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STUDY OF TEMPERATURE AND RAINFALL VARIABILITY OVER BANGLADESH IN WINTER SEASON

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Abstract

In this paper, we have investigated long term variability of temperature and rainfall in winter season (November-February) using observational data for a 33 years period (1979-2012) over seven divisional station areas of Bangladesh. In this study, trends of rainfall and the average maximum temperature has been analyzed and a correlation between them has also been calculated. In winter season, rainfall has decreased with a rate of 159.9 mm, 200.8 mm, 160.7mm, 150.6 mm, 97.7 mm, 87.77mm and 99.3mm per 100 years in Dhaka, Rajshahi, Khulna, Barisal, Sylhet, Chittagong and Rangpur. On the other hand, mean maximum temperature has shown an increasing trend 3.22ºC per 100 years except in Dhaka. The correlation coefficient (r) confirms the result which is contradictory with the regularity that rainfall is increased with temperature. In this paper, it has been seen that Rangpur is the lowest rainfall area and also the coolest area in the winter season and Chittagong is the highest rainfall zone and hottest area among the seven districts.

Key Words: Winter season, Rainfall, Temperature, Correlation coefficient

Introduction

From the meteorological point of view, there are four climate seasons in Bangladesh. Winter is one of them. Meteorological winter is the method of measuring the winter season used by meteorologists based on "sensible weather patterns" for record keeping purposes (Huttner, 2007) so the start of meteorological winter can change depending on how far north one lives (NOAA, 2003). Winter is often defined by meteorologists to be the three calendar months with the lowest average temperatures. This corresponds to the months of December, January and February in the Northern Hemisphere which include Bangladesh, and June, July and August in the Southern Hemisphere. As a disaster-prone country, Bangladesh almost every year, experiences disasters such as tropical cyclones, coastal erosion, floods, and droughts causing heavy loss of lives and property. These natural calamities add an extra burden to the Bangladesh is likely to be one of the most vulnerable countries of the world affected by the effect of climate change (Ali, 1999). Bangladesh is highly vulnerable as it is low-lying, located on the Bay of Bengal in the delta of the Ganges, Brahmaputra and Meghna and heavily populated. Economy of

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Bangladesh strongly depends on agriculture and natural resources that is sensitive to climate change and Sea Level Rise (SLR).

The influence of higher temperatures, more extreme weather events such as floods, cyclone, severe drought and SLR are already being felt in South Asia and will continue to intensify (Haq et. al., 1998; Karim et. al., 1998). But compared to the importance of the atmosphere, our knowledge about it is limited. Many aspects of the atmosphere (temperature, wind, rainfall) may change due to greenhouse gas induced warming. It is expected that the intensity of the hydrological cycle will increase as the climate warms. In particular precipitation extremes are generally expected to increase at the same rate with temperature. The saturated amount is found to increase with 7% per ºC. However, data analysis of precipitation showed different behavior when the temperature becomes bigger than 12ºC (Geert Lenderink and Erik van Meijgaard, 2008). Recent studies shown that the amount of rainfall decreases in the last decade in this part of South Asia, which includes Bangladesh (Bhuyan et. al., 2013) in summer monsoon season.

Intergovernmental Panel on Climate Change (IPCC) has reported in their fourth assessment report that global surface temperature increased 0.74 ± 0.18 °C during the 100 years ending in 2005 (IPCC 2007). It has been also noted by IPCC that the rise of mean annual temperature will be 3.3 °C per century. In the past, a number of studies have been carried out for showing the changes of climate parameters over Bangladesh. Chowdhury and Debsharma (1992) and Mia (2003) pointed out that the temperature has been changed by using historical data of some selected meteorological stations. Parathasarathy et. al., (1987) and Divya and Mehritra (1995) reported mean annual temperature of Bangladesh has increased during the period of 1895-1980 at 0.3ºC over the past two decades. Karmakar and Shrestha (2000) projected that annual mean maximum temperature will increase to 0.4ºC and 0.73ºC by the year of 2050 and 2100 respectively using the 30 years (1961-1990) data for Bangladesh.

The objective of this study is to identify the trend of temporal statistics (standard deviation, mean and co-efficient of variation, moving average) division wise with respect to year and observe climate variability of rainfall and temperature. This study also observes the variability of rainfall and temperature over time and space in the winter season in a particular division with the increase of years.

Materials and Methods

Maximum daily temperature and daily total rainfall data from November-February of last 33 years (1979 to 2012) collected from 34 stations of BMD (Bangladesh Meteorological Department), Dhaka, Bangladesh located over Bangladesh have been used in this study. Fig. 1 shows the location of the BMD stations over Bangladesh. Here we take only seven divisional station area that means Dhaka (Lat.: 23Deg.46Mts.N; Long.: 90Deg. 23Mts.

E), Rajshahi (Lat.: 24 Deg. 22Mts.N; Long.: 88 Deg. 42Mts. E), Khulna (Lat.: 22 Deg. 47 Mts. N; Long.: 89 Deg. 32 Mts. E), Barisal (Lat.: 22Deg. 45 Mts. N; Long.: 90 Deg. 20 Mts. E), Sylhet (Lat.: 24 Deg. 54 Mts. N; Long.: 91 Deg. 53 Mts. E), Chittagong (Lat. 22 Deg. 16 Mts. N; Long.: 91 Deg. 49 Mts. E) and Rangpur (Lat.: 25 Deg. 44 Mts. N; Long.: 89 Deg. 14 Mts. E).

Fig. 1. Location of meteorology observation of BMD

The data were subjected to a visual assessment and the suspected data were deleted and marked as blank. These suspected data points and missing entries were filled up by cubic spline interpolation technique.

Consider the climate variable x, which could represent monthly, seasonal, annual or even decadal-mean temperature at a prescribed latitude, longitude, and height above the earth's surface. Let X be the climatological mean value of x. the departure of x from its (seasonally varying) climatological mean value, namely

$$x' = x - X \tag{1}$$

is referred to as the anomaly in *x*. The variance of *x* about the climatological mean is

$$\overline{x'^2} = \overline{(x - X)'^2} \tag{2}$$

where $\overline{(\ )}$ denotes a time mean over the reference period upon which the climatology is based on variance. It's a positive definite quantity with units of the square of the variable under examination which is a measure of the amplitude of the variability (or dispersion) of *x* about its climatological–mean value. The standard deviation or root mean squared (r.m.s) amplitude of the variations in *x* about the time mean

$$\sigma(x) = \sqrt{x'^2} = \sqrt{(x - X)^2} \tag{3}$$

is widely used as a measure of the dispersion. Note that variance and standard deviation do not carry algebraic signs. The standardized anomaly

$$x^* = \frac{x'}{\sigma(x)} \tag{4}$$

is a dimensionless measure of the amplitude of the departure from the mean. A standardized anomaly x^* with a value of 1.0 or -1.0 can be considered typical in terms of r.m.s amplitude.

Now let us consider the relationship between two time series *x(t)* and *y(t)*, which might represent a series of values of the same climate variable at two different geographical locations or might represent two different variables at the location. It is assumed that *x(t)* and *y(t)* span a common period of record. The dimensionless statistic

$$r \equiv \overline{x^* y^*} \equiv \frac{\overline{x'y'}}{\sigma(x)\sigma(y)} \tag{5}$$

called the correlation coefficient between *x* and *y*, is a measure of the degree to which *x* and *y* are the linearly related (i.e., that one is simply a linear multiple of the other). The value of *r* is such that $-1 \leq r \leq +1$. The + and – signs are used for positive linear correlations and negative linear correlations respectively. On the other hand, the P-value is the probability that we would have found the current result if the correlation coefficient were in fact zero (null hypothesis). If this probability is lower than the conventional 5% ($P<0.05$) the correlation coefficient is called statistically significant.

Result and Discussion

Spatial Analysis

Yearly observation of average maximum temperature and total rainfall in winter season during 1979-2012 over seven divisional stations of Bangladesh is follows:

Table 1. Average of mean maximum temperature and average rainfall over seven divisional stations in winter season.

Station	Average of mean maximum temperature in ºC	Average rainfall in mm
Dhaka	27.51	18.45
Rajshahi	26.74	11.11
Khulna	27.63	22.30
Barisal	27.65	21.69
Sylhet	27.29	20.25
Chittagong	28.04	23.80
Rangpur	25.69	9.35

Dhaka

Fig. 2 shows total rainfall and the average maximum temperature with trend line in winter season over Dhaka. Data within last 33 years period (1979-1912) from Dhaka station of BMD is used here. During these years, total rainfall and the average maximum temperature fluctuate in each year that means not steady. In some seasons, they are positively correlated and in some seasons, they are negatively correlated that means rainfall increase with the increase temperature or rainfall decrease with the increase of temperature.

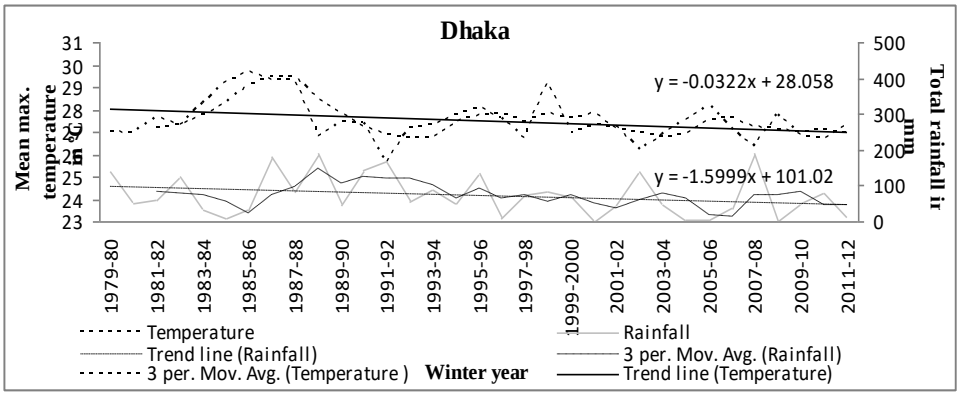


Fig. 2. Mean maximum temperature and total rainfall (with linear trend line, 3 years moving average) in winter season over Dhaka.

The trend line of total rainfall shown in Fig.2 shows that total rainfall has decreased with a rate 159.9 mm per 100 years. The trend line of average maximum temperature shown in Fig. 2 shows that average maximum temperature has also decreased with a rate of 3.22ºC per 100 years. Total rainfall was high in 2007-08 winter seasons (190mm) and minimum in 2000-01 season (1mm) and the average was 18.45 mm. But in other years, the average rainfall fluctuates randomly. The average maximum temperature also fluctuates randomly in winter from 1979 to 2012. This figure also shows that the average maximum temperature was highest (29.6ºC) in 1985-86 and it was minimum (25.6ºC) in 1991-92 and the average was 27.51ºC.

Rajshahi

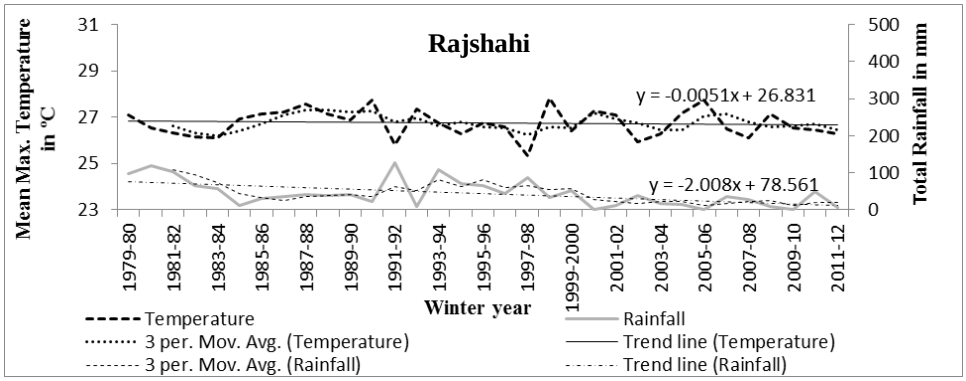


Fig. 3. Mean maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Rajshahi.

Scenario of the total rainfall and the average maximum temperature in the winter season over Rajshahi are shown in Fig. 3. Data within last 33 years period (1979-1912) from the Rajshahi station of BMD is used here. During these years, the average rainfall was 11.11 mm and mean of average maximum temperature was 26.74ºC. The figure shows that the total rainfall was maximum in 1991-92 winter season (126mm) and that was minimum (0mm) in 2005-06 and average was 11.11 mm. The trend line of the total rainfall shown in Fig. 3 shows that the total rainfall has decreased with a rate of 200.8mm per 100 years and mean max. temperature also decreased with a rate of 0.5ºC per 100 years.

Khulna

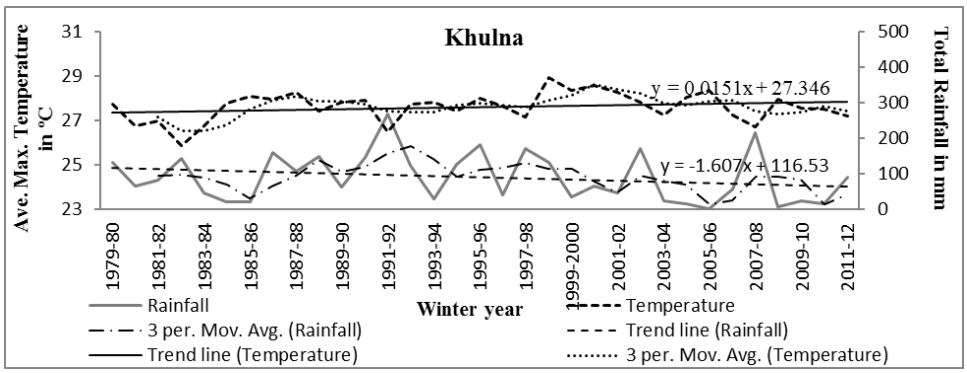


Fig. 4. Average maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Khulna.

Fig. 4 shows the total rainfall and the average maximum temperature fluctuation in winter season from 1979-2012 over Khulna. Here, the mean value of average maximum temperature was 27.63ºC and the average rainfall was 22.3 mm. Maximum value of average maximum temperature was 28.9ºC and the minimum was 25.8ºC. On the other hand, maximum value of total rainfall was 267mm and the minimum was 0 mm. From the trend lines shown in Fig. 4 it

has been seen that rainfall has decreased with a rate of 160.7mm per 100 years but the average maximum temperature has slightly increased with a rate of 1.51ºC per 100 years in winter seasons that means they are negatively correlated.

Barisal

The average maximum temperature and the total rainfall in winter season over Barisal are shown in Fig. 5. Data within last 33 years period (1979-1912) from the Barisal station of BMD is used here. We observe the same trend line shown in Fig. 5 like Khulna, i.e., rainfall has decreased with a rate of 150.6mm per 100 years, but the average maximum temperature has increased to a rate of 2.33ºC per 100 years that means they are negatively correlated. During this season, the mean value of average maximum temperature and the average rainfall were 27.65ºC and 21.69 mm respectively and the maximum value of average maximum temperature was 28.97ºC and the minimum was 26.03ºC. On the other hand, the maximum value of total rainfall was 282 mm and the minimum was 0 mm during these periods.

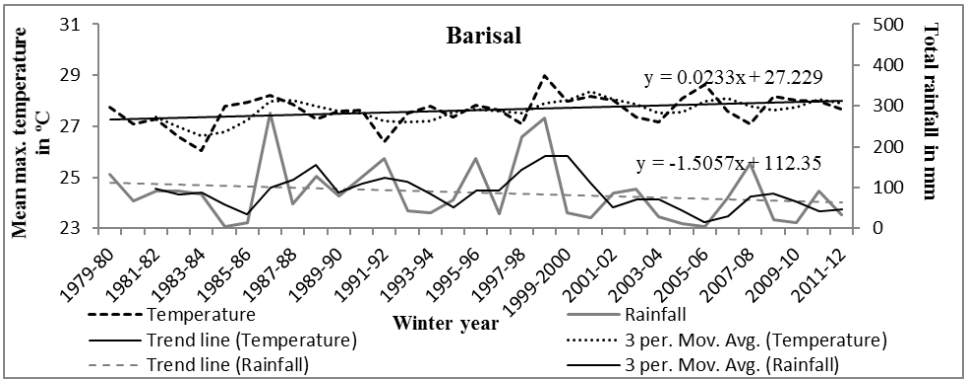


Fig. 5. Mean maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Barisal.

Sylhet

The variation of average maximum temperature and the total rainfall with trend line in winter season over Sylhet are shown in Fig. 6. Data within last 33 years period (1979-1912) from the Sylhet station of BMD is used here. The trend line shown in Fig. 6 shows that the total rainfall and the average maximum temperature were negatively correlated in 1987-1990, 2006-09. But in the other years, they were positively correlated. The average maximum temperature increased (with a rate of 4.58ºC per 100 years) and the total rainfall decreased (with a rate of 99.7mm per 100 years) that means they are negative correlated. Average maximum temperature trend line shows temperature has increased from 1979-2012 and total rainfall has decreased in the same time. In winter season, average rainfall was 20.25 mm and average of mean maximum temperature was 27.3ºC.

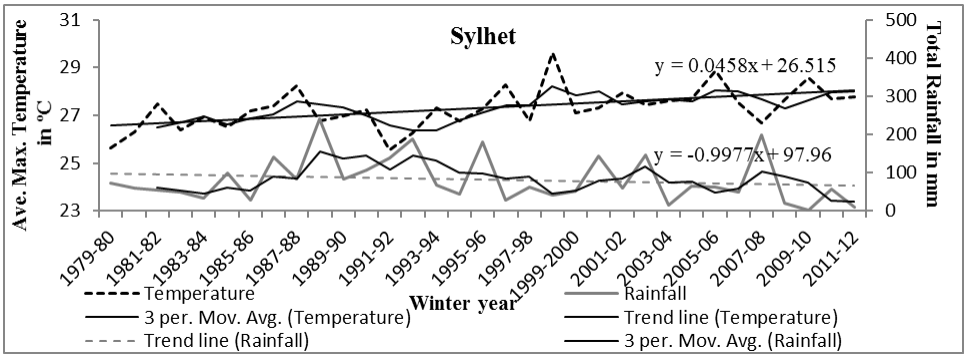


Fig. 6. Average maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Sylhet.

Chittagong

The average maximum temperature and the total rainfall in winter season for the Chittagong are shown in Fig. 7. Data within last 33 years period (1979-1912) from the Chittagong station of BMD is used here. The trend line of total rainfall has slightly decreased (with a rate of 87.77mm per 100 years) and the trend line of the average maximum temperature has increased (with a rate of 4.59ºC per 100 years) that means they are negative correlated. In Chittagong, average rainfall was 23.80 mm and average of mean maximum temperature was 28.04ºC. The highest amount (429mm) in winter season of 1995-96 and mean maximum temperature was 30.1ºC (1998-99).

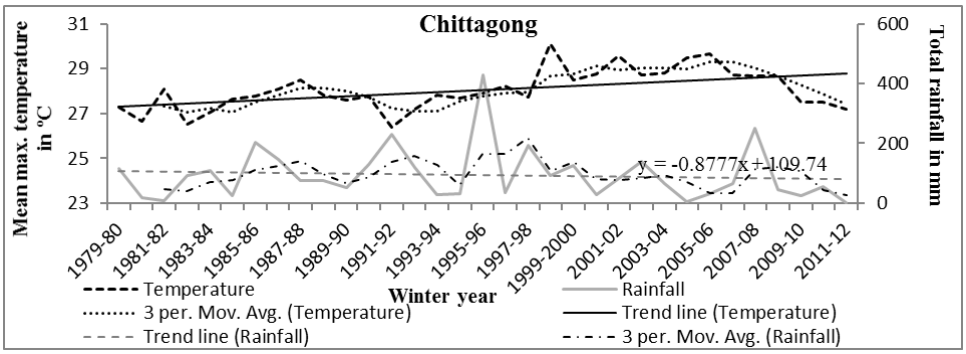


Fig. 7. Average maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Chittagong.

Rangpur

Fig. 8 shows average maximum temperature and total rainfall with trend line in winter season over Rangpur. The trend line of the average maximum temperature shown in Fig. 8 was almost same from 1970 to 2012 that means the change was too small (with a rate of 0.38ºC per 100 years). And the trend line of total rainfall shows that total rainfall has decreased with a rate of 99.3mm per 100 years in winter season that means two sets of data are negative correlated. By analyzing data, it has been seen that the mean value of

average maximum temperature was 25.7ºC and average of total rainfall was 9.35 mm in winter season. The maximum amount (125mm) of rain fell in winter year 1995-96. We also observe that this area was the lowest rainfall region and also the coolest area among the seven areas in winter season.

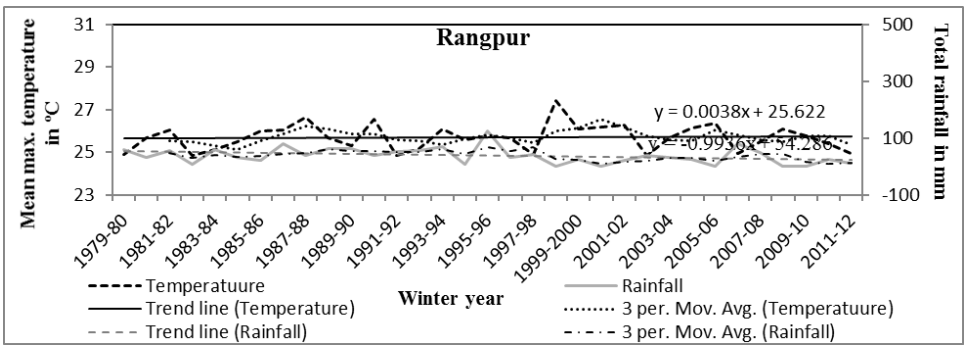
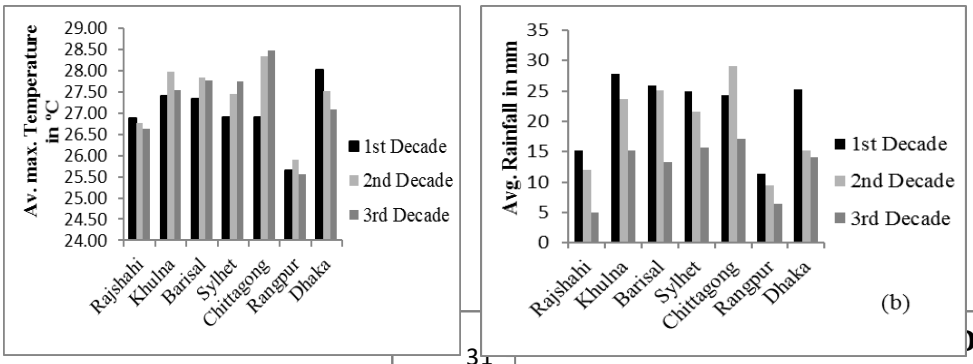


Fig. 8. Average maximum temperature and total rainfall (with trend line and 3 years moving average) in winter season over Rangpur.

Decadal Comparison

In the last three decades, i.e., 1982-83 to 1991-92, 1992-93 to 2001-02 and 2002-03 to 2011-12, change of average maximum temperature is shown in the Fig. 9 (a) over seven divisional station areas. From the bar chart, it has been seen that the average maximum temperature decreased linearly in Rajshahi (26.87ºC, 26.77ºC and 26.62ºC, respectively) and Dhaka (28.03ºC, 27.52 ºC and 27.08 ºC, respectively), but increased linearly in Sylhet (26.92ºC, 27.46ºC and 27.75ºC, respectively) and Chittagong (26.92ºC, 28.4ºC and 28.49ºC, respectively) in the last three decades. Changes were same in Khulna, Barisal and Rangpur i.e., in the second decade average maximum temperature increased and then decreased in the third decade. Fig. 9(b) shows an interesting result, that is, the average rainfall decreased in all areas except the Chittagong in the past three decades.



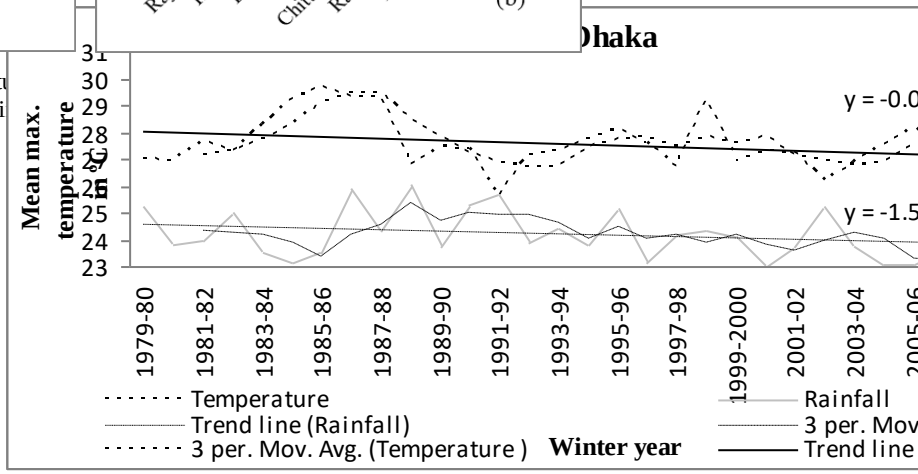


Fig. 9. (a) Average maximum temperatu
station areas. (b) Average rainfall i
station areas.

Correlation

From the Table 2, it has been seen that in Chittagong the average maximum temperature and average rainfall are maximum (28.07 ºC, 23.80 mm). On the other hand, the average maximum temperature and average rainfall are minimum (25.69ºC, 9.35 mm) in Rangpur. If we consider inter seasonal data, then it shows a positive correlation between the monthly average maximum temperature and monthly average rainfall in all areas except Rangpur where r-value is negative that means rainfall decreases with the increases of temperature and vise-versa. By analyzing p-value it has been seen that correlation is significant in all areas except Sylhet and Khulna.

Table 2. Average temperature and average rainfall, correlation coefficient (r) between monthly average maximum temperature and average rainfall and P-value of winter season from 1979-80 to 2011-12.

	Avg. Max.Temperature (T) in ºC				T_{mean}	Avg. Rainfall (R) in mm						
Station	Nov	Dec	Jan	Feb		Nov	Dec	Jan	Feb	R_{mean}	r	P-value
Chittagong	30.16	27.33	26.16	28.61	28.07	55.52	12.78	5.88	21.03			
Dhaka	29.11	26.35	25.44	29.15	27.51	32.27	12.91	7.39	21.24	18.45	0.905	0.047
Barisal	29.85	26.70	25.47	28.58	27.65	45.09	7.00	10.58	24.09	21.69	0.913	0.044
Khulna	29.96	26.50	25.31	28.76	27.63	34.70	6.85	14.00	33.67	22.31	0.883	0.058
Rajshahi	29.36	25.73	24.01	27.94	26.76	12.30	10.06	8.79	13.27	11.11	0.903	0.049
Rangpur	28.44	24.98	23.02	26.31	25.69	7.97	8.88	8.97	11.58	9.35	-0.100	0.045
Sylhet	29.56	26.68	25.38	27.76	27.35	27.70	12.97	6.42	33.91	20.25	0.802	0.099

Table 3 shows Standard Deviation (SD) of average maximum temperature and total rainfall, Correlation coefficient (r) between them and P-value. From this table it has been seen that the value of correlation coefficient is negative in seven districts that means rainfall decreases with the increases of temperature or rainfall increases with the decreases of temperature which is not a common scenario. Because it is common that rainfall increases with the increases of temperature or vise-versa. The correlation is significant in Khulna, Rajshahi and Sylhet because the p-value is ≥ 0.05.

Table 3. Standard Deviation (SD) of average maximum temperature and total rainfall, correlation coefficient (r) between them and P-value from 1979-80 to 2011-12 (winter season).

Station	Parameter	SD	r	P-value
Barisal	Avg. max. Temp. (ºC)	0.60	-0.063	0.365
	Rainfall (mm)	73.16		
Dhaka	Avg. max. Temp. (ºC)	0.962	-0.278	0.059
	Rainfall (mm)	58.43		
Chittagong	Avg. max. Temp. (ºC)	0.90	-0.118	0.256
	Rainfall (mm)	88.83		
Khulna	Avg. max. Temp. (ºC)	0.65	-0.325	0.032
	Rainfall (mm)	68.3		
Rajshahi	Avg. max. Temp. (ºC)	0.61	-0.483	0.002
	Rainfall (mm)	35.83		
Rangpur	Avg. max. Temp. (ºC)	0.61	-0.275	0.061
	Rainfall (mm)	28.63		
Sylhet	Avg. max. Temp. (ºC)	0.85	-0.389	0.013
	Rainfall (mm)	59.36		

Conclusion

The analysis gives the result that overall rainfall has decreased, but temperature has increased over seven divisional station areas in Bangladesh within 33 years. It has been found that rainfall is least in Rangpur and maximum in Chittagong and temperature is high also in Rangpur and low in Chittagong. Finally, we conclude that the work describes the scenario of the rainfall and temperature variability of Bangladesh in the last three decades. This will be helpful to give a model about temperature and rainfall variations of Bangladesh.

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