The Analysis of Rainfall Variability in Bangladesh

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Abstract

Climate change has created a new challenge to hamper development process throughout the world. Of the burning climatic situations of these times like global warming, floods, drought, heat waves, soil erosion and many other climatic issues are directly related with rainfall. Climate Change is already a painful reality in Bangladesh: farmers and peasants are facing losses of their harvest every year due to continual reduced rainfall. In this study data have been extracted from the Bangladesh Meteorological Department (BMD). The variability and distribution of rainfall has been analyzed using statistical tools. The average annual and monsoon rainfall for different stations and regions of Bangladesh are anticipated to analyze the variation and to estimate trend for the period 1975 to 2017. The excessive and deficient rainfall years have been identified. The average and standard deviation of rainfall in Bangladesh have been estimated from yearly rainfall data. The analysis of the present study on the variability and trends of annual and monsoon season rainfall of regional and all over Bangladesh have been analyzed. Findings reveal that the annual average rainfall amount is found to be between 154 mm to 247 mm, having standard deviation of 41 mm to 97 mm, whereas the monsoon season's average rainfall amount is found to be between 333 mm to 539 mm, having standard deviation of 113 mm to 235 mm. It has been also observed from the analyses that the annual and monsoon rainfall are in a decreasing trend in all regions of the study except East region. The outcome of this study would expectantly help the planners and program managers to take necessary actions and to measure disaster management, drought mitigation, flood control agricultural production etc.

Keywords - *variability, trend, analysis, rainfall, Climate change, Bangladesh*

I. INTRODUCTION

In recent decades, rapid climate change has created a new challenge to hamper development process throughout the world. It is widely acknowledged that the impacts of climate-change amplify unfavorable climatic and environmental situations, particularly in developing countries. The World Bank climate related scholars and experts opined that the poorest of the poor people in South Asian regions are mostly affected by climate change. The impact of higher temperature, more extreme weather events such as floods, cyclone, severe drought, and sea level rise are already being felt in this region which perhaps be continued. Most of the burning issues of our time like global warming, floods, drought, heat waves, soil erosion and many other climatic issues are directly related with rainfall. Bangladesh is one of the most vulnerable countries related to climatic change in the world. The country is geographically located between the Himalaya massive and the Bay of Bengal, and at the bottom of a river delta comprising the three major rivers of the region (Ganges, Meghna, Brahmaputra) and its 57 tributaries draining into the Indian Ocean. Climate Change is already a painful reality in Bangladesh: farmers and peasants are facing losses of their harvest every year due to continual reduced rainfall. Agriculture is still the main source of economic activities in the most of Bangladesh. In order to increase crop production and protecting crops, human life, and ecosystem there is an increasing demand from the policy makers for a reliable prediction, and in particular, the rainfall. The crop yielding depends on the rainfall amount and rain duration. The crop production uncertainty is generally defined by the variability of climate and especially for rainfall variability.

Climate change is anticipated to aggravate the frequency and intensity of extreme weather events in Bangladesh [1]. Variability of climatic events like rainfall is the most important meteorological parameter which is linked with agricultural aspects of Bangladesh [2]. In another study Begum and his colleagues (2013) obtain that the rainfall is decreasing in recent years due to climate change and the sharp decreasing trend of rain over Sylhet division may be the key or one cause for decreasing trend of rainfall over the whole country. The findings of a more recent study reveals that in North-West region of Bangladesh, annual rainfall was decreasing by 0.66 mm annually during the period 1975 to 2014, whereas this amount for monsoon was estimated to be 1.49 mm [3]. In another study Rahman and his colleagues (2016) estimated the mean annual and monsoon rainfall and anomalies for monsoon period [4]. The findings reveal wide variations of rainfall for both annual and monsoon period. Bangladesh is facing major changes in its climatic behavior and weather pattern [5]. The agricultural productions in Bangladesh mostly depend on rainfall, but not all the rain that falls on the earth's surface is useful for agricultural purpose [6]. The rainfall of country is mainly governed by the activities of

South-West summer monsoon. The summer monsoon is the main rainy season in Bangladesh which accounts for about 72% of the annual rainfall during monsoon season [7]. Rainfall and temperature are important climatic inputs in the context of climate variability. Due to rapid climatic oscillation more work is now being done on climate indices like rainfall, temperature and so on [8]. The spatial patterns of the trends of long-term annual and seasonal rainfall as well as the number of wet and dry months to detect the changes in rainfall and rain induced extreme events in Bangladesh [9]. Agriculture activities of Bangladesh, being dependent on seasonal rainfall, are adversely affected by the shortage of seasonal rainfall during dry periods. Therefore, the study of rainfall variability, regional distribution and predictions and to adopt needful actions is utmost importance to mitigate the problems due to rainfall in an agrarian country like Bangladesh.

II. DATA

Data for this study have been extracted from the Bangladesh Meteorological Department (BMD). The BMD collects everyday surface data through weather stations situated all over Bangladesh. There are 34 old rain gauge stations under BMD in Bangladesh. Among them 30 stations collected data for a period of 43 years during 1975 to 2017 and other 4 stations (Mongla, Chuadanga, Syedpur and Tangail) did so for 28 years during 1990 to 2017. Our study period is January 1975 to December 2017. It is notable that, there were some missing data in some days. In this study, the missing rainfall values were completed by expectation maximization (EM) method by using the precipitation records of the nearest gauging stations. The EM algorithm iteratively computes the maximum likelihood estimates to increase the relationship between the missing value and the unknown parameters of a data model. A full description of EM algorithm can be found in [10]. The collected data have been compiled, tabulated and analyzed by MS Excel and ArcGIS.

III. METHODS

The annual and monsoon average of rainfall for different stations and regions of Bangladesh are anticipated to analyze the variation and to estimate trend line for the period 1975 to 2017. The excessive and deficient rainfall years have been identified. The average and standard deviation (SD) of rainfall in Bangladesh have been estimated from yearly rainfall data.

We computed and analyzed the linear trend models by using least square estimation.

$$y = ax + b \qquad \dots\dots\dots\dots\dots\dots (1)$$

where $$b = \frac{\sum y_i \sum x_i^2 - \sum x_i \sum x_i y_i}{n.\sum x_i^2 - \left(\sum x_i\right)^2} \qquad \dots\dots\dots (2)$$

and $$a = \frac{n.\sum x_i y_i - \sum x_i \sum y_i}{n.\sum x_i^2 - \left(\sum x_i\right)^2} \qquad \dots\dots\dots\dots (3)$$

x_i represents years in the time series and y_i represent the weather parameter considered (the mean annual or monsoon rainfall). All summations run through $i = 1, 2, 3, \dots\dots\dots, 43$ i.e. a total of 43 years. The linear fit, thus obtained determines the behavior of the concerned climatic factors over the indicated period. The parameter considered is SD, a commonly used measure of accuracy of fitted time series values. SD is computed using the following formula:

$$SD = \sqrt{\frac{\sum_{t=1}^{n} (y_t - \hat{y}_t)^2}{n}} \qquad \dots\dots\dots\dots (4)$$

The excessive or deficient rainfall years have effects on the economy of the country, so it is necessary to identify those years. The excessive and deficient rainfall years have been identified using following formulae.

Let R_i be the rainfall of *i*-th year, then

if $R_i \geq \overline{R} + \sigma$ the year is called an excess rainfall year

and if $R_i \leq \overline{R} - \sigma$ the year is called the deficient year.

Let us assumed that if $R(u_i, t)$ is the rainfall at u station of *i*-th year for time t, and $R(t) = \left(R(u_1, t), R(u_2, t), \dots\dots\dots, R(u_k, t)\right)$ point $u_1, u_2, \dots\dots\dots\dots, u_k$.

Therefore, the spatial mean and standard deviation for time t can be represented as

$$\overline{R}(t) = \frac{1}{k}\sum_{i=1}^{k} R(u_i, t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\sigma^2(t) = \frac{1}{k}\sum_{i=1}^{k} \left[R(u_i, t) - \overline{R}(t) \right] \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

IV. RESULTS

The data were analyzed to investigate the variability and trends of annual (January-December) and monsoon season (June-September) rainfall over Bangladesh. The analysis and results of the present study on the variability and trends of annual and monsoon season rainfall of regional and all over Bangladesh have been discussed in the subsequent sub sections.

A. Monsoon Rainfall Variability over Bangladesh

The monsoon average rainfall variations in study area for 34 stations data are analyzed and exhibited. The actual situations of monsoon average rainfall are shown in Figure 1. The monsoon average rainfall amount ranges between 333 mm to 553 mm, having standard deviation of 113 mm to 235 mm. Results suggest that the average rainfall of this season was 437 mm. In North-West region (NWR), the monsoon average rainfall was found 333 mm and noted that the highest rainfall was 677 mm (1987) in Rangpur and lowest 143 mm (2010) in Ishurdi. In South-West region (SWR), the monsoon average rainfall was found to be 374 mm and in this region the highest amount of rainfall was 823 mm in 1982 in Patuakhali and lowest 136 mm in 2010 in Chuadanga. In Central region (CR), the monsoon average rainfall was recorded 384 mm and highest average rainfall was found to be 1003 mm in Maijdi Court and lowest 126 mm in Feni in 1984 and 1980 respectively. In East region (ER), it was 600 mm and average rainfall in this region was highest 1180 mm in Teknaf in 2008 and lowest 82 mm in Kutubdia in 1980.

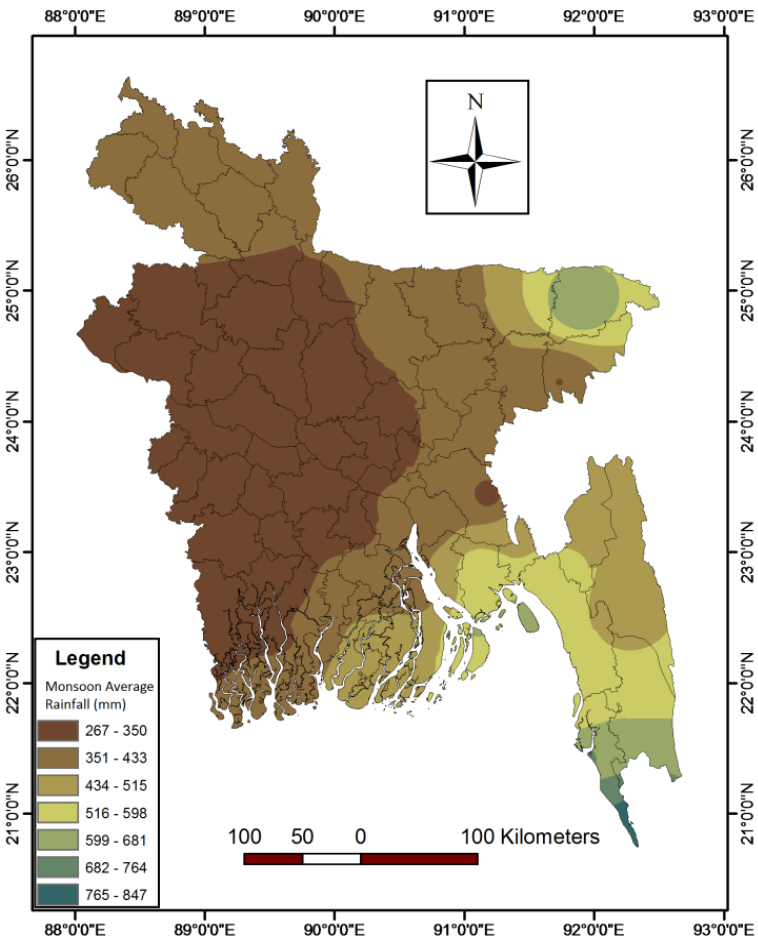

Figure 1: Monsoon average rainfall variability over Bangladesh from 1975 to 2017

B. Annual Rainfall Variability over Bangladesh

The annual average rainfall variation are analyzed for 34 stations and presented below. The actual situations of annual average rainfall as found in the analyses are shown in Figure 2. The annual average rainfall amount was found to be between 154 mm to 247 mm, having standard deviation of 41 mm to 97 mm. The annual average rainfall of the study was 197 mm. In NWR, the annual average rainfall was found to be 153 mm and highest average rainfall 312 mm (1984) in Rangpur and lowest 66 mm (2010) in Rajshahi.

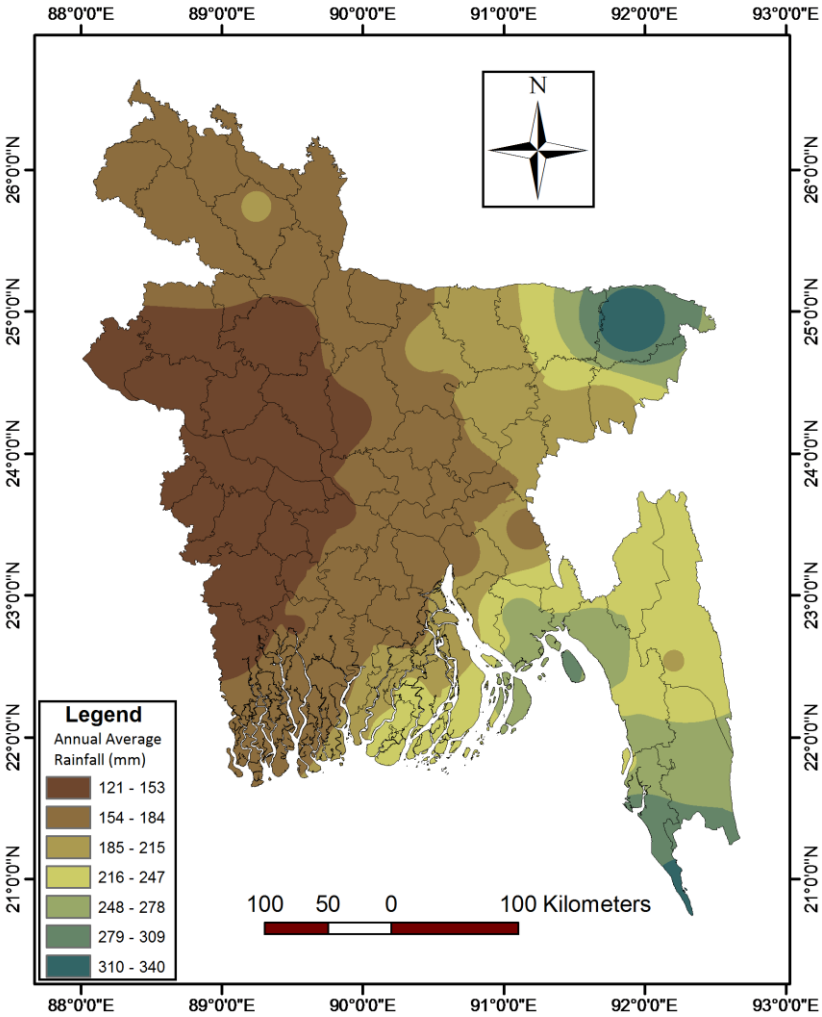

Figure 2: Annual average rainfall variability over Bangladesh from 1975 to 2017

C. Trends of Monsoon Season Rainfall

The data are analyzed to investigate the trends of regional monsoon rainfall over Bangladesh and are pictured in figure 3. The trend of monsoon season rainfall decreases by 1.19 mm/year in the NWR, 0.48 mm/year in the SWR, 0.30 mm/year in the CR, however, monsoon average rainfall increased by 3.06 mm/year in the ER and 0.38 mm/year in overall Bangladesh. The analyses suggest that the trend of rainfall of this season in the NWR, SWR and CR decreased except ER. The excessive and deficient rainfall years of monsoon have been shown in figure 3.

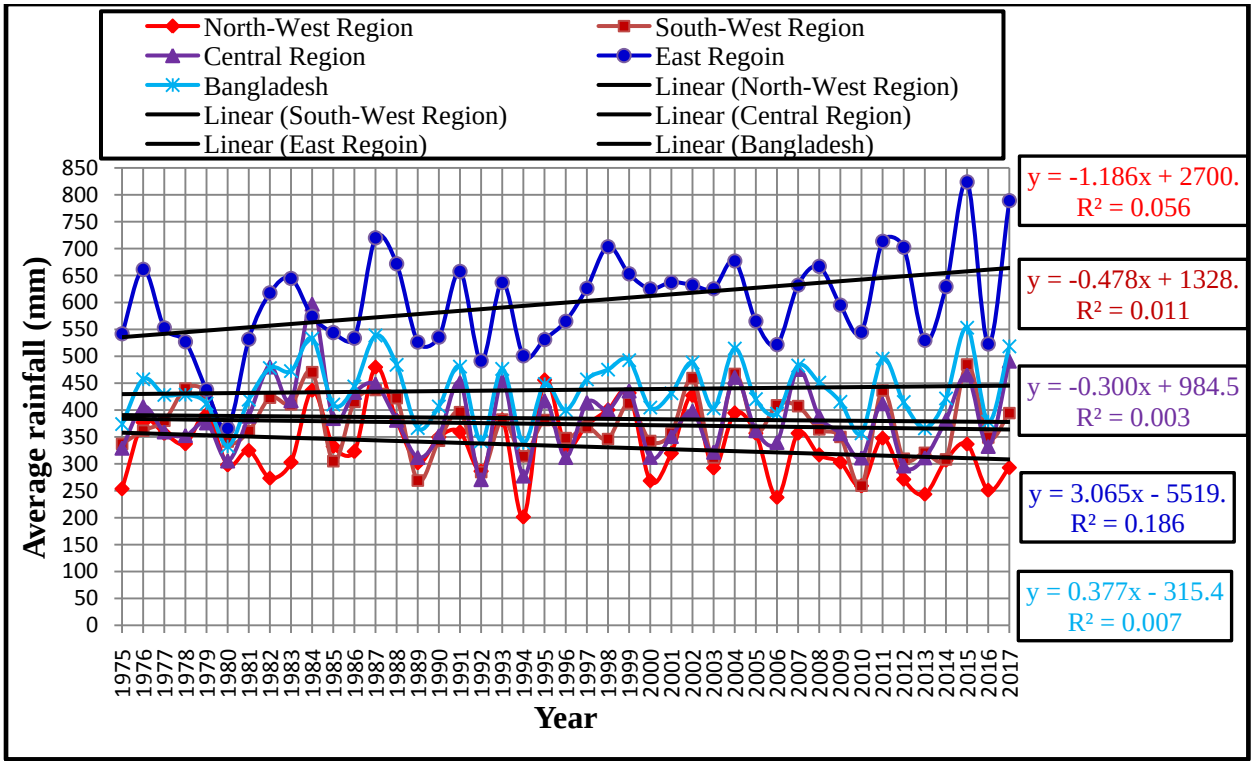

Figure 3: Trends of monsoon season average rainfall over Bangladesh from 1975 to 2017

D. Trends in Annual Rainfall

The trends of annual average rainfall by region for all over Bangladesh are pictured in figure 4. The estimated liner line show predominantly negative trends for Bangladesh and also for all regions except the East region. The trend of annual rainfall decreases by 0.42 mm/year in the NWR, 0.33 mm/year in the SWR, 0.39 mm/year in the CR, whereas the average rainfall increased by 1.24 mm/year in the ER and the change was not found to be statistically significant for all over Bangladesh. Therefore, annual rainfall all the regions are decreases except ER. The excessive and deficient rainfall years of annual have been shown in Figure 4.

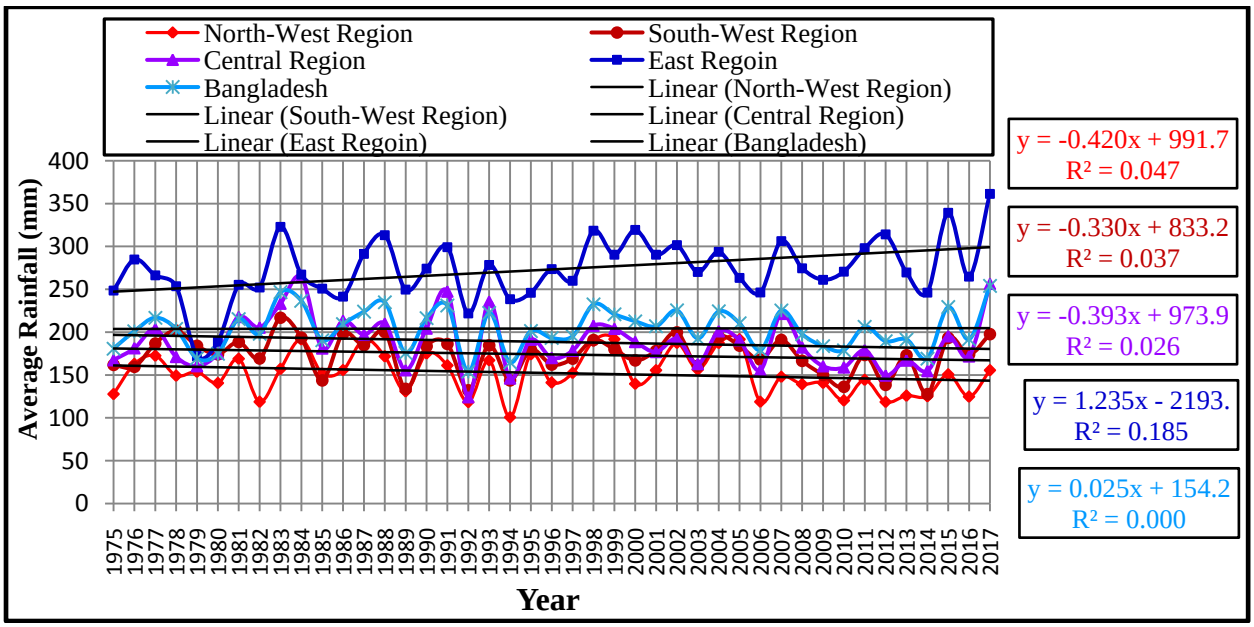

Figure 4: Trends of Annual average rainfall over Bangladesh from 1975 to 2017

VI. DISCUSSION AND CONCLUSION

The analysis of the present study on the variability and trends of annual and monsoon season rainfall of regional and all over Bangladesh have been analyzed and discussed. It has been observed that the annual average rainfall amount is found to be between 154 mm to 247 mm, having standard deviation of 41 mm to 97 mm, whereas the monsoon season's average rainfall amount is found to be between 333 mm to 553 mm, having standard deviation of 113 mm to 235 mm. It has been observed from the analyses that the annual and monsoon rainfall are in a decreasing trend in all regions of the study except ER. Finally, it can be concluded that the amount of rainfall is in a decreasing trend in recent years due to climate change over Bangladesh.

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