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DECADAL VARIATION OF WINTER RAINFALL AND RAINY DAYS OVER BANGLADESH

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ABSTRACT

In the present study, sixty five years (1948-2012) daily rainfall data of 30 meteorological stations of Bangladesh Meteorological Department (BMD) have been used to understand the rainfall characteristics during winter season over Bangladesh. Yearly variations of rainfall and rainy days have been studied to see the long term variability. The study period is divided into six decades starting from 1950 to investigate the decadal and interdecadal, spatial and temporal variations. Average rainfall is found to be 0.39 mm/day with standard deviation (SD) of ±0.29 mm/day and coefficient of variation (CV) is 75.03% during 65 years in the winter season. Average rainy days is found to be 3.30 days with SD of ±1.89 days and CV 57.26%. Both rainfall and rainy days are found to have an annual increasing trend. Rainfall is found highly correlated with rainy days with coefficient of correlation (CC) 0.85 with 99.5% level of confidence. Rainfall and rainy days both is found maximum in the fifth decade.
Key Words: *Rainfall, rainy day, winter, decadal variation*.

1. INTRODUCTION

Precipitation is a natural process and is related to the amount of latent heat transported from the surface to the atmosphere. It is an essential component of scientific investigation of the hydrologic cycle, the global water balance and large scale global atmospheric modeling. But it is one of the most difficult atmospheric parameters to measure because of the large variations in space and time (Kummerow *et al*., 2000).

Indian subcontinent is well known as a southwest monsoon region (Gadgil *et al.* 2005; Goswami *et al.* 1994; Hastenrath 1995; Kumar *et al.* 1995; Pattanaik *et al.* 2015; Rajeevan 2001; Thapliyal and Kulshreshtha 1992) and Bangladesh is a heavy rainfall area in it. Bangladesh is a narrow flat low land, the maritime continent Bay of Bengal is located in the south and the highly elevated Himalayas and Tibetan Plateau are situated in the north. The climate of this country is comprised of four seasons: pre-monsoon (March–May), monsoon (June–September), post-monsoon (October and November) and winter (December–February).

Kripalani and Kumar, (2004) studied rainfall variability over south peninsular India during northeast monsoon (NEM) and found interannual and decadal variabilities in NEM with alternate epochs of above- and below-normal rainfall. Dimri *et al.* (2016) studied the Indian winter monsoon and found influence of western disturbances in winter precipitation. Alam *et al.* (2010) studied temporal variation of rainfall over southwestern part of Bangladesh and found increasing trend of seasonal rainfall. Ahmed *et al*. (1996) and Reza *et al*. (2004) worked on seasonal rainfall variation over Bangladesh and found negative correlation with ENSO and southern oscillation index (SOI) respectively. Reza *et al.* (2015) studied the spatial and temporal variations of rainfall and rainy days during post-monsoon season and found increasing trend in both rainfall and rainy days. In this study, an attempt has been made to study decadal variation of rainfall and rainy days over Bangladesh during winter season.

2. DATA AND METHODOLOGY

Daily rainfall data of 30 meteorological stations of Bangladesh Meteorological Department (BMD) from 1948 to 2012 is used in this study. Data have been collected from the Climate Division of BMD, Dhaka. It is important to note that some of the stations started its operation after 1948 and some data were not available in some stations for a few years. These data have been considered as missing and have not been used in statistical computations.

The daily rainfall data is used to obtain monthly and seasonal mean. This is worthy to note December rainfall has been added to the January and February rainfall of the next year for the rainfall of winter. The

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station wise rainy days is identified (if there is any rain) and accumulated for the season. Yearly variations of the rainfall and rainy days along with the trend lines, standard deviation, coefficient of variation and time variant coefficient of correlation are studied with the standard statistical technique. Statistical significance is calculated with student's t distribution: $t = r\sqrt{\frac{n-2}{1-r^2}}$; where r is the coefficient of correlation and n is the number of events. Thirty years moving average is computed for both rainfall and rainy days and their variations along with the trend lines have also been studied to understand the climatic swing.

To study the decadal variations of the studied parameters the study period is divided into six decades starting from 1950. 1950-1959 has been designated as Decade1 (D1), 1960-1969 as Decade2 (D2), 1970-1979 as Decade3 (D3), 1980-1989 as Decade4 (D4), 1990-1999 as Decade5 (D5) and 2000-2009 as Decade6 (D6). Here after different decades will be used as D1, D2, D3, D4, D5 and D6. From seasonal average rainfall decadal average is made for each station for each decade during winter season (December-February). Spatial distribution of rainfall is studied for each decade. To understand the climatological variation of rainfall over the country 60 years average (1950-2009) are made for each station. From this 60 years average rainfall; anomaly (Decade average-60 years station average) are calculated for each decade during winter for individual station. Distributions of rainfall anomaly are studied for each decade over the country during winter season. Similar works are done with respect to 60 years country average rainfall. Rainfall anomaly (60 years average for each station - 60 years average for all stations) is calculated. Distribution of this rainfall anomaly has also been studied during this season. Decadal average is also computed to study the interdecadal variation of rainfall and rainy days over the country.

3. RESULTS AND DISCUSSIONS

Spatial and temporal variations of rainfall and rainy days of thirty meteorological stations over Bangladesh are studied and presented in Figures 1-7.

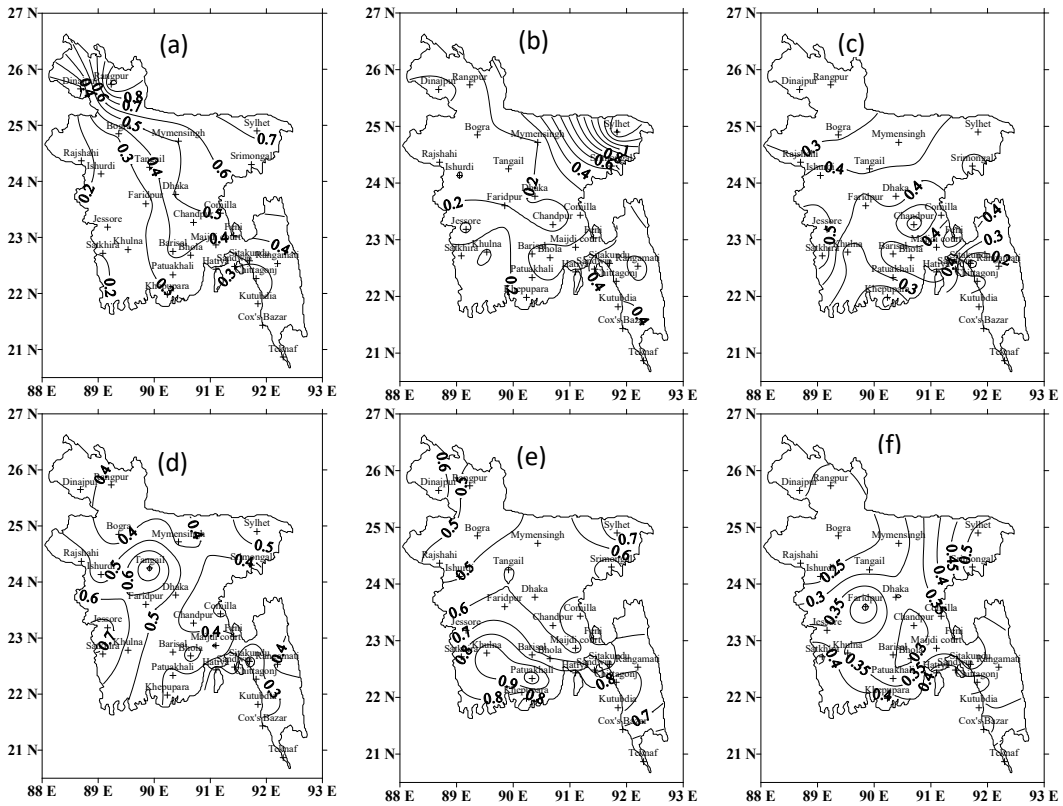

Figure 1: Distribution of average rainfall (mm/day) during winter season for (a-f) D1-D6 respectively

Decadal distributions of average rainfall of decade1 to decade 6 (D1-D6) during winter season are presented in Figure 1(a-f). Rainfall is found minimum in the western part of the country in D1 [Figure 1 (a)]. Rainfall contour of 0.2 mm/day passes over Satkhira, Rajshahi and Dinajpur regions. Rainfall is found to increase in the north and northeastern part of the country. In most of the places over central and western part of the country are found to have 0.2mm/day rain in D2 [Figure 1 (b)]. Rainfall in the eastern part is higher than the western part and found maximum in the northeast part of Bangladesh. In D3 [Figure 1 (c)], most of the places over the country rainfall are found to have 0.4mm/day. Maximum rainfall of 0.7mm/day is found over Jessore and Satkhira region in D4 [Figure 1 (d)] and minimum rainfall of 0.3mm/day is found over Cox's Bazar, Chittagong and adjoining area. In D5 [Figure 1 (e)], maximum amount of rainfall is found in the southwestern part of the country. However in D6 [Figure 1 (f)], northwestern part of the country is found to have the minimum amount of rain and the northeastern part of the country has got the maximum.

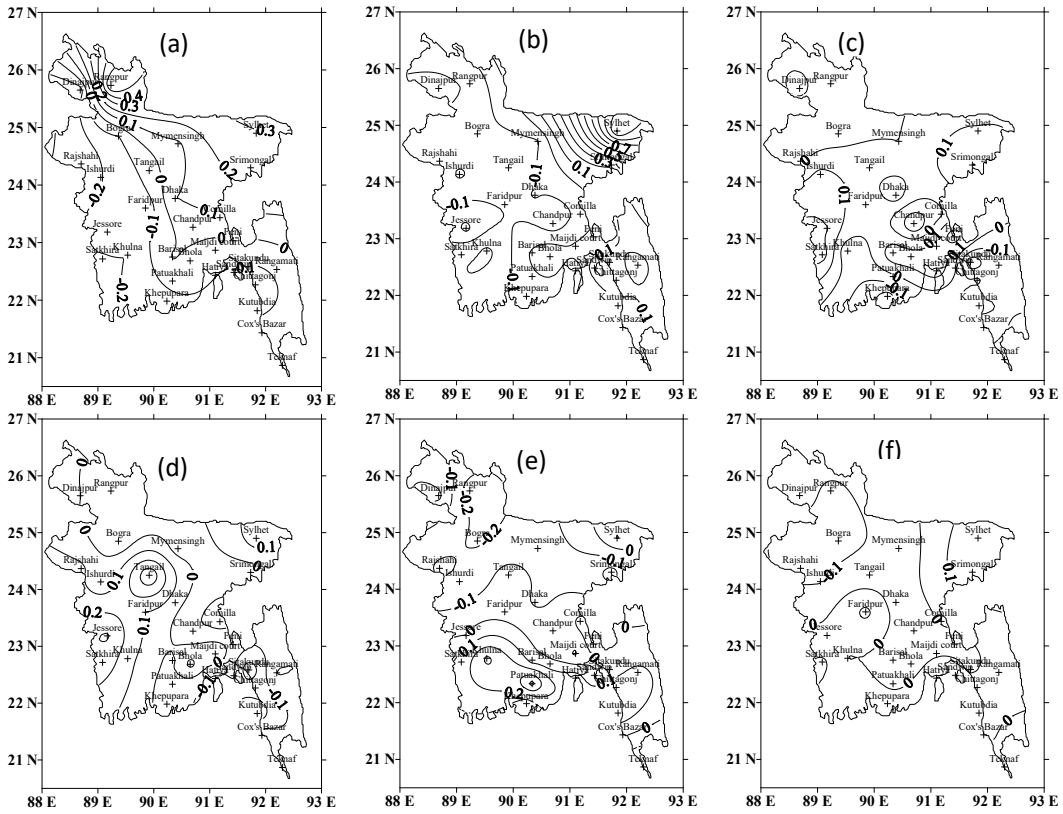

Figure 2: Rainfall anomaly (mm/day) with respect to decadal country average during winter for (a-f) D1-D6 respectively

Decadal distributions of rainfall anomaly (mm/day) with respect to decadal country average during winter season are presented in Figure 2(a-f). In D1, western and southwestern parts of the country are found to have deficit of rain [Figure 2 (a)]. The north and northeastern parts of the country are found to have excess of rain. Zero anomaly line passes over Bogra, Barisal and Feni. In D2 [Figure 2 (b)], northeastern and southeastern parts of the country are found to have excess of rain and most of the region of the country is found to have deficit of rain. The positive anomaly is found in the northeast and southwestern regions and negative anomaly is found in the southern and southeastern regions of the country in D3 [Figure 2(c)]. Southwestern and northeastern parts of the country are found to have excess of rain in D4 [Figure 2 (d)] and negative anomaly is found in the south to southeastern region. Negative anomaly is found from central to north northwestern region and positive anomaly in the southern region of the country in D5 [Figure 2 (e)]. Zero anomaly is found all over the country except northeast and northwestern regions where found positive and negative anomalies are respectively in D6 [Figure 2(f)].

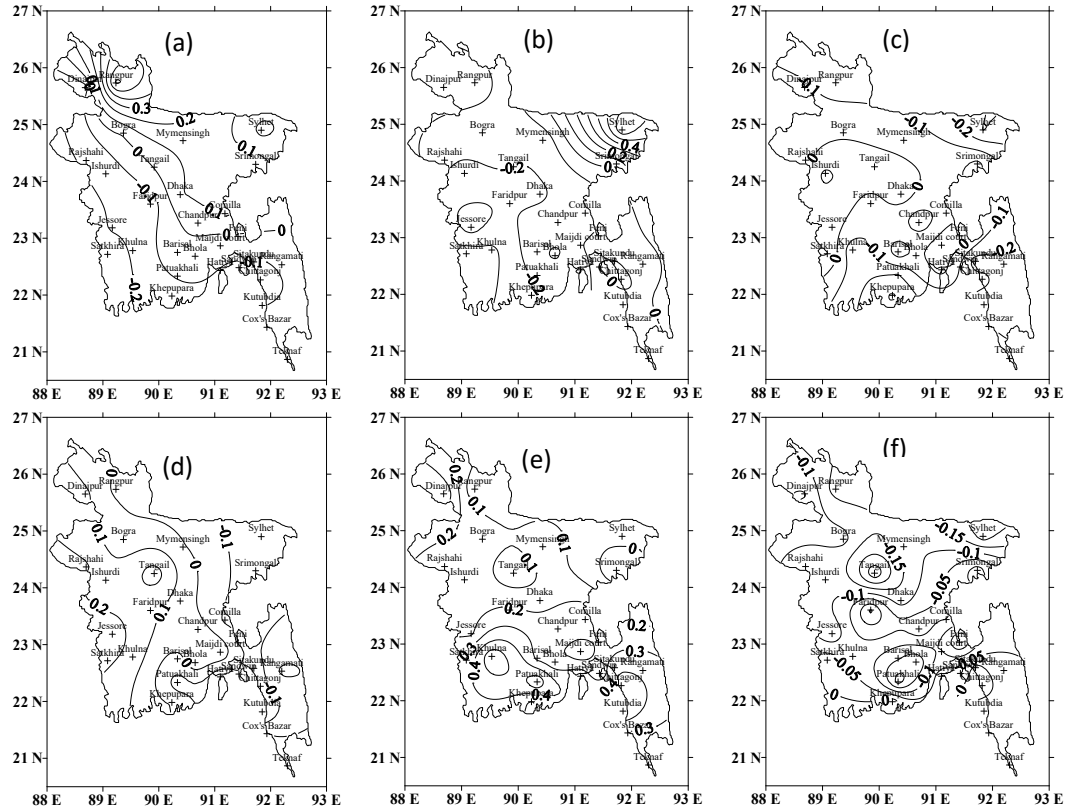

Figure 3: Rainfall anomaly (mm/day) with respect to 60 years station average during winter for (a-f) D1-D6 respectively

Rainfall anomalies with respect to sixty years station average are presented in Fig 3(a-f). No anomaly is found over Dinajpur, Bogra, Tangail, Feni and adjoining area in D1 [Fig 3(a)]. Southern and western parts of the country is found to have deficit of rain and northwest, north and northeastern parts of the country are found to have excess of rain. Maximum excess rainfall 0.6 mm/day is found at Rangpur region in D1. Over a large part of the country there is deficit in rain with 0.2 mm/day in D2 [Fig 3(b)] and the northeast part of the country is found to have excess of rain 0.6 mm/day. In D3 [Fig 3(c)], there is no anomaly over the central region and the rest of the country is found to have deficit of rain. Eastern part of the country has deficit in rain in D4 [Fig 3(d)] while central and western parts of the country have excess of rain. In D5 [Fig 3(e)], positive anomaly is found all over the country. The anomaly is found maximum in the southeast and southwestern parts of the country. However in D6 [Fig 3(f)], negative anomaly dominates all over the country.

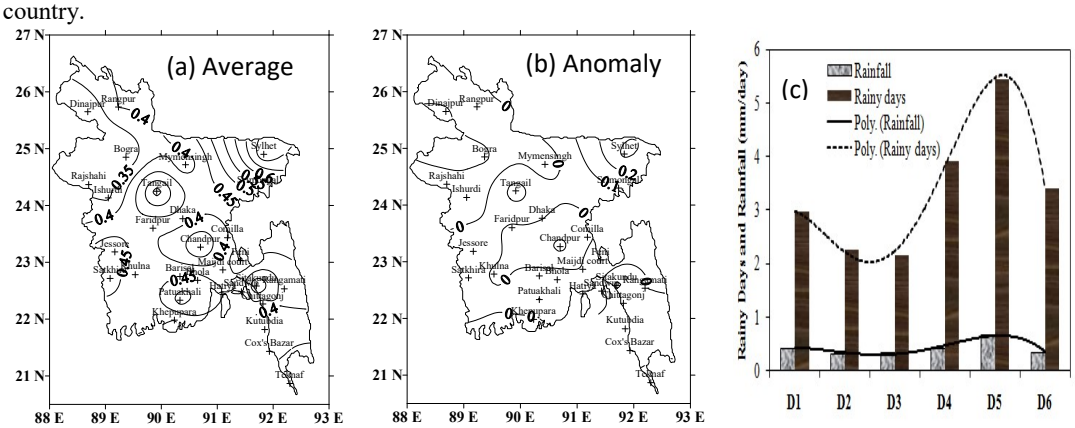

Figure 4: a) Distribution of 60 years average rainfall (mm/day) b) Rainfall anomaly (mm/day) with respect to 60 years country average and c) Decadal average rainfall (mm/day) & rainy days during winter season over Bangladesh

It is observed that 60 years average rainfall minimum is in the north western part of Bangladesh [Fig 4(a)]. Over a large part of the country including Rangpur, Dhaka, Mymensingh, Comilla, Maijdi Court, the average rainfall is found 0.4 mm/day. The rainfall is found to increase in the northeast direction with maximum 0.7mm/day over Sylhet. There was no anomaly over the country with respect to 60 years average [Fig 4(b)] except in the northeast part of Bangladesh where the anomaly increases in the northeast direction.

Decadal average rainfall and rainy days along with their polynomial fittings are presented in Figure 4(c). Both rainfall and rainy days are found to have similar pattern with maximum in D5 and minimum in D3. The maximum rainfall and rainy days are 0.67 mm/day & 5.43 days and minimum are 0.33 mm/day and 2.14 days respectively. Polynomial curves are fitted to the decadal rainfall and rainy days. The fourth order time variant polynomials are:

$$y = -0.013x^4 + 0.158x^3 - 0.580x^2 + 0.747x + 0.102 \text{ for rainfall and}$$

$$y = -0.095x^4 + 1.081x^3 - 3.712x^2 + 4.230x + 1.470 \text{ rainy days respectively.}$$

Anomaly of rainy days with respect to sixty years station average is presented in Figure 5(a-f). Anomaly of rainy days is mainly negative over the country with a few exceptions in the north and northeast parts of the country where it is positive [Fig 5(a)]. Negative anomaly prevails over the country in D2 and D3 [Fig 5(b & c)] with minimum in the southwest part of the country. Anomaly of rainy days is found positive over the country in D4 and D5 with maximum in the southwest part of the country [Fig 5(d & e)] and in D5 is significantly higher than that of D4. In D6 there is no anomaly over most of the places over the country and anomaly is positive over a few places over the northwestern part of the country.

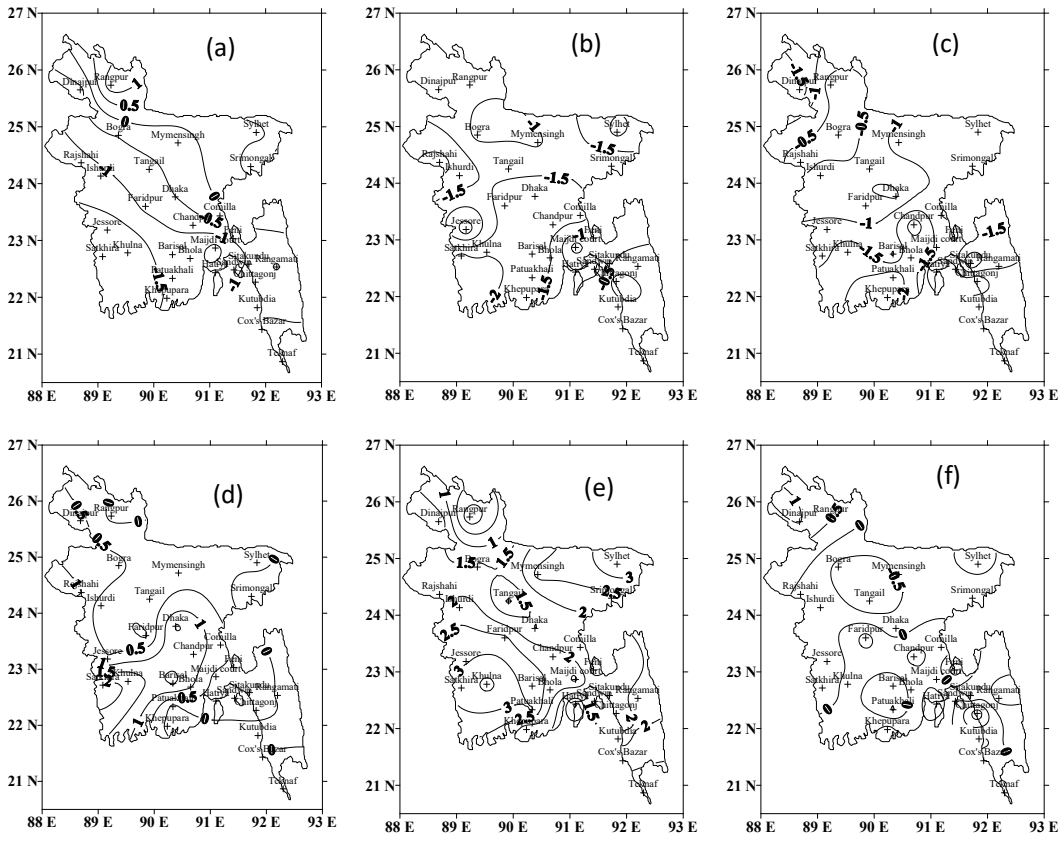

Figure 5: Anomaly of rainy days with respect to 60 years station average during winter season for (a-f) D1-D6 respectively over Bangladesh

Rainfall and rainy days of 65 years (1948-2012) during winter season over Bangladesh are analyzed. Average rainfall is found 0.39 mm/day with standard deviation ±0.29 mm/day and coefficient of variation 75.03% during 65 years in the winter season. Average rainy days are found 3.30 days with standard deviation of ±1.89 days and coefficient of variation 57.26%.

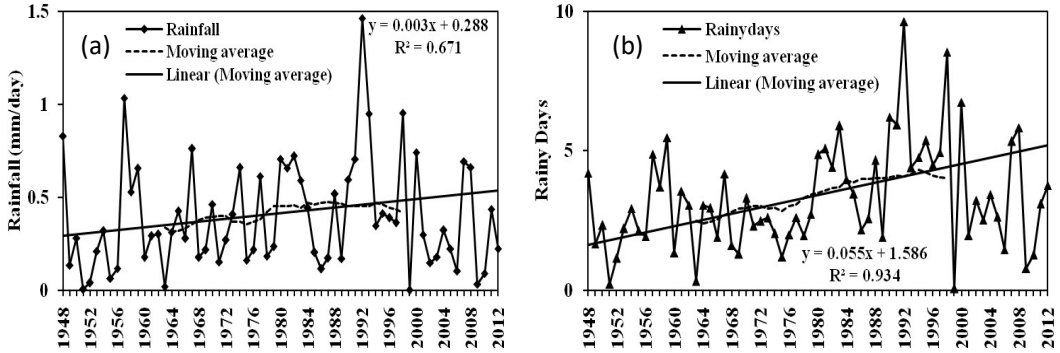

Figure 6: a) Annual variation of rainfall (mm/day) along with thirty years moving average and the linear trend line and b) Same as (a) but for rainy days

Annual variation of rainfall and rainy days along with thirty years moving average and linear trend lines are presented in Figure 6(a-b). Highest rainfall and rainy days have been found in the year 1992 and lowest in 1999. Both rainfall and rainy days are found to have an increasing trend with 0.003mm/day/year and 0.055 days/year with time variant coefficient of correlation 0.82 and 0.97 respectively at 99.5% level of confidence.

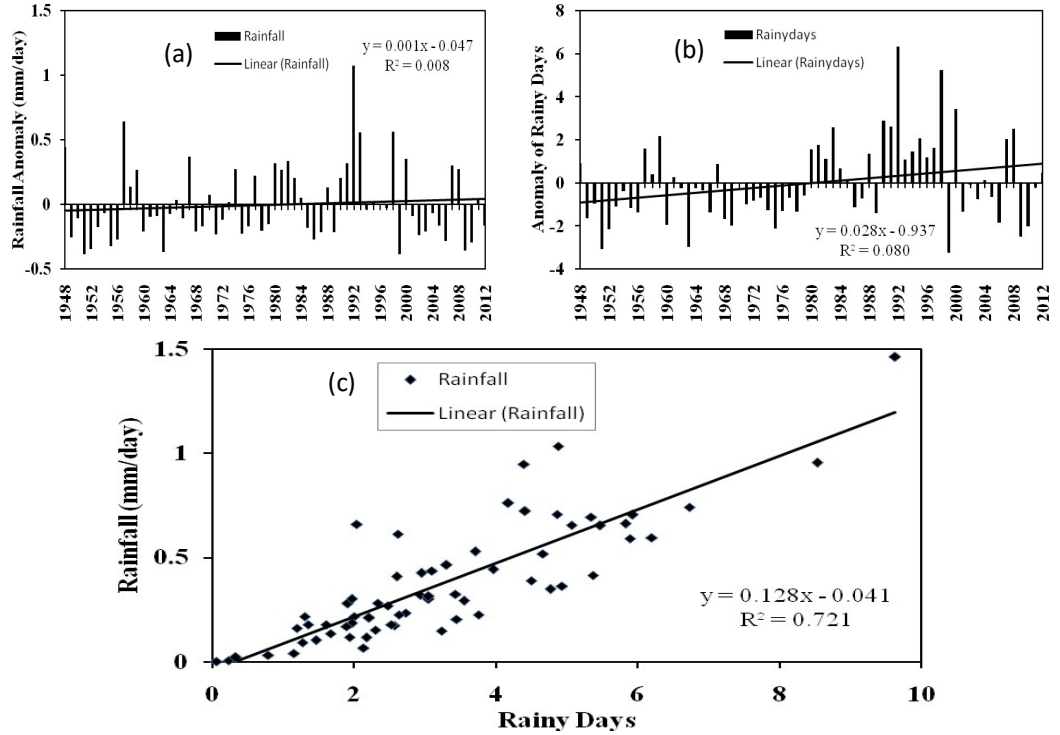

Figure 7: a) Variability of rainfall, b) rainy days and c) rainfall vs rainy days for the period 1948-2012

Variability of rainfall and rainy days are presented in 7(a-b). There are some similarities in the 80s and 90s among the rainfall and rainy days. Both rainfall and rainy days are found to have maximum positive anomaly in the year 1992 with 1.07mm/day and 6.33 days respectively and minimum anomaly in the year 1999 with -0.39 mm/day and -3.24 days respectively. Both the parameters are found to have an annual

increasing trend. Although increasing rate of rainfall is not statistically significant but increasing rate of rainy days is significant with 97.5% confidence level. The relation between rainfall and rainy days are presented in Figure 7(c). Rainfall is found to be highly correlated with rainy days with coefficient of correlation 0.85 at 99.5% level of confidence.

4. CONCLUSIONS

On the basis of the study presented in this paper the following conclusions have been drawn:

i) All decades except D3 have similar rainfall distribution pattern and it increased in the northeastern part of Bangladesh. Minimum amount of rainfall is found in the northwestern part of Bangladesh in D3, D4 and D6.

ii) The northwestern part of the country is found to have deficit of rain and the northeastern part of the country is found to have excess of rain.

iii) Rainfall and rainy days are found to have similar patterns with maximum in D5 and minimum in D3. The maximum rainfall and rainy days are 0.67 mm/day & 5.43 days and minimum are 0.33 mm/day & 2.14 days respectively.

iv) Rainy days are found above normal distribution in D4 and D5 and below normal in D2 and D3 over the country.

v) Rainfall and rainy days both are found highly variable with CV 75.03% and 57.26%. Average rainfall is found 0.39 mm/day with SD ±0.29 mm/day and average rainy days is 3.30 days with SD ±1.89 during 65 years in the winter season.

vi) 30 years moving averaged rainfall and rainy days both are found to have an increasing trends with 0.003mm/day/year and 0.055 days/year with time variant CC 0.82 and 0.97 respectively at 99.5% level of confidence.

vii) Variability of rainfall and rainy days shows that both the parameters have an annual increasing trend. Although increasing rate of rainfall is not statistically significant but increasing rate of rainy days is significant with 97.5% confidence level.

Rainfall is found to be highly correlated with rainy days with CC 0.85 with 99.5% level of confidence.

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