ANALYZING CHANGES OF TEMPERATURE OVER BANGLADESH DUE TO GLOBAL WARMING USING HISTORIC DATA

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Abstract. *Long term changes of near surface air temperature over Bangladesh have been studied using the available historical data collected by the Bangladesh Meteorological Department (BMD). Maximum and minimum daily temperature data of last sixty years (1948-2007) collected from 34 stations of BMD located all over the Bangladesh have been used in this study. It has been found that daily maximum temperature shows a positive trend of increase at a rate of 0.621 ± 0.491 ^{0}C per 100 year. The maximum increase occurred during November at a rate of 2.7 ^{0}C per 100 year. However, daily minimum temperature shows more significant trend of increase at a rate of 1.536 ± 0.461 ^{0}C per 100 year. The maximum increase occurred during February at a rate of 3.4 ^{0}C per 100 year. Daily mean temperature shows positive trend of increase at a rate of 1.026 ± 0.403 ^{0}C per 100 year. It has been clearly found that temperature of winter season (December to February) has been raised much higher rate than that of summer season (June to August). This study also reveals that temperature has been increase predominantly over the last 30 years (1978-2007) than last 60 years (1948-2007).*

INTRODUCTION

Now it is evident from scientific study that our mother climate has undergone an abnormal human induced change. Various climatic parameters such as rainfall, temperature, humidity, sunshine hour etc. of various regions of the world have shown significant trends. Global warming is mainly caused by the increase of green house gases of the atmosphere. Green house gases such as carbon dioxide, methane and nitrous oxide etc. has been increased significantly over the last century. Such increased amount of green house gases act as a blanked to store infrared radiation of solar energy. Stored energy is radiated as heat and make warmer of the cooler parts of the atmosphere as well as land surface. 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 is also noted by IPCC (2007) 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 on trend of climate change in climatic parameters over Bangladesh. Chowdhury and Debsharma (1992) and Mia (2003) pointed out that temperature has been changed by using historical data of some selected meteorological station. Parathasarathy et al. (1987) and Divya and Mehritra (1995) reported mean annual temperature of Bangladesh has increased during the period of 1895-1980 at 0.31^{0}C over the past two decades. Karmakar and Shrestha (2000) using the 1961-1990 data for Bangladesh projected that annual mean maximum temperature will increase to 0.4 ^{0}C and 0.73 ^{0}C by the year of 2050 and 2100 respectively. In this context, it is essential to quantify changes of temperature in recent years based on the historical data. This paper

presented a study conducted on the long term changes of near surface air temperature of Bangladesh using data from historic period up to recent year.

DATA SETS AND METHODS

Maximum and minimum daily temperature data of last sixty years (1948-2007) has been collected from 34 stations of BMD located all over the Bangladesh have been used in this study. Figure 1 shows location of the BMD stations over Bangladesh. These stations are mainly located at the city center of an urban district. Trend analysis has been conducted on monthly average data for all the stations. Monthly average value for both last 60 years and last 30 years (1978-2007) has been studied.

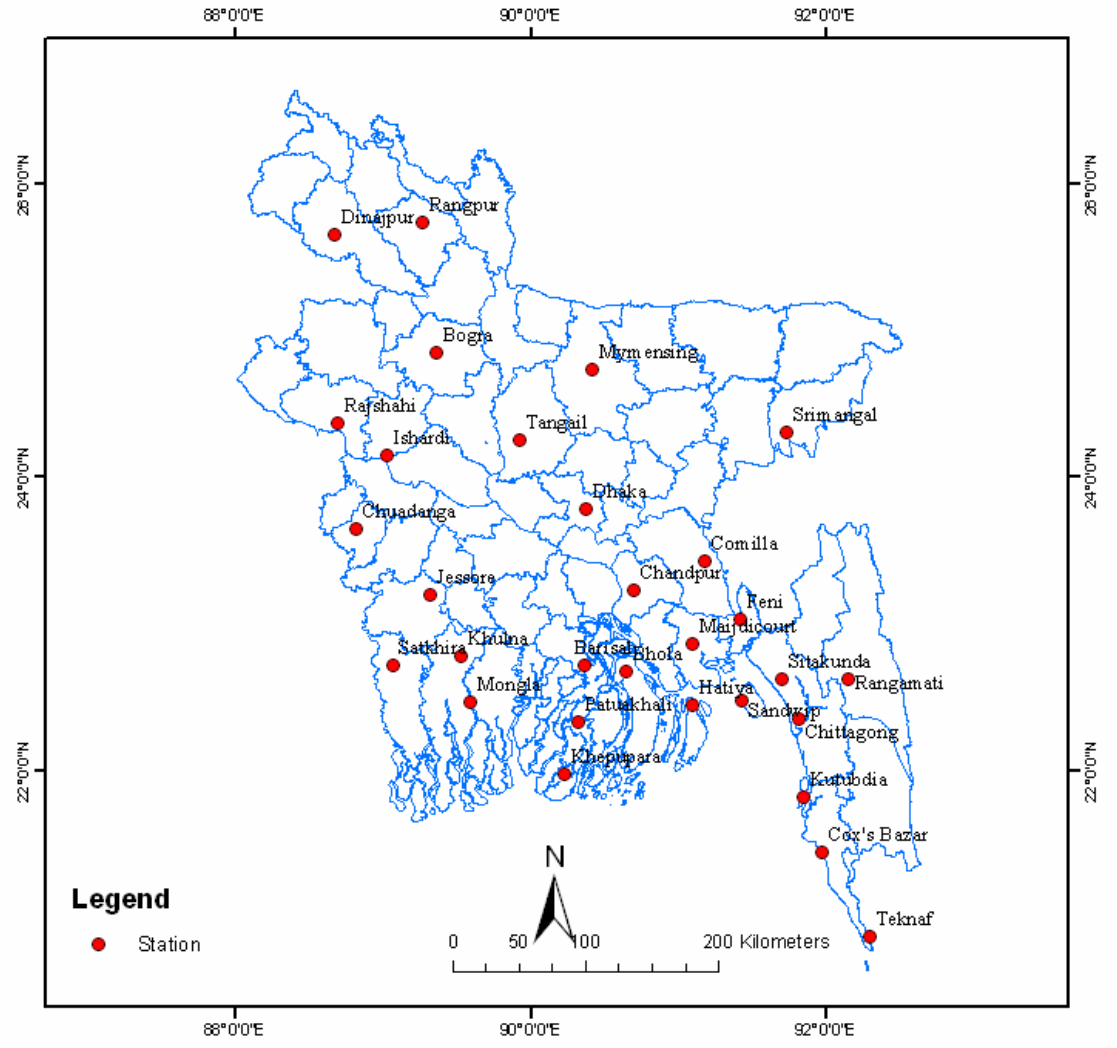

Figure 1. Thirty four ground base measuring stations of Bangladesh Meteorological Department (BMD)

Spatial distribution map has been developed using inverse distance weighted interpolation techniques. Interpolated values, z for a point (x,y) can be found number of points (x_1,y_1) , (x_2,y_2) ….(x_n,y_n) having values of $z_1,z_2…z_n$ respectively by using the following formula.

$$Z = \frac{\sum w_i z_i}{\sum w_i}$$

Where, weight of w_i can be calculated using the distance between the point (x,y) and (x_i,y_i) within a radius of D unit from the point of (x,y) as follows.

$$w_i = 1 - \left(\frac{d}{D}\right)^2$$

Trend of a time series data can be found by using the following formula.

$$b = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

Where, x_i is the independent variable, $\bar{x}$ is the average of the independent variable, y_i is the dependable variable and $\bar{y}$ is the average of dependable variable. One way of testing significance of trends of temperature is calculating the Coefficient of determination, R^2 of the trend. Values of R^2 vary between 0 and 1. It can be found by using the following formula.

$$R^2 = \frac{\left[\sum (x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}$$

Highest correlation of the dataset can be found at 1 and it gradually reduces towards zero. Value less than 0.5 has been considered as less significant correlation.

RESULTS AND DISCUSSION

Daily Maximum, Minimum and Mean Temperature

The maximum, minimum and mean temperature of the country has been determined using historic available data from the all the meteorological stations of Bangladesh. Figure 2 shows month-wise distribution of the mean of maximum, minimum and mean temperature. Data within last 60 years period (1948-2007) from all the 34 stations of BMD is used to determine mean monthly temperature over Bangladesh. Daily maximum data has shown its peak at 33.5 ^{0}C during April. However, Daily minimum data has shown the highest rise of temperature of 25.7 ^{0}C during August. Moreover, daily mean temperature has shown the highest rise of temperature of 28.9 ^{0}C during May.

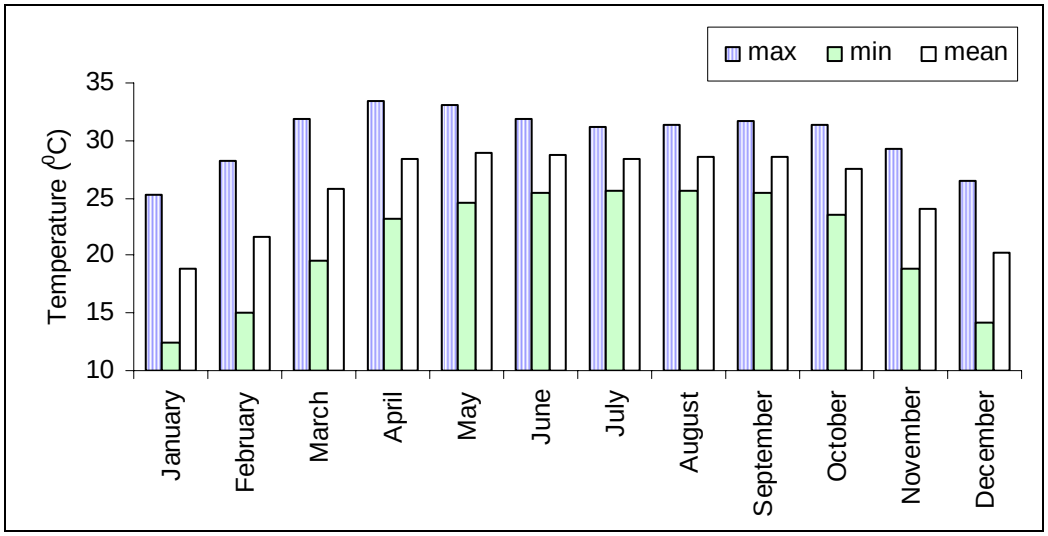

Figure 2. Monthly average daily maximum, minimum and mean temperature (^{0}C) during the last sixty years period (1948-2007).

Trends of daily maximum, minimum and mean temperature

In this study, average trends of daily temperature data for all the 34 stations of BMD have been analyzed during the period 1948-2007. Daily maximum temperature data have shown an increasing trend of 0.62 ^{0}C per 100 years (Figure 3(a)). On the other hand, daily minimum temperature data have exhibited more significant trends of 1.54 ^{0}C per 100 years and shown in Figure 3(b). Also, mean daily temperature have increased with a rate of 1.03 ^{0}C per 100 years. It has also evident from these plots that the rate of change has more accelerated in the last 30 years. Therefore, data of daily temperature of last 30 years (1978-2007) have been also studied for trend analysis. Daily maximum, minimum and mean temperature have shown positive increase with a rate of 2.05 ^{0}C, 1.2 ^{0}C and 1.64 ^{0}C per 100 years and shown in Figure 3(d), 3(e) and 3(f) respectively. It has clearly found that maximum temperature has been increased dramatically over the last 30 years period.

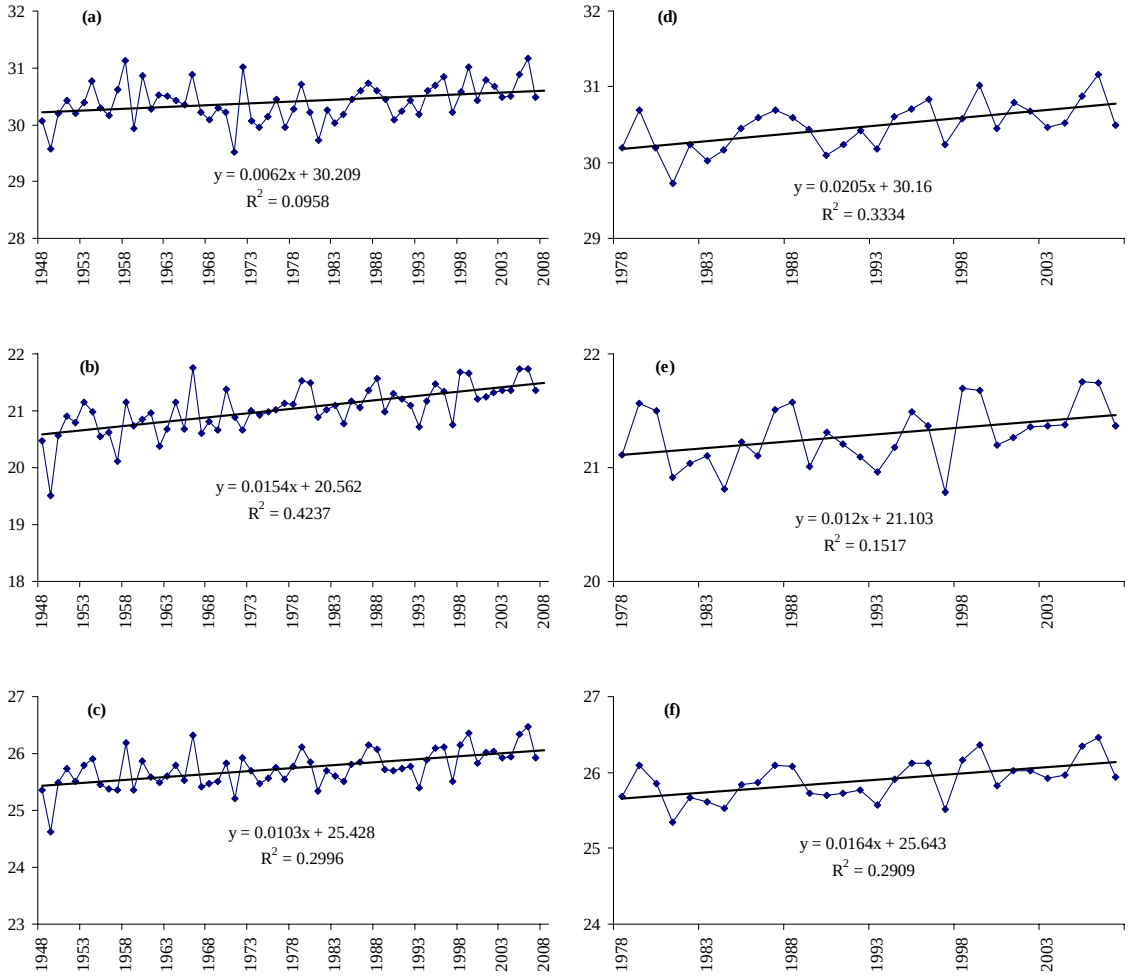

Figure 3. Trends of daily (a) maximum, (b) minimum and (c) mean temperature of all the stations using the period of last 60 years data (1948-2007). Trends of daily (d) maximum, (e) minimum and (f) mean temperature of all the stations using the period of last 30 years data (1978-2007)

Station-wise trends of daily maximum, minimum and mean temperature

Trends of daily maximum, minimum and mean temperature have been analyzed for each station of BMD. A summary of the trend analysis is presented in Table 1. In this table, station number, latitude, longitude and altitude also have shown in this table. Available years of data and beginning year of each data set are also presented for each station. Trends of daily maximum temperature vary from -2.59 to 5.81 ^{0}C per 100 year. Maximum value of trends of daily maximum temperature has found at Satkhira of 5.81^{0}C per 100 year. On the other hand, trends of daily minimum temperature vary from -2.34 to 4.04 ^{0}C per 100 year. Station Bogra exhibits the highest value of

maximum trends among all the stations with a value of 4.04 ^{0}C per 100 year. Variation of mean temperature is slightly less than the variation of trends of maximum or minimum temperature. Trends of mean temperature vary from -1.05 to 3.27 ^{0}C per 100 year. At Kutubdia, trend of mean temperature is the highest among all the stations with a value of 3.27 ^{0}C per 100 year. Coefficient of determination, R^2 of the trend analysis of daily maximum, minimum and mean temperature varies from 0 to 0.67, from 0 to .59 and from 0 to 0.66 respectively. R^2 value less than 0.5 has found in many stations which represents poor statistical significance of the trend. It is found that trends are found more than 2 ^{0}C per 100 year for stations with R^2 value more than 0.5.

Table 1. Trends (^{0}C per 100 year) and R^2 of daily maximum and minimum temperature changes for all the stations.

Station ID	Station Name	Lat.	Lon.	Alt.	Start Yr.	No. Yrs	Maximum		Minimum		Mean	
							Trend	R^2	Trend	R^2	Trend	R^2
11704	Barisal	22.72	90.37	2.1	1949	55	0.77	0.06	-1.63	0.06	-0.48	0.01
11706	Bhola	22.68	90.65	4.3	1966	41	1.7	0.26	2.06	0.36	2.07	0.43
10408	Bogra	24.85	89.37	17.9	1948	56	1.17	0.03	4.04	0.15	2.56	0.10
11316	Chandpur	23.23	90.7	4.9	1964	40	1.63	0.09	1.61	0.06	1.62	0.08
11921	Chittagong	22.35	91.82	33.2	1949	59	2.24	0.53	0.9	0.15	1.58	0.41
41926	Chuadanga	23.65	88.82	11.6	1989	19	-0.38	0.00	2.17	0.14	0.9	0.03
11313	Coilla	23.43	91.18	9	1948	56	0.49	0.02	-0.09	0.00	0.22	0.01
11927	Cox's Bazar	21.45	91.97	2.1	1948	60	2.95	0.52	2.2	0.59	2.59	0.66
11111	Dhaka	23.78	90.38	6.5	1953	54	1.19	0.12	2.25	0.40	1.72	0.33
10120	Dinajpur	25.65	88.68	37.6	1948	52	-2.13	0.25	1.51	0.09	-0.27	0.01
11505	Faridpur	23.93	89.85	8.1	1948	60	2.75	0.44	--	--	--	--
11805	Feni	23.03	91.42	6.4	1973	35	1.74	0.07	3.31	0.15	2.42	0.11
11814	Hatiya	22.45	91.1	2.4	1966	35	2.61	0.38	-2.02	0.06	0.31	0.01
10910	Ishardi	24.15	89.03	12.9	1961	46	0.32	0.01	0.37	0.00	0.26	0.00
11407	Jessore	23.2	89.33	6	1948	59	1.47	0.20	1.13	0.17	1.39	0.34
12110	Khepupara	21.98	90.23	1.8	1975	33	2.66	0.36	0.37	0.00	1.56	0.13
11604	Khulna	22.78	89.53	2.1	1948	57	0.37	0.01	-0.53	0.01	-0.16	0.00
11925	Kutubdia	21.82	91.85	2.7	1985	23	4.16	0.50	2.48	0.13	3.27	0.41
11513	Madaripur	23.17	90.18	7	1977	30	0.47	0.01	--	--	--	--
11809	Maijdicourt	22.87	91.1	4.9	1951	54	1.93	0.32	2.04	0.27	2.03	0.36
41958	Mongla	22.47	89.6	1.8	1989	19	4.3	0.54	1.04	0.09	2.7	0.41
10609	Myensing	24.73	90.42	18	1948	58	-0.86	0.11	0.86	0.06	0.01	0.00
12103	Patuakhali	22.33	90.33	1.5	1973	33	3.28	0.45	2.6	0.14	2.17	0.16
10320	Rajshahi	24.37	88.7	19.5	1964	43	1.1	0.05	0.27	0.00	0.64	0.02
12007	Rangaati	22.63	92.15	68.9	1957	51	-0.39	0.01	-1.78	0.09	-1.05	0.09
10208	Rangpur	25.73	89.27	32.6	1957	45	-2.59	0.19	2.81	0.13	0.16	0.00
11916	Sandwip	22.48	91.43	2	1966	39	0.74	0.02	-1.82	0.10	-0.53	0.02
11610	Satkhira	22.72	89.08	4	1948	58	0.65	0.04	1.07	0.09	0.88	0.11
41858	Sayedpur	25.75	88.92	39.6	1991	17	2.66	0.12	--	--	--	--
11912	Sitakunda	22.63	91.7	7.3	1977	31	5.81	0.67	-2.12	0.16	1.85	0.21
10724	Sriangal	24.3	91.73	22	1948	58	0.3	0.01	2.37	0.26	1.39	0.19
10705	Sylhet	24.9	91.88	33.5	1956	51	--	--	0.57	0.01	--	--
41909	Tangail	24.25	89.93	10.2	1987	21	1.74	0.07	-2.34	0.07	-0.31	0.00
11929	Teknaf	20.87	92.3	5	1977	31	2.42	0.33	2.36	0.28	2.25	0.33

Spatial Distribution of temperature and its trends

Using inverse distance surface interpolation technique, spatial distribution maps of average value of daily maximum, minimum and mean temperature and trends over Bangladesh have been developed. Figure 4(a) shows distribution of average of daily maximum temperature over Bangladesh. West and south-west parts show higher average value of daily maximum temperature than that of other parts of the country. Spatial distribution of the trends of daily maximum temperature has been shown in Figure 4(b). Southern parts of the country show higher trends of daily maximum temperature than that of other parts of the country.

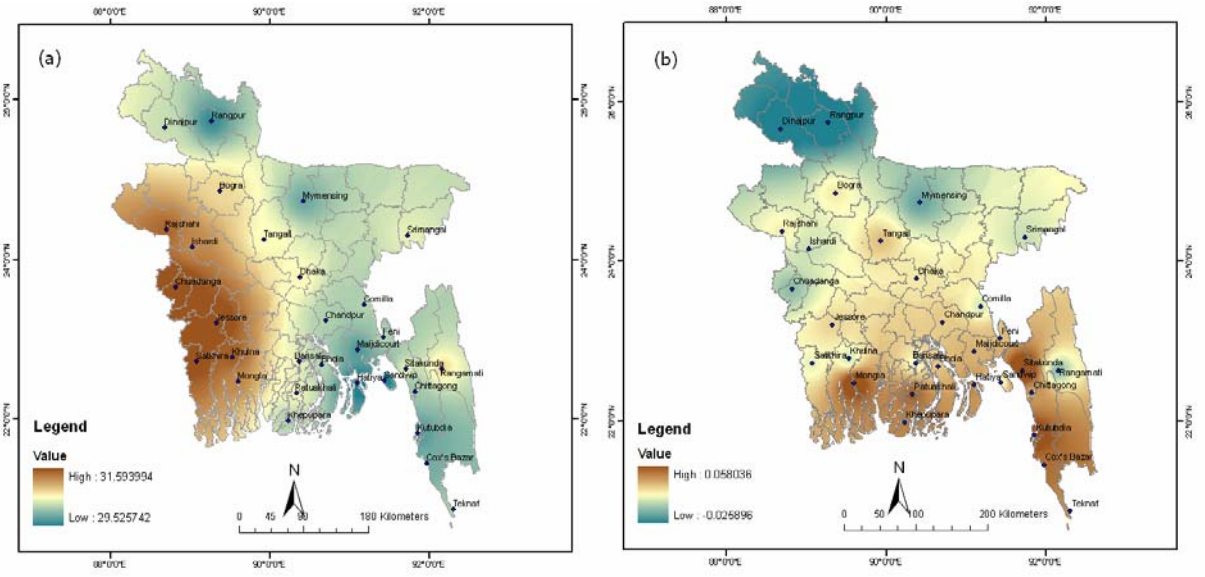

Figure 4. (a) Average of daily maximum temperature (^{0}C) and (b) trends (^{0}C per year) over Bangladesh.

Spatial distribution map of the average value of daily minimum temperature has shown in Figure 5(a). Southern part has found warmer than the northern parts of the country. Interpolation surface of the trends of daily minimum temperature over Bangladesh has been developed and shown in Figure 5(b). Northern and north-western parts of the country have higher rate of increase of daily minimum temperature than other parts of the country. During winter season, cold loving Rabi crops are mainly planted in the northern parts of the county. It is evident that Rabi crops during winter will be highly effected because of global warming.

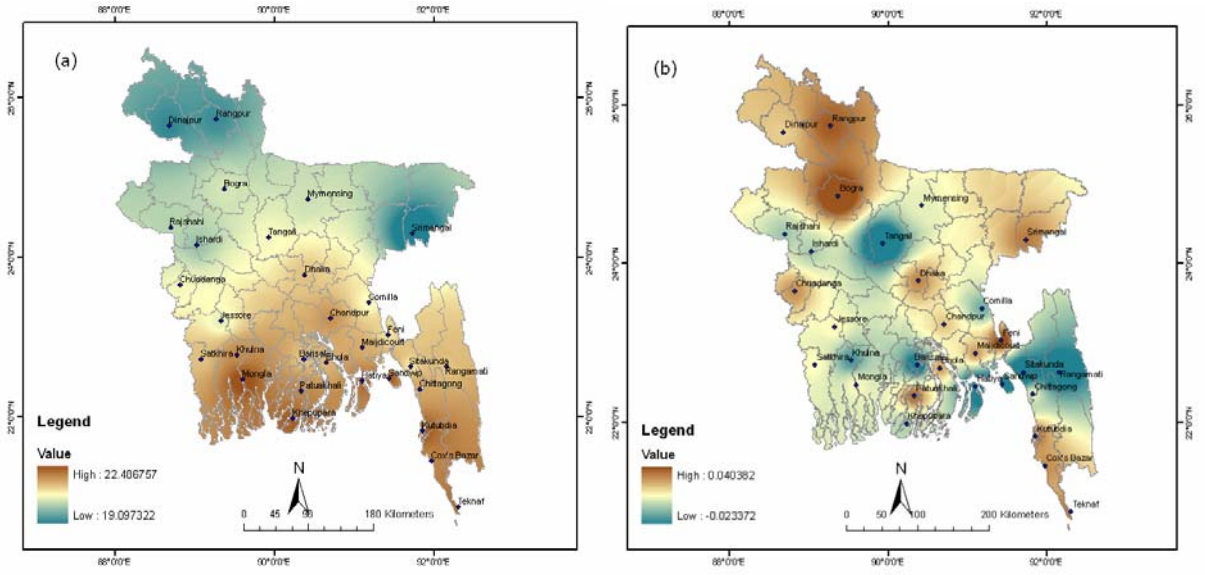

Figure 5. Daily minimum temperature (^{0}C) and its trends (^{0}C per year) over Bangladesh.

Interpolation surface has been created for average of mean daily temperature using all the station data and shown in Figure 6(a). Mean daily temperature map shows higher values in the southern and eastern parts of the country than other parts of the country. Trends of mean daily temperature have been shown in Figure 6(b) as a surface map. It is clearly found that mean temperature has increased more in the southern and south-western parts of the county.

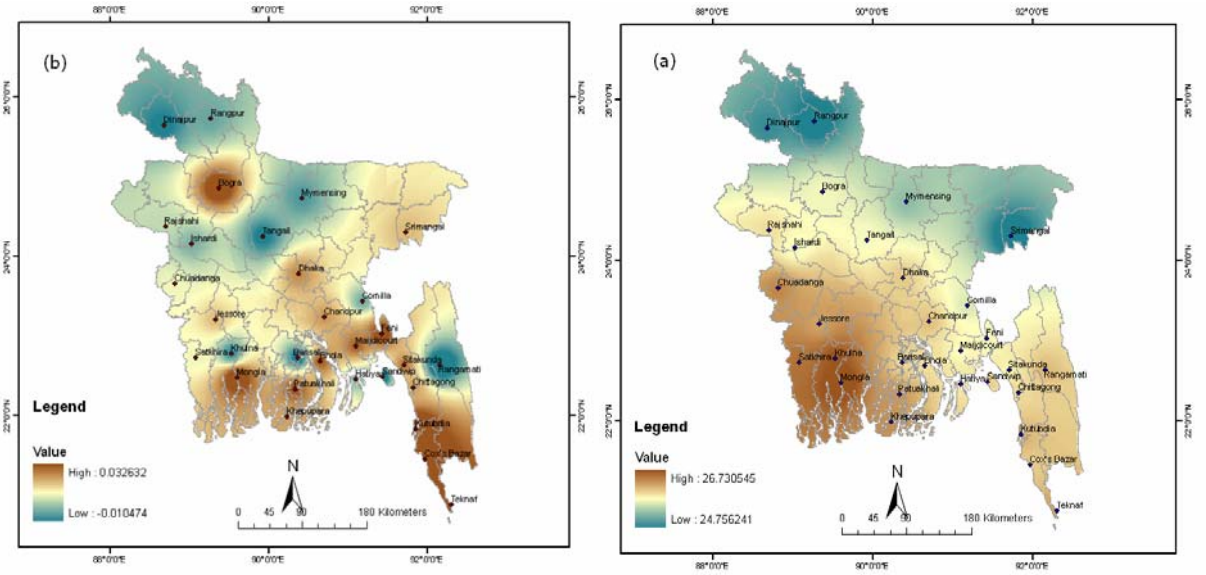

Figure 6. Daily mean temperature (^{0}C) and its trend (^{0}C per year) over Bangladesh.

Monthly trends of daily maximum, minimum and mean temperature

Monthly average rate of change of temperature during last 60 years (1948-2007) has been studied. Table 2 shows a summary of trends ^{0}C per 100 year of daily maximum, minimum and mean temperature over Bangladesh for each month. Coefficient of determination, R^2 of the trends are also presented in Table 2. Daily maximum data exhibits trends from -1.4 ^{0}C per 100 year during April to 2.7 ^{0}C per 100 year during November. On the other hand, the maximum trend of daily minimum temperature is 3.4 ^{0}C per 100 year in February. The minimum trend of daily minimum temperature is 0.3 ^{0}C per 100 year in September. T However, the maximum and minimum values of trends of daily mean temperature have found as is 2.7 ^{0}C per 100 year in November and is -0.8 ^{0}C per 100 year in April respectively. It can be clearly found that daily minimum temperature has been increased significantly during the winter season (October to February) over the last 60 years.

Trends of daily maximum, minimum and mean temperature over the last 30 years (1978-2007) have also determined and presented in Table 2. The maximum trend of daily maximum temperature is found as -2.3 0C per 100 year in January and minimum trend is found as 4.2 ^{0}C per 100 year in February. Similar results can be found for daily minimum and mean temperature. The highest value of trends of daily minimum and mean temperature are found as 4.1 and 4.2 ^{0}C per 100 year in February respectively. During the last 30 years, trends of daily maximum temperature exhibit higher value in summer season (June-September) with trends of more than 3 ^{0}C per 100 year.

Table 2. Monthly average trends (^{0}C per 100 yr.) and R^2 value of daily maximum, minimum and mean temperature during last 60 years period (1948-2007) and last 30 years period (1978-2007).

Month	Average of 60 years period (1948-2007)						Average of 30 years period (1978-2007)					
	Max.	R^2	Min.	R^2	Mean	R^2	Max.	R^2	Min.	R^2	Mean	R^2
January	**-1.4**	0.10	1.0	0.05	**-0.3**	0.01	-2.3	0.05	**-1.9**	0.05	**-2.0**	0.06
February	0.0	0.00	3.4	0.34	1.6	0.093	4.2	0.11	4.1	0.18	4.2	0.18
March	**-1.2**	0.05	2.2	0.12	0.5	0.01	1.6	0.02	1.9	0.03	1.7	0.03
April	**-1.4**	0.04	1.2	0.06	**-0.8**	0.00	0.4	0.00	1.2	0.01	0.9	0.01
May	0.1	0.00	0.5	0.02	0.3	0.00	2.9	0.07	2.1	0.07	2.5	0.08
June	1.4	0.11	1.0	0.19	1.1	0.14	3.3	0.17	1.0	0.05	2.2	0.14
July	1.2	0.14	0.8	0.16	0.9	0.14	3.1	0.34	1.8	0.29	2.5	0.34
August	1.8	0.32	0.8	0.24	1.2	0.27	3.9	0.42	1.5	0.38	2.7	0.45
September	0.7	0.06	0.3	0.04	0.4	0.04	3.0	0.28	0.9	0.07	1.9	0.22
October	1.8	0.26	0.8	0.05	1.2	0.18	1.5	0.06	1.5	0.05	1.5	0.08
November	2.7	0.41	2.9	0.20	2.7	0.32	0.7	0.02	0.9	0.01	0.8	0.01
December	1.5	0.12	2.7	0.25	2.0	0.23	2.5	0.10	0.8	0.01	1.6	0.05
Average	0.6		1.5		0.9		2.1		1.3		1.7	

Changes of trends of temperature within last 60 years and within last 30 years have been compared. A comparison of the trends of daily maximum, minimum and mean temperature has been presented in Table 3. There has been a significant increase of the values of trends of daily maximum and mean temperature during summer season. On the other hand, over the last 30 years trends of daily minimum and mean temperature have been diminished than that of last 60 years during winter season.

Table 3. Change of trends (^{0}C per 100 yr.) of daily maximum, minimum and mean temperature over the last 30 years (1978-2007) than that of over last 60 years (1948-2007).

	Max.	Min.	Mean.
January	**-0.9**	**-2.9**	**-1.7**
February	4.2	0.7	2.6
March	2.8	**-0.3**	1.2
April	1.8	0.0	1.7
May	2.8	1.6	2.2
June	1.9	0.0	1.1
July	1.9	1.0	1.6
August	2.1	0.7	1.5
September	2.3	0.6	1.5
October	**-0.3**	0.7	0.3
November	**-2.0**	**-2.0**	**-1.9**
December	1.0	**-1.9**	**-0.4**
Average	1.5	**-0.2**	0.8

Impact of Climate Change on Agriculture

In winter season (November-February), the main crops of Bangladesh are Boro (rice), wheat, potato, vegetables. Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in Rabi season. Figure 7 shows the wheat and Boro coverage area of Bangladesh. During the winter and pre-monsoon season (March-May) wheat and Boro mainly grow in the north and central parts of the country. Figure 5 shows that the trend of daily minimum temperature is higher in north and central parts of the country. Therefore, changes of climate will severely decline grown of various winter crops in the north and central parts of the country.

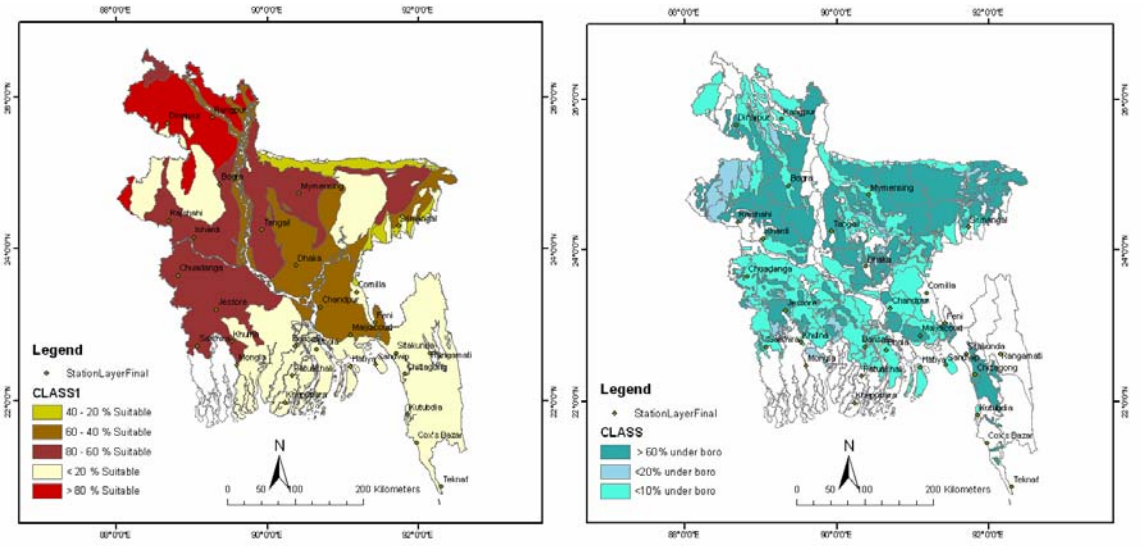

Figure 7. Wheat and Boro coverage area of Bangladesh respectively.

CONCLUSION

Daily maximum, minimum and mean temperature shows positive trends over Bangladesh. Increase of daily maximum temperature is 0.62 ^{0}C, daily minimum temp is 1.54 ^{0}C and daily mean temperature is 1.02 ^{0}C per 100 years. Maximum increase of daily maximum temperature has occurred in November at 2.7 ^{0}C and daily minimum temperature has occurred in February at 3.4 ^{0}C in 100 years. The highest increase of daily maximum temperature has occurred as 5.81 ^{0}C per 100 years at Shitakunda and daily minimum temperature has occurred as 5.04 ^{0}C per 100 years at Bogra. It has clearly found that maximum temperature has been increased dramatically over the last 30 years period. Daily maximum, minimum and mean temperature has shown positive increase with a rate of 2.05 ^{0}C, 1.2 ^{0}C and 1.64 ^{0}C per 100 years respectively during the period of last 30 years (1978-2007). Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in Rabi season.

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