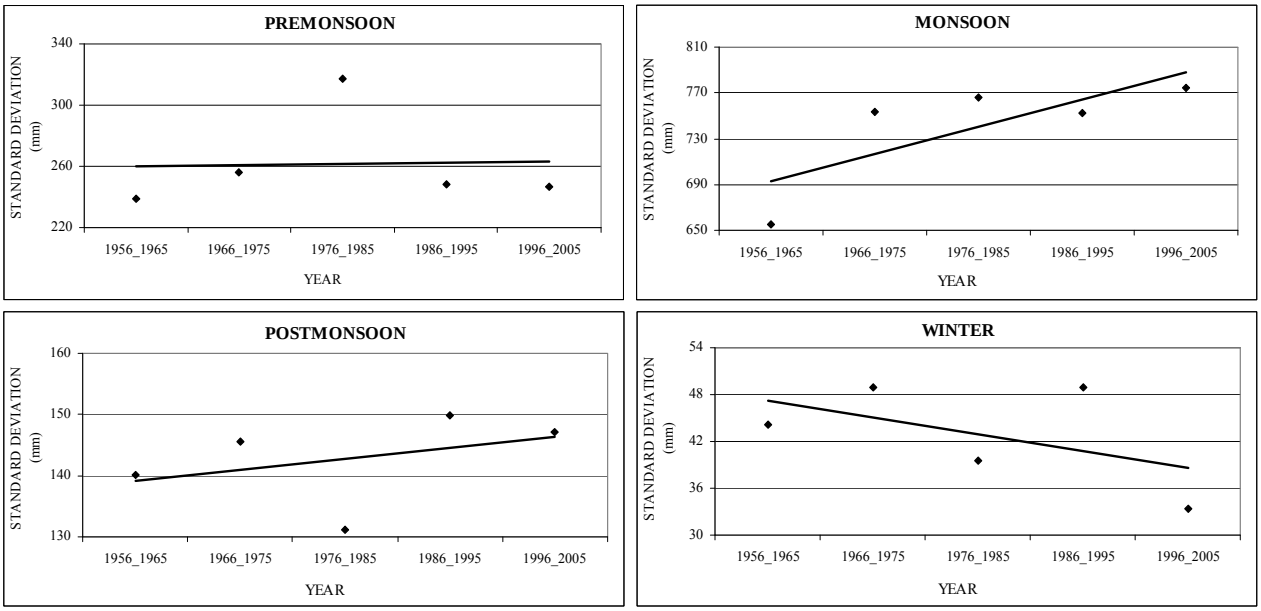

Figure 2. Variation of standard deviation of rainfall over time countrywide of Bangladesh

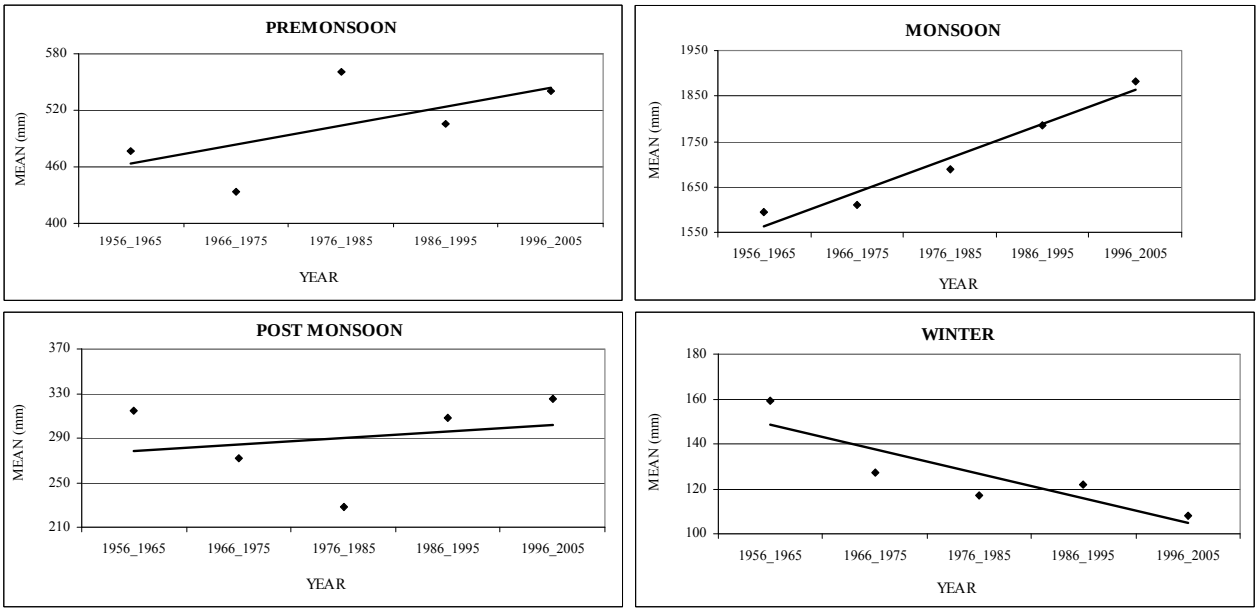

Figure 3. Variation of mean of rainfall over time countrywide of Bangladesh

In Figure 4 the trend of co-efficient of variation of rainfall is downward as the year increases except in winter. It means that except winter the possibility of deviation of rainfall with respect to mean is low as the year advances. As the year increases the occurrence of rainfall becomes close to mean and is more certain and predictable in premonsoon, monsoon, and postmonsoon. The coefficient of variation is a scale, which measures the uncertainty with respect to mean. The analysis performed over the whole country is summarized in Table 1.

From the above table, the monsoon rainfall deviates in significant amount from mean. So, as the year advances the trend of monsoon rainfall becomes more uncertain and unpredictable. In winter the trend of standard deviation is decreasing, therefore the winter rainfall becomes more certain and predictable. The mean rainfall increases high in monsoon and decreases in winter.

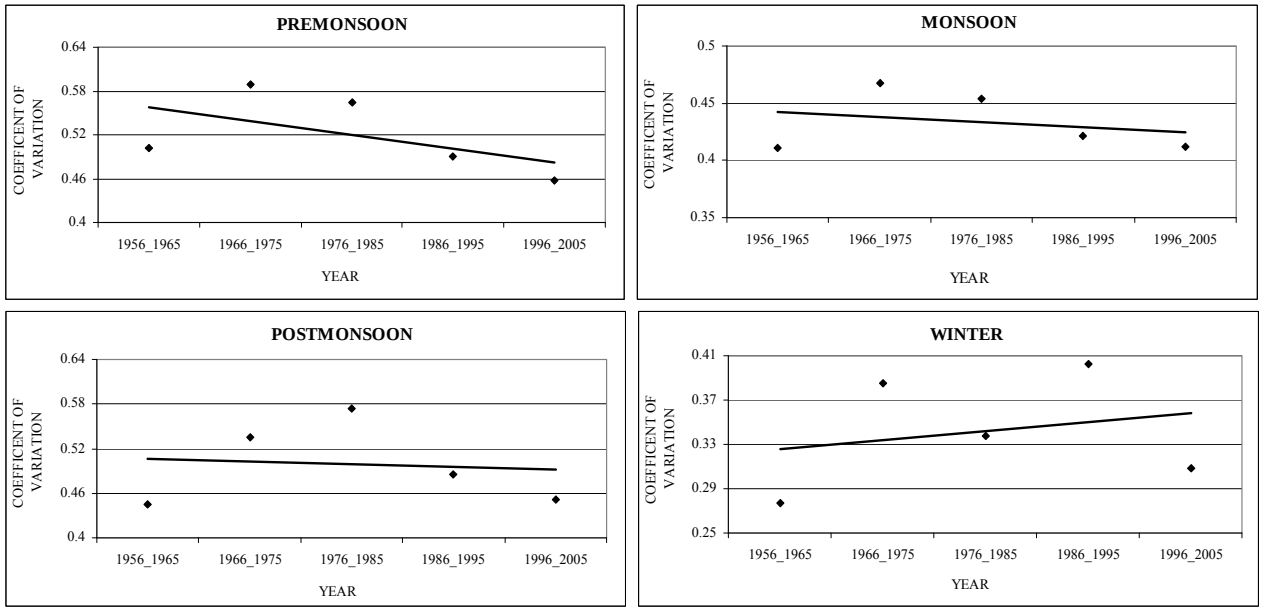

Figure 4. Variation of co-efficient of variation of rainfall over time countrywide of Bangladesh

Table 1: Trend of country wide standard deviation, mean and coefficient of variation with respect to year

Type	Standard deviation (mm/year)x(10^{-1})	Mean (mm/year)	Coefficient of variation (mm/year)x (10^{-3})
Premonsoon	7.9	19.9	-18.9
Monsoon	238.2	74.9	-4.5
Postmonsoon	18.3	5.8	-3.6
Winter	-21.6	-10.8	8.1

3.2 Trend of temporal statistics district wise

Graphs are generated for the standard deviation, mean and co-efficient of variation of rainfall with respect to year in 10 years interval from 1956 to 2005 in premonsoon, monsoon, postmonsoon and winter in different location of Bangladesh (27 stations).The analysis performed over the country is summarized in the following Figure 5 to Figure 8.

From figure 5 the standard deviation of rainfall decreases with the increase of years (1956-2005) at Chittagong in pre-monsoon. The standard deviation expresses the uncertainties in terms of depth of rainfall. Here the slope is downward, which means the possibility of deviation of rainfall with respect to mean is low. As the year increases the occurrence of rainfall becomes close to mean, more certain and predictable. The trend of standard deviation of rainfall (mm) with respect to year at Chittagong in post-monsoon and winter is upward. Here the possibility of deviation of rainfall with respect to mean is high. As the year increases the possibility of rainfall deviates from mean and becomes more uncertain and unpredictable.

The figure 6 represents the co-efficient of variation of rainfall with respect to year in 10 years interval from 1956 to 2005 in premonsoon, monsoon, post monsoon and winter at Chittagong. Co-efficent of variation is calculated by dividing the standard deviation by mean. It is a scale which measures the uncertainty with respect to mean. Here the trend of co-efficient of variation of rainfall is downward with the increase of years, which means that the possibility of deviation of rainfall with respect to mean is low as the year advances. As the year increases the occurrence of rainfall becomes close to mean, more certain and predictable.

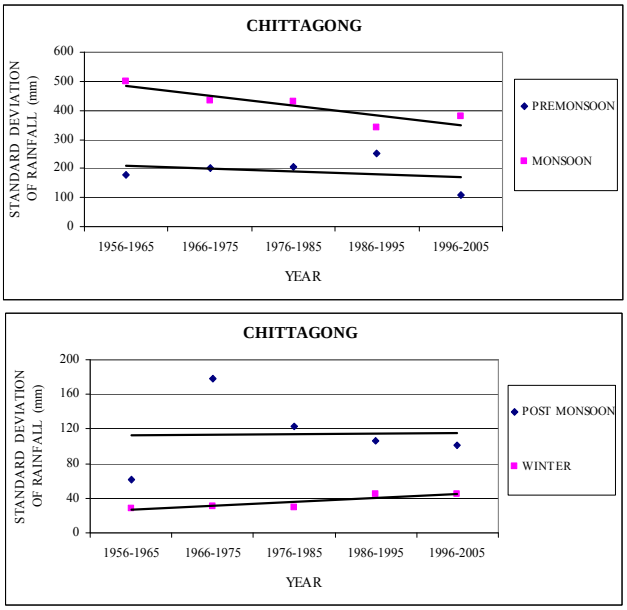

Figure 5. Variation of seasonal standard deviation of rainfall over time in Chittagong

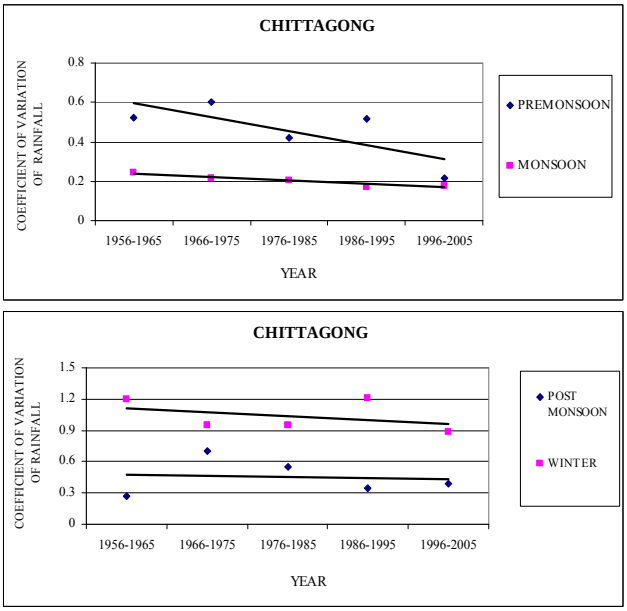

Figure 6. Variation of seasonal co-efficient of variation of rainfall over time in Chittagong

The figure 7 represents the mean of rainfall (mm) with respect to year in 10 years interval from 1956 to 2005 in premonsoon, monsoon, post-monsoon and winter at Chittagong. Here the trend of mean of rainfall is upward. The mean of rainfall increases as the year increases. If the mean increases then the average rainfall also increases.

The figure 8 represents the co-efficient of variation of rainfall with respect to year in 10 years interval from 1956 to 2005 including all seasons at Chittagong.Here the trend of co-efficient of variation of rainfall is downward, which means that the possibility of deviation of rainfall with respect to mean is low as the year advances. As the year increases the occurrence of rainfall becomes close to mean, more certain and predictable. The standard deviation of annual rainfall in 10 years interval from (1956-2005) decrease with the increase of years. Here the slope is downward, which means the possibility of deviation of rainfall with respect to mean is low. As the year increases the occurrence of rainfall becomes close to mean, more certain and predictable. The mean of annual rainfall (mm) with respect to year in 10 years interval from 1956 to 2005 including all seasons at Chittagong. Here the trend of annual mean rainfall is upward. The mean of annual rainfall increases as the year increases which indicates that the total rainfall increases. The analysis performed over the whole country is summarized in the following Table 2 to Table 4.

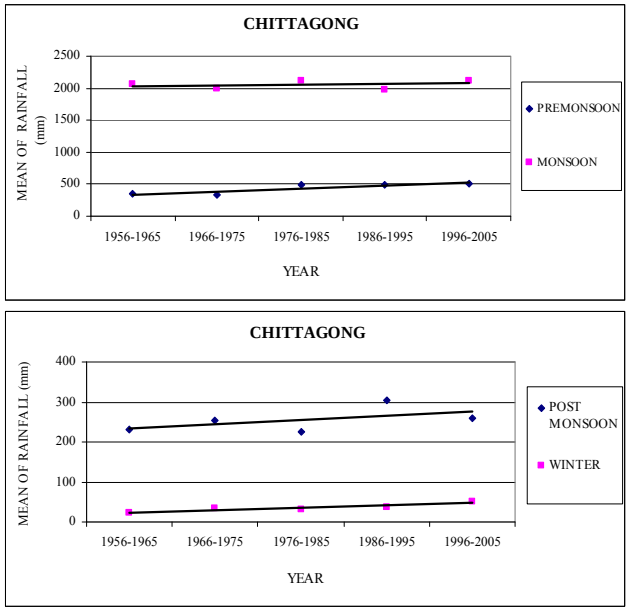

Figure 7. Variation of seasonal mean rainfall of rainfall over time in Chittagong

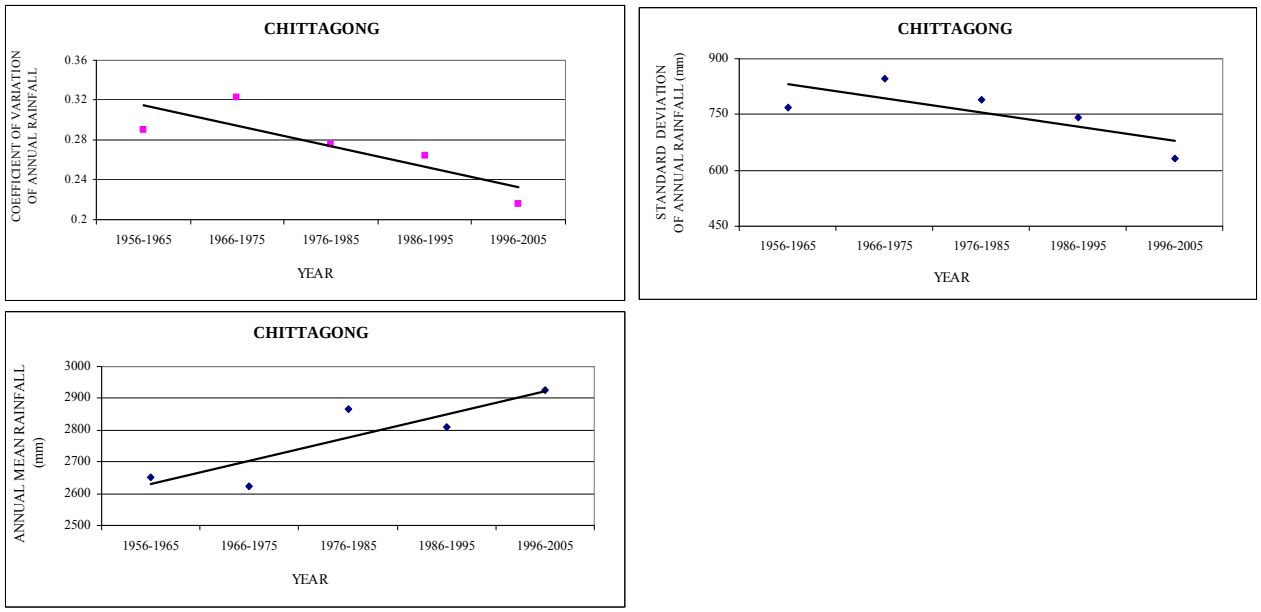

Figure 8. Variation of annual co-efficient of variation, standard deviation and annual mean rainfall over time in Chittagong

In Table 2 the standard deviation decreases more in the district of Feni, Patuakhali and Teknaf. So, the possibility of deviation of rainfall in these districts becomes more certain and predictable. On the other in districts of Sandip the standard deviation increases more therefore, the possibility of deviation of rainfall in these districts becomes less certain and unpredictable.

In above Table 3 the mean of rainfall (1956-2005) decreases more in the district of Comilla in monsoon. So, the average rainfall decreases more in Comilla in monsoon period .On the other in districts of Sitakunda and Feni the mean of premonsoon rainfall and in Teknaf the mean of monsoon rainfall increases more. Therefore the average rainfall increases more in these districts.

In above Table 4, the standard deviation decreases more in the district of Patuakhali and Teknaf in premonsoon and monsoon. So, the possibility of deviation of rainfall with respect to mean in these districts becomes more certain and predictable. On the other in districts of Sandip the standard deviation increases more in monsoon season therefore, the possibility of deviation of rainfall in this district becomes less certain and unpredictable.

Table 2: Trend of standard deviation of rainfall with respect of year

Zone	Premonsoon (mm/year)	Monsoon (mm/year)	Post monsoon (mm/year)	Winter (mm/year)	Annual (mm/year)
Barishal	-38.5	13.3	1.6	2.2	-21.5
Bogra	34.8	-10.2	7.2	1.0	32.9
Chadpur	-38.3	-62.4	1.7	4.7	-94.2
Chittagong	-34.1	-9.6	0.9	4.7	-38.1
Comilla	-34.4	-34.4	-10.2	3.3	-24.6
Cox's Bazar	-65.6	-16.6	-9.2	-2.0	-93.5
Dinajpur	-2.5	5.3	29.0	9.2	41.1
Dhaka	26.3	13.7	-4.3	-5.8	29.8
Khulna	-12.2	-14.5	0.0	7.5	-19.2
Faridpur	8.6	-9.3	-17.4	6.7	-11.5
Feni	-267.2	-14.1	-3.8	-7.0	-292.1
Sylhet	8.1	4.2	-12.9	-11.0	-11.7
Jessore	17.5	-4.7	-2.9	-0.1	9.7
Kutubdia	78.1	-96.8	-34.4	-36.5	-89.6
Mymensingh	8.6	9.9	-2.8	-7.5	8.3
Rajshahi	-7.0	-7.7	10.8	1.5	-2.4
Patuakhali	-290.8	-138.2	43.6	-2.6	-388.1
Rangamati	25.9	2.2	5.6	-2.5	31.1
Rangpur	15.5	-11.2	39.5	1.7	45.5
Sandip	123.8	24.5	22.9	-6.6	164.7
Sitakunda	-97.5	-63.4	-145.6	-6.1	-312.6
Srimangal	-44.0	18.3	5.4	-3.6	-24.0
Teknaf	-114.4	-23.6	47.3	-0.2	-90.9
Hatia	50.8	-7.8	-26.3	2.2	19.0

Negative value: close to mean and more certain, Positive value: deviate from mean and more uncertain.

Table 3: Trend of mean of rainfall with respect to year

Zone	Premonsoon (mm/year)	Monsoon (mm/year)	Postmonsoon (mm/year)	Winter (mm/year)	Annual (mm/year)
Barishal	-23.2	15.7	1.4	0.9	-5.2
Bogra	32.5	24.0	7.4	1.2	65.1
Chadpur	4.3	-11.5	34.2	7.3	34.3
Chittagong	9.9	46.5	11.2	5.9	73.5
Comilla	-83.4	38.7	0.1	1.9	-42.7
Cox's Bazar	18.3	35.1	7.3	0.8	61.4
Dinajpur	108.0	32.9	33.7	7.7	182.2
Dhaka	-13.3	23.8	17.2	-2.2	25.6
Khulna	40.4	14.8	27.9	8.6	91.8
Faridpur	-3.7	9.9	4.3	4.8	15.3
Feni	192.9	-65.1	55.3	-9.0	174.2
Sylhet	38.0	32.2	3.4	-3.6	70.1
Jessore	44.4	18.4	16.7	1.2	80.7
Kutubdia	35.8	19.7	1.4	-35.6	21.3
Mymensingh	34.7	53.1	32.4	-0.7	119.6
Rajshahi	36.8	21.6	9.2	1.4	69.0
Patuakhali	26.5	-42.6	87.4	-1.6	69.7
Rangamati	152.0	96.1	9.0	0.8	257.8
Rangpur	150.2	24.9	50.9	2.0	228.0
Sandip	89.2	14.1	61.3	-3.3	161.3
Sitakunda	187.0	33.7	-160.0	-5.4	55.3
Srimangal	35.7	51.4	4.6	-10.3	81.5

Table 4: Trend of coefficient of variation of rainfall with respect to year

Zone	Premonsoon Slope x (E-03)	Monsoon Slope x (E-03)	Postmonsoon Slope x (E-03)	Winter Slope x (E-03)	Annual Slope x (E-03)
Barishal	-13.4	-9.4	26.7	-0.5	-7.4
Bogra	-78.9	21.8	10.8	25.3	6.5
Chadpur	-123.7	-26.3	-343	-111.9	-48.8
Chittagong	-70.6	-17.6	-37	-10.5	-20.7
Comilla	4.5	-11.3	15.3	-45.8	-5.9
Cox's Bazar	-76.6	-22.8	-61.1	-34.3	-28.4
Dinajpur	-41.9	-20.7	-134.6	9.3	-12.2
Dhaka	14.7	21.4	-78.5	-77.3	11.1
Khulna	-73.9	-21.4	-88.2	-113.5	-33.2
Faridpur	-36.6	7.6	58.6	-91.6	-9
Feni	18.3	-166.7	2.6	-200	-126.1
Sylhet	-5.4	-0.2	-91	-62.9	-7.3
Jessore	-51.3	5.6	-29.8	-80.8	-11.3
Kutubdia	-270.2	30.8	-93.2	-133.9	-32.5
Mymensingh	-35.4	-4.7	-192.4	-128.7	-20.5
Rajshahi	-98.5	-16.5	47.9	58	-17.5
Patuakhali	-275.8	-152.8	-32	-14.6	-157.7
Rangamati	-136.4	-3.1	-77.3	2.2	-20.5
Rangpur	-52.3	-13.7	29.7	43.3	-11.8
Sandip	26	37.6	-69.6	-37.3	31.5
Sitakunda	-132.8	-63.6	-37.8	-203.1	-106.3
Srimangal	-4.4	-38.6	27.2	13.2	-22.4
Teknaf	-215.2	-32.8	-88.4	-88.4	-27.2
Hatia	-73.5	21.5	-41.2	-212.5	-5.5

*Negative value: close to mean and more certain, Positive value: deviate from mean and more uncertain.

4 CONCLUSION

The sets of analysis that are carried out for the rainfall data series are intuitively focused towards examining any discernable trends in these time series. Due to unequal length of records, comparison of result with respect to different stations and seasons are difficult. In Bangladesh, information on data quality is very sparse. There are lots of missing data, which would affect the result related to the trend analysis substantially. With respect to year from 1950-1999, the standard deviation of annual rainfall is significantly decreasing at 388.1 mm/year at Patuakhali, and increasing at 164.7 mm/year at Sandip. The mean of annual rainfall is significantly decreasing at 42.7 mm/year at Comilla, and increasing at 257.8 mm/year at Rangamati. The coefficient of variation of annual rainfall is significantly decreasing at 157.7×10^{-3} mm/year at Patuakhali, and increasing at 31.5×10^{-3} mm/year at Sandip. With respect to year from 1950-1999, in monsoon the countrywide standard deviation of rainfall is significantly increasing at 238.2×10^{-1} mm/year and countrywide mean rainfall is significantly increasing at 74.9 mm/year.

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