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Research Paper

Climate Change in Bangladesh: A Historical Analysis of Temperature and Rainfall Data

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Abstract

The article provides an assessment of climate change and variability based on analysis of historical data of temperature and rainfall recorded at 34 meteorological stations located at seven regions in Bangladesh for the period of 1976-2008. The trend of variation of yearly average maximum temperature has been found to be increasing at a rate of 0.0186 ^{o}C per year, whereas the rate was 0.0152 ^{o}C per year for yearly average minimum temperature. Analysis of monthly average maximum temperature also showed increasing trend for all months except January and April. The increasing trend was particularly significant for May to September and February. Monthly average minimum temperature data also showed increasing trends for all months except January and November. Analysis of rainfall data showed that for a large majority of stations, the total rainfall showed increasing trend for monsoon and post-monsoon seasons, while decreasing trend was observed for the winter; pre-monsoon rainfall did not show any significant change. These observations are particularly significant in the context of Bangladesh where agriculture is heavily dependent on temperature and rainfall patterns.

Keywords: *Bangladesh, Climate Change, Rainfall, Temperature, Meteorological Stations*

1. Introduction

Climate change is no longer something to happen in future but rather an ongoing phenomenon. It is now unequivocally established that climate change is reality, and the adversities of climate transformations pose of the greatest challenges facing humanity today (IUCN, 2011). The Inter-Governmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer". The Fourth Assessment Report of IPCC (2007) has observed that the 100-year linear trend (1906-2005) of global average surface temperature is 0.74 (0.56 to 0.92) ^{o}C and is larger than the corresponding trend of 0.6 (0.4 to 0.8) ^{o}C (1901-2000). The report also states from 1900 to 2005, precipitation has found to either increase or decrease in different parts of the world and globally, the area affected by drought might have increased since the 1970s (IPCC, 2007).

Bangladesh is one of the top most nations vulnerable to climate change (Harmeling, 2008). IPCC also recognizes Bangladesh as one of the most vulnerable countries in the world to the negative impacts of climate change. In Bangladesh, different climate changes like recurring floods, river bank erosion, drought in dry season, salinity increase as a result of back water effect, downing ground water level, have been contributing to augment the vulnerability of

many regions. Nevertheless, many regions of this country remain outside the ambit of climate change related actions (Titumir & Basak, 2012). Thus, immediate actions by employing innovative approaches on climate change adaptation and community resilience are of utmost importance that simultaneously would ensure food security and livelihood stability (Basak, 2011).

IPCC in one of its Technical Paper on "Climate Change and Water" indentified that several gaps in knowledge exist in terms of observations and research needs related to climate change and water (Bates et al, 2008). Thus, better observational data and data accesses are necessary to improve knowledge of ongoing changes and to facilitate adaptive management required under conditions of climate change. A strong and robust hydrometeorology monitoring network is therefore fundamental to further work on detection and attribution of present-day hydrological changes; in particular, changes in water resources and in the occurrences of extreme events like floods, cyclones, droughts, erratic rainfall, storms, cold spells etc. (IUCN Bangladesh, 2011).

However, numbers of studies have been carried out on trends of change in climate parameters in the context of Bangladesh like Warrick et al (1994), Karmakar & Shrestha (2000) and Debsarma (2003) provided assessment of changes in temperature and precipitation over Bangladesh, while Chowdhury & Debsarma (1992) and Mia (2003) reported changes in temperature based on analysis of historical data of some selected weather stations in Bangladesh. Karmakar & Nessa (1997) and Karmakar (2003) provided assessment of the effects of climate change on natural disasters.

Modeling studies by Haque et al (1992) indicated that the average increase in temperature would be 1.3 ^{o}C and 2.6 ^{o}C for the projected years of 2030 and 2075, respectively. Similar to IPCC projections, the rise in winter temperature in Bangladesh was predicted to be higher probably due to significant increase in monsoon precipitation, which could also cause severe flooding in the future. Chowdhury & Debsarma, (1992) studied that the projected changes will be 1.4 ^{o}C in the winter and 0.7 ^{o}C in the monsoon months in 2030. For 2075, the variation would be 2.1 ^{o}C and 1.7 ^{o}C for winter and monsoon respectively. It is also observed that the increasing tendency of lowest minimum temperature over Bangladesh.

Warrick et al (1994) studied the variation of temperature and rainfall over Bangladesh. In this study, mean-annual temperatures have been expressed as departures from the reference period 1951-1980. It is evident that, on this time scale, Bangladesh region has been getting warmer. Since the later part of the last century, there has been, on average, an overall increase in temperature by 0.5 ^{o}C which was comparable in magnitude to the observed global warming. Karmaker & Nessa, (1997) studied on climate change and its impacts on natural disasters and southwest-monsoon in Bangladesh and the Bay of Bengal. They found that the decadal mean annual temperature over Bangladesh have shown increasing tendency especially after 1961-1970.

The present study has provided an assessment of climate change and variability in Bangladesh based on analysis of historical data of temperature and rainfall recorded at 34 meteorological stations in Bangladesh. Assessments have been made, in particular, of changes in maximum temperature, changes in minimum temperature and changes in rainfall pattern.

2. Materials and Methodology

2.1. Study Sites

The study was conducted on 34 meteorological stations in Bangladesh for the period of 1976 to 2008. Among them, Bogra, Dinajpur, Rangpur and Sayedpur were selected for Northern region; Chuadanga, Faridpur, Ishuridi and Rajshahi were selected for Northwestern region; Jessore, Khulna, Mongla, Patuakhali, Satkhira and Khepupara for Northsouthern region, Tangail, Dhaka and Mymensingh for Central region; Barisal, Bhola, Chandpur, Comilla, Feni, Hatiya, M.Court, Madaripur for Southern region; Chittagong, Cox's Bazar, Kutubdia, Rangamati, Shandwip, Sitakundu, and Teknaf for Southeastern region and Sylhet and Srimangal for Eastern region in Bangladesh (Figure 1).

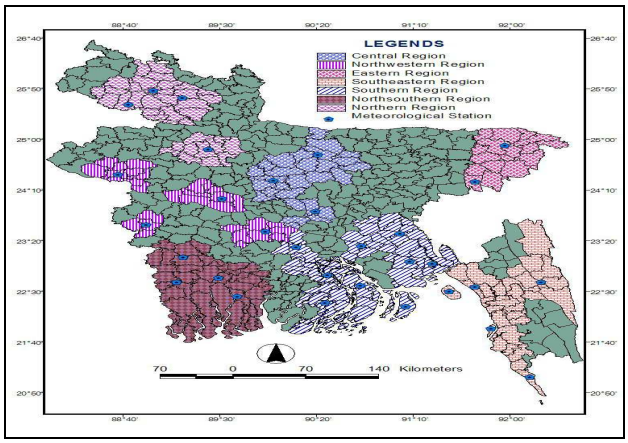

Figure 1. Location Map of the Study Area

2.2. Data Collection and Data Range

In this study, data on temperature and rainfall of all 34 weather stations in Bangladesh were collected from the Bangladesh Meteorological Department (BMD). Temperatures data included daily, monthly average and annual mean maximum and minimum temperatures for the period

January 1948 through December 2008 and daily rainfall data for the same period. However, data for the 33-year period from 1976 to 2008 have been used in the present study, because data for the period 1948-1975 were not considered reliable due to some missing data and unrest conditions in the country. It should also be noted that there are some missing data for some months at some stations, which have been excluded in the trend analysis.

2.3. Maximum and Minimum Temperature

Monthly-average maximum temperature data for the period January 1976 to December 2008 have been used to assess the changes in maximum temperature. These data were used to assess trend in yearly-average maximum temperature (calculated from monthly average values) as well as trends in monthly-average maximum temperature. These trends were assessed for each of the 34 stations. In each case, only linear trend was assessed for the period 1976-2008 and the nature (increasing or decreasing) and significance of trend was estimated from the R^2 value of the fit.

Monthly average minimum temperature data have been used to assess the changes in minimum temperature. From the monthly average, the yearly average temperature was computed. Trends of both yearly-average minimum temperature and monthly-average minimum temperature have been assessed.

2.4. Rainfall Pattern

In this study, changes in rainfall pattern have been assessed by analyzing changes in total rainfall during four seasons i.e., pre-Monsoon (March-May), Monsoon (June-September), post-Monsoon (October-November) and winter (December-February) for the period 1976 to 2008; analysis was made separately for each weather station. Analysis of "intense rainfall events" could not be made from the available data on rainfall.

3. Result and Discussion

3.1. Changes in Annual Temperature

The trend of variation of yearly average maximum temperature was analyzed for each of the 34 stations. The yearly average maximum temperature increased at all regions in Bangladesh during the period of 1976-2008 and the rates of changed of temperature were 0.014 ^{o}C, 0.007 ^{o}C, 0.024 ^{o}C, 0.003 ^{o}C, 0.014 ^{o}C, 0.039 ^{o}C and 0.022 ^{o}C per year for Northern, Northwestern, Northsouthern, Central, Southern, Southeastern and Eastern region respectively. On an average (i.e. average of 34 stations) yearly average maximum temperature of Bangladesh has been found to be increasing at a rate of 0.018 ^{o}C per year. Significant increase of temperature during this 33-years period was observed at South Eastern region (1.287 ^{o}C) and minimum at Central region (0.11 ^{o}C) (Figure 2).

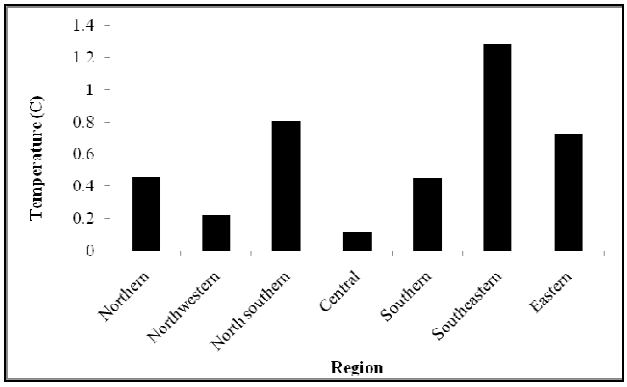

Figure 2. Yearly Average Maximum Temperature Changed at Different Regions in Bangladesh

Likewise, yearly average maximum temperature, yearly average minimum temperatures also have been increased in all regions of Bangladesh during the past 33-years period. The rates of changed of minimum temperature were 0.032 ^{o}C, 0.023 ^{o}C, 0.011 ^{o}C, 0.003 ^{o}C, 0.020 ^{o}C, 0.001 ^{o}C and 0.016 ^{o}C per year for Northern, Northwestern, Northsouthern, Central, Southern, Southeastern and Eastern region respectively. Moreover, yearly average minimum temperature of Bangladesh has been found to be increasing at a rate of 0.015 ^{o}C per year. Significant increase of minimum temperature was observed at Northern region (1.056 ^{o}C) and minimum at Southeastern region (0.033 ^{o}C) (Figure 3) for the past 33-years period in Bangladesh.

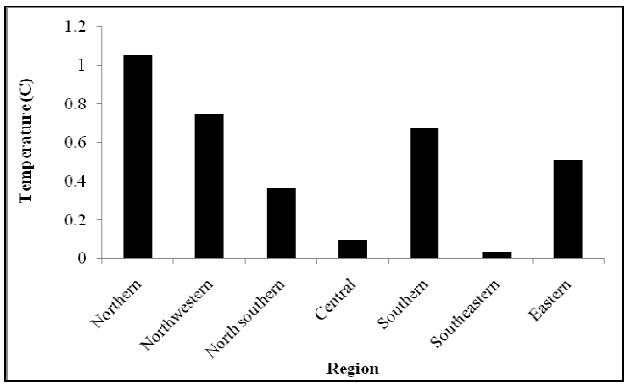

Figure 3. Yearly Average Minimum Temperature Changed at Different Regions in Bangladesh

3.2. Changes of Monthly Average Maximum and Minimum Temperature

The trends of variation of monthly average maximum and minimum temperatures were analyzed for 34 weather

stations and results are summarized in Table 1 and 2. Table 1 shows that except for January and April, monthly average maximum temperature follows increasing trend for majority of the meteorological stations of these regions. Increasing trends were particularly significant for the months of May to September and February. Calculated (from trend lines) changes in monthly average maximum temperature of Bangladesh was found to be increasing (on an average i.e. average of 34 stations) at rate of 0.027 ^{o}C, 0.033 ^{o}C, 0.031 ^{o}C, 0.036 ^{o}C, 0.027 ^{o}C and 0.040 ^{o}C per year for the months of May, June, July, August, September and February respectively, whereas decreasing trends were observed for January (0.023 ^{o}C per year) and April (0.002 ^{o}C per year) for the same period. Highest change of month-ly average maximum temperature was found for Southeastern region in Bangladesh for maximum months, whereas the lowest change was recorded for Northern region during this period of 1976-2008 (Figure 4).

nd to be increasing (on an average i.e. average of 34 stations) at rate of 0.031 ^{o}C, 0.025 ^{o}C, 0.019 ^{o}C, 0.025 ^{o}C, 0.022 ^{o}C, and 0.031 ^{o}C per year for the months of February, March, April, May, October and December respectively, whereas decreasing trends were observed for January (0.002 ^{o}C per year) and November (0.002 ^{o}C per year) for the same period. Highest change of monthly average minimum temperature was found for Northern region in Bangladesh for maximum months, whereas lowest change for Southeastern region during the period of 1976-2008 (Figure 5).

3.3. Trend of Seasonal Rainfall

The changes in rainfall pattern are important climate change phenomena, which are likely to be observed all over the land. In the study, efforts were made to assess if there is any significant change in trends of rainfall.

Table 1. Total Changes of Monthly Average Maximum Temperature (^{o}C) from 1976 to 2008

Region/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern	-1.423	1.122	-0.446	-1.576	0.619	0.685	0.974	1.667	1.122	-0.239	0.223	0.132
Northwestern	-1.633	1.254	-0.248	-0.347	0.792	1.419	0.759	1.196	0.322	0.008	0.173	0.644
Northsouthern	-0.310	1.4982	0.449	0.356	1.531	1.135	1.261	1.287	0.970	0.349	0.363	1.003
Central	-1.760	0.726	-0.451	-1.342	0.858	0.869	0.704	0.814	0.671	0.319	0.044	0.836
Southern	-0.777	0.920	-0.165	0.627	0.865	1.118	1.118	1.019	0.649	0.352	-0.062	0.964
Southeastern	0.486	1.975	1.443	1.575	0.924	1.381	1.504	1.707	1.494	1.626	1.480	1.961
Eastern	0.033	1.732	-0.215	0.33	0.545	1.205	0.924	0.743	1.122	0.726	0.479	1.304

(Jan: January; Feb: February; Mar: March; Apr: April; Jun: June; Jul: July; Aug: August; Sep: September; Oct: October; Nov: November; Dec: December)

Table 2. Total Changes of Monthly Average Minimum Temperature (^{o}C) from 1976 to 2008

Region / Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern	0.066	2.162	2.360	0.874	1.004	0.726	0.825	0.586	0.619	0.553	1.273	1.848
Northwest	-0.132	1.460	1.113	1.180	1.015	0.429	0.322	0.281	0.066	0.677	-0.025	1.427
Northsouth	-0.898	0.172	0.052	0.343	0.653	0.244	0.515	0.468	0.092	0.475	-0.746	0.330
Central	-0.154	1.584	1.265	0.517	1.254	0.836	0.990	0.275	-0.330	0.044	-0.253	1.243
Southern	0.066	1.100	0.440	0.587	0.825	0.469	0.638	0.631	0.359	0.968	-0.062	0.950
Southwast	-0.391	0.127	0.033	0.344	0.396	0.660	0.731	0.556	0.269	0.806	-0.853	-0.127
Eastern	0.990	0.578	0.429	0.479	0.726	0.429	0.396	0.396	0.677	1.518	0.215	0.908

(Jan: January; Feb: February; Mar: March; Apr: April; Jun: June; Jul: July; Aug: August; Sep: September; Oct: October; Nov: November; Dec: December)

Similarly monthly average maximum and minimum temperatures also follow increasing trend -particularly significant for the months of February to May and October and December. Calculated (from trend lines) changes in monthly average minimum temperature of Bangladesh was fou-

Among the 34 stations, 16 stations showed increasing trend, while 18 showed decreasing trends in total rainfall in winter season in Bangladesh. On the other hand, 31 stations showed rising trend for monsoon season; 30 stations showed increasing trend of total rainfall for post monso-

on and 20 stations for Pre-monsoon among 34 weather stations. Moreover, the observed trends were not statistically significant in most cases. Nevertheless, majority of stations showed increasing trend of rainfall during monsoon and post-monsoon seasons, while significant number of stations showed decreasing trend of total rainfall during winter. These results are consistent with the general climate change predictions that wet periods would become wetter and dry periods would become drier. Table 3 shows the variation in total amount of rainfall in 4 seasons for 34 meteorological stations located seven regions in Bangladesh.

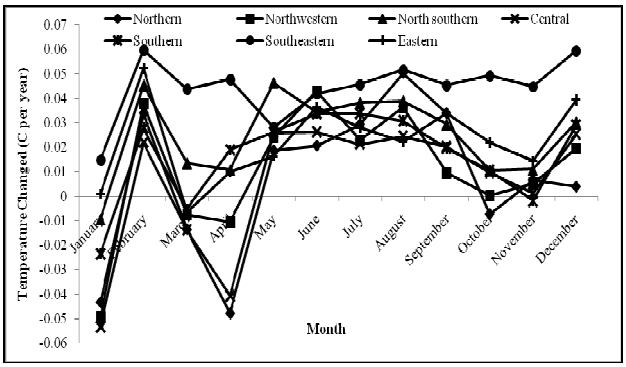

Figure 4. Changes in Monthly Average Maximum Temperature per Year during 1976-2008

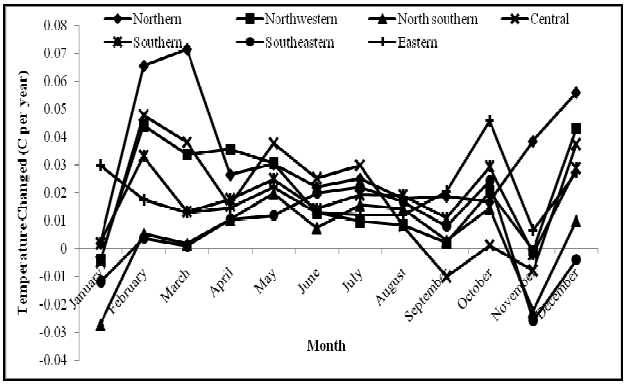

Figure 5. Changes in Monthly Average Minimum Temperature per Year during 1976-2008

4. Conclusion

Temperature and precipitation data of all 34 meteorological stations of Bangladesh for the period 1976-2008 have been analyzed. Analysis of temperature data showed that at majority of these stations, the yearly average maximum and minimum temperatures had increasing trends. Analysis of monthly average maximum temperature also showed increasing trend for all months of the year except January and April; the increasing trend was particularly significant for the months of May to September and February. Calculated average increase in temperature for these months was about 1 ^{o}C for the 33-years period from 1976 to 2008. Monthly average minimum temperatures also showed increasing trends for all months except January and November. Average increase in monthly average minimum temperature was about 0.7 ^{o}C, while for January and November; average decrease was about 0.06 ^{o}C during the same period. The magnitude of increase in monthly average maximum and minimum temperatures during the 33-years period from 1976 to 2008 is quite significant. Moreover, significant increase of maximum temperature was observed at Southeastern region for both yearly and monthly average data and Northern region for minimum temperature.

Analysis of precipitation data during 1976-2008 show-ed increasing trend of rainfall for majority of stations during Monsoon and post-Monsoon seasons, while decreasing trend of total rainfall during winter was found for significant number of weather stations; pre-Monsoon period did not show any significant change in total rainfall. In general, these trends are consistent with the general climate change predictions.

The temperature and precipitation pat-terns are of great importance for an agro-based economy like Bangladesh. Moreover, these changes will threaten the significant achievements Bangladesh has made over the last 20 years in increasing incomes and reducing poverty. In view of these changes, it is necessary to regularly and systematically compile, monitor and analyze the relevant climatic parameters for assessing the impacts of climate change.

Table 3. Changes in Amount of Rainfall (mm per year) in four Seasons during 1976-2008

Region / Month	Winter	Pre-Monsoon	Monsoon	Post-monsoon
North	-0.617	1.242	11.811	8.761
North West	-1.170	0.943	4.599	2.563
North South	-1.595	2.145	11.716	5.178
Central	-1.787	-1.659	2.274	5.484
South	-0.098	-1.321	7.362	2.503
Southeast	0.578	7.102	17.970	2.580
Eastern	0.795	0.999	8.639	0.449

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