Journal of Engineering Science 09(1), 2018, 11-20

JES
an international Journal

CLIMATE CHANGE AND ITS IMPACT ON ENVIRONMENT, AGRICULTURE AND WATER USE AT RAJSHAHI

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Received: 10 October 2017 Accepted: 21 January 2018

ABSTRACT

Attempts have been made to highlight the Global warming and Global sea surface temperature together with the climatic trends of mean dry-bulb temperature and rainfall at Rajshahi. The annual mean temperature at Rajshahi has a sharp increasing trend of 0.013°C/year during the period 1981-2016. The seasonal mean temperature has increasing trends in pre-monsoon, monsoon and post-monsoon seasons during 1981-2016, having the rates of increase 0.021, 0.024 and 0.004 °C/year respectively and during the winter season has a slight increasing trend during the period 1990-2016. The annual rainfall at Rajshahi during the period 1981-2016 has decreasing trend at a rate of 6.968 mm/year. This decreasing rate is alarming and is likely to cause drought at Rajshahi in future. The seasonal rainfall has decreasing trends during the monsoon, post-monsoon and winter seasons, having the maximum decreasing rate of 6.433 mm/year in monsoon season. This indicates that the drought condition is likely to increase at Rajshahi even in the monsoon season. Inter-annual and inter-decadal climate variability exists at Rajshahi as well as in Bangladesh. Rise in temperature at Rajshahi will have profound effect on agriculture. Due to less availability of water, the climate is changing at Rajshahi. Temperature is increasing and rainfall is decreasing. Frequency of heat waves in summer and cold waves in winter are increasing. Production of agricultural crops is decreasing as per the perception of community people.

Keywords: *Agriculture and Community people, Climate Change, Environment.*

1. INTRODUCTION

The climate change issues have become international priorities during the last three decades. It is generally accepted that the global mean surface air temperature has increased by 0.3°C to 0.6°C over the last 100 years. The magnitude of the global warming is broadly consistent with the prediction models, but is also of the same magnitude as natural climatic variability. There is no firm evidence that climate has become more variable over the last few decades. The current scientific consensus is that increasing atmospheric concentrations of greenhouse gases should have caused world to warm. The rate of warming however is very uncertain. In 1990, the Intergovernmental Panel on Climate Change (IPCC, 1990) estimated that with a "Business-as-usual" scenario of green house gas emissions, the world should be 3.3°C warmer by the end of the next century, with a range of uncertainty of 2.2 to 4.9°C. Subsequent analyses by IPCC and others suggest somewhat lower rates of warming. Nevertheless, such rates of global temperature change are greater than those, which have occurred naturally over the last 10,000 years. By the second half of the present century (2001-2200), the global temperature could well exceed that which has occurred over the last 150,000 years, at least. Bangladesh is a least developed nation of the world and may also be most vulnerable to climate change. The increasing trend of global temperature may increase the intensity of different climatic hazards like tropical cyclones, thunderstorms, floods, drought etc. The possibility of changes in climate must be considered seriously in the context of future development of Bangladesh.

Warrick *et al.* (1994) studied the variations of temperature and rainfall over Bangladesh. They have expressed mean annual temperatures as departures from the reference period 1951-80. They found that, on this time scale, Bangladesh region has been getting warmer from the later part of the last century. They noted an overall increase in temperature by 0.5°C, which is comparable in magnitude to the observed global warming. The analysis of annual rainfall of Bangladesh for the period 1970-1991 showed no discernible long-term trend in mean annual rainfall (Folland *et al*., 1992). Some other studies have been made on rainfall variability and climate change in Bangladesh (Karmakar and Khatun, 1995; Karmakar and Nessa, 1997; Karmakar, 2000) and are important for agricultural purposes in the country.

Crops are very sensitive to temperature in agriculture sector. In a study made by Kabir (2015), it found that the model predicted significant reduction in yield of both varieties of boro rice (BR3 and BR14) in southwestern part of Bangladesh due to climate change; yield reductions of over 20% and 50% have been predicted for both rice varieties for the years 2050 and 2070, respectively. According to him, increases in daily maximum and minimum temperatures have been found to be primarily responsible for reduction in yield. Rimi *et al.* (2009) made a study on

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the trend analysis of climate change and investigated the probable impacts on rice production at Satkhira, Bangladesh. They concluded that effects of the climate changes would vary depending on the differences in the variety and local differences in growing seasons, crop management etc. Higher temperature and precipitation would aggravate declining condition of the soils. As a result, food-grain production would certainly have adversely affected. The rice varieties, which are in use, might not be able to tolerate temperature rise and sustain current level of yield.

Karmakar and Shrestha (2000) studied the recent climatic changes in Bangladesh and concluded that mean maximum temperature during 1961-90 over Bangladesh during the pre-monsoon season has a decreasing trend up to 1977 after which it has a slight increasing trend. During the southwest monsoon season, it has significant increasing trend after 1976. The mean maximum temperature during the post-monsoon season has increasing trend, which is highly significant. Whereas during the winter season, it has significant decreasing trend up to 1984 beyond which it increases significantly. The annual mean maximum temperature over Bangladesh has significant decreasing trend up to 1975 and very significant increasing trend after 1975. The overall trend of annual mean maximum temperature for the period 1961-1990 is of increasing order which is statistically significant. The mean minimum temperature over Bangladesh has decreasing trend up to 1978 and increasing trend after 1978. During the southwest monsoon season, it has significant decreasing trend up to 1976 and then it has a slight increasing trend after 1976 but not significant. The mean minimum temperature has an increasing trend up to 1976 during the post-monsoon and then decreasing trend after 1976, both the trends being very significant. During the winter season, it has a significant decreasing trend up to 1977 and then an increasing trend, which is not statistically significant. The mean minimum temperature for the overall period 1961-90 has increasing trends during all the seasons except the post-monsoon season when it has decreasing trend. The annual mean minimum temperature over Bangladesh has an increasing trend up to 1978 which is statistically significant and after 1978 it has a slight decreasing trend which is not significant. The overall annual mean minimum temperature over Bangladesh for the period 1961-90 has a slight decreasing trend. The mean temperature over Bangladesh has a slight increasing trend during the whole period 1961-90, but the trend is not statistically significant.

In Rajshahi, Farakka Barrage also plays an important role in changing the climate because of the reduced flows in the River Padma. According to Adel (2013), the riverine ecosystem of Bangladesh has been facing ecocide due to this Barrage. India has been drawing at least 60% of the downstream Bangladesh Ganges basin ecosystem's water without regard to the condition of the ecosystem in Bangladesh. Gain and Giupponi (2014) studied the impact of the Farakka Dam on thresholds of the hydrologic flow regime in the lower Ganges River Basin (Bangladesh) and the reduced flow in the Ganges is responsible for the increase of salinity in the southwest coastal region of Bangladesh and a reduction of fish and agricultural diversity. They concluded that future studies are required, aiming at a more in-depth understanding of the system to investigate the combined impact of climate change and human-induced perturbation.

The present study aims at the analysis of temperature and rainfall together with frequency of heat waves and cold waves at Rajshahi to see the trends of these elements and their impacts on environment, agriculture and the use of water especially in the Rajshahi region. Community perception on the impact of climate change on agriculture and water at Rajshahi has also been investigated.

2. DATA USED AND METHODOLOGY

Daily data on maximum temperature, minimum temperature, mean dry-bulb temperature and daily rainfall at Rajshahi station of Bangladesh Meteorological Department (BMD) for the period January through December of 1981-2016 have been used to study the climatic pattern in Rajshahi.

From the daily data, monthly, seasonal mean and annual mean values have been computed for the four seasons e.g. pre-monsoon southwest monsoon, post-monsoon and winter. It is important to note that for the computation of seasonal mean values for the winter season, the data in December of one year has been used with the data in January and February of the following year to represent the winter mean value of the following year (e.g. mean data of December 1981, and January and February of 1982 represents the mean data for the winter of 1982 and so on). The daily maximum and minimum temperatures are used to find the frequency of heat waves and cold wave and their trends are studied.

To obtain the community's idea about the climate change and its impacts on the environment, agriculture, water use etc, a workshop was organized at Rajshahi in collaboration with a local NGO and community people.

3. GLOBAL WARMING

The Figure1 shows the trend in global mean surface temperature. According to IPCC, the global average air temperature near the Earth's surface is found to rise by 0.74 ± 0.18 °C during the hundred years ending in 2005. It was emphasized that human-caused global warming brings serious threats from increased flooding to the spread of disease to the disruption of agriculture in many parts of the world. The global average and combined land and ocean surface temperature, show a warming of 0.85 [0.65 to 1.06] °C, in the period 1880 to 2012, based on multiple independently produced datasets. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C, based on the single longest dataset available (IPCC, 2013). Global Sea surface temperature is rising and the oceans are warming. Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m (IPCC, 2007) (Figure 2).

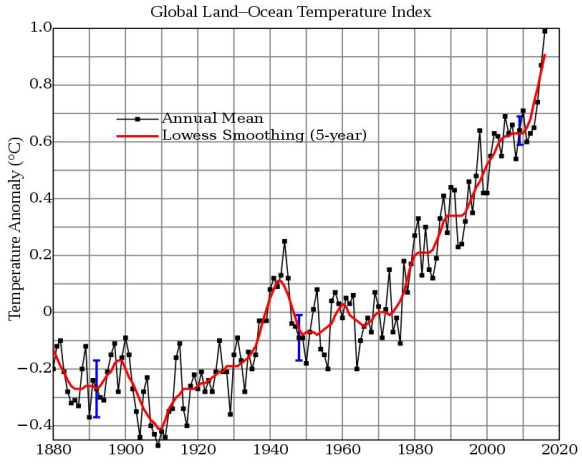

Figure 1: Global mean surface temperature change from 1880 to 2016, relative to the 1951–1980 mean. [The black line is the global annual mean and the red line is the five-year lowess smooth. The blue uncertainty bars show a 95% confidence limit. Source: NASA GISS (https://en.wikipedia. org/wiki/ Instrumental_ temperature record]

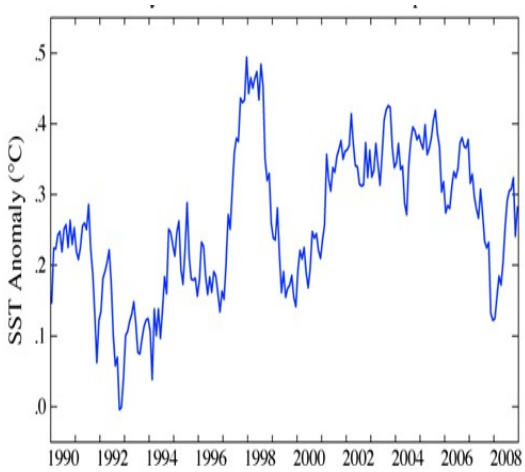

Figure 2: Global average SSTs from 1990-2008. SSTs have not increased in the past seven years. Image credit: NASA/GISS. (Source: https://www. wunderground.com/blog/JeffMasters/is-the-globe-cooling. html

4. RESULTS AND DISCUSSION

4.1 Trends in annual mean and seasonal mean temperature at Rajshahi

The trends in annual and seasonal mean temperature at Rajshahi during the period 1981-2016 is shown in Figures. 3-7. Figure 3 shows the trend in annual mean temperature, which has a sharp increasing trend of +0.013°C/year. The pre-monsoon mean temperature has also increasing trend during the period 1981-2016 and is +0.021°C/year, which is higher than the rate of annual mean temperature (Figure 4). From the analysis of the annual and seasonal mean temperature except the winter that the increasing trend in temperature is found to start from 1980 or 1981 at Rajshahi.

Figure 5 gives the trend in mean temperature at Rajshahi in the southwest monsoon season during 1981-2016, having a positive trend of +0.024°C/year, which is statistically significant up to 95% level of significance. The mean temperature in post-monsoon season has also slight increasing trend during the period 1981-2016 and is +0.004°C/year and it is not statistically significant (Figure 6). The trend in mean temperature at Rajshahi in the winter season during the period 1981-2016 is shown in Figure 7. The mean temperature in winter has decreasing trend at -0.007 °C/year during 1981-2016. It is interesting to note that the mean temperature during the winter season has a slight increasing trend (0.001C/year) during the period 1990-2016. It is, therefore, evident that the seasonal mean temperature at Rajshahi has started increasing during the winter season from 1990, although there is always inter-annual variability.

Decadal variability of annual mean temperature at Rajshahi is shown in Figure 8, which shows that the annual mean temperature has lower trend rate in the decade 1991-2000 and then it has higher increasing trend, having the

maximum trend of 0.049° C/year in the decade 2001-2010. The figure also shows inter-decadal variability of annual mean temperature.

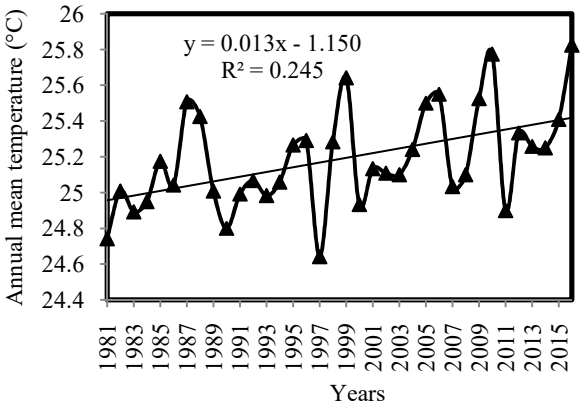

Figure 3: Temporal variation of annual mean temperature (ºC) at Rajshahi during the pre-monsoon season of 1981-2016

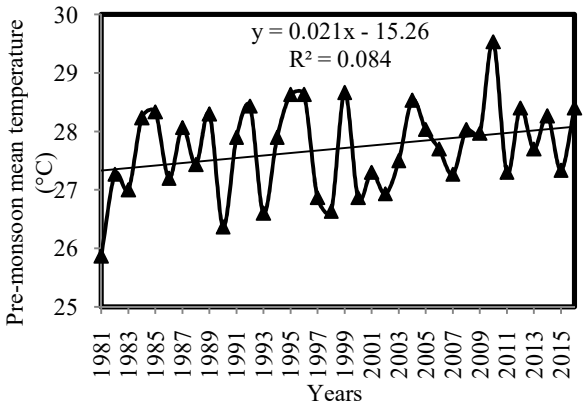

Figure 4: Temporal variation of mean temperature (ºC) at Rajshahi during the pre-monsoon season of 1981-2016

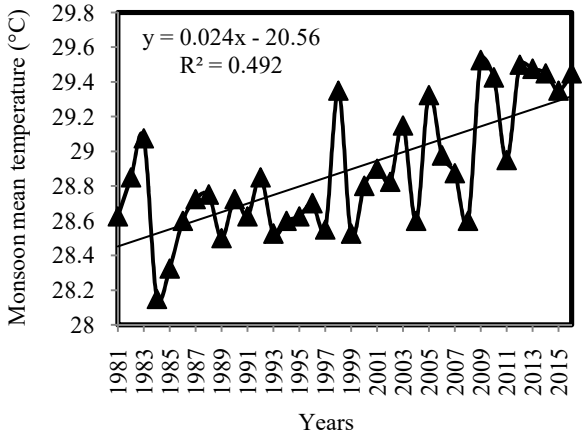

Figure 5: Temporal variation of mean temperature (ºC) at Rajshahi during the SW monsoon season of 1981-2016

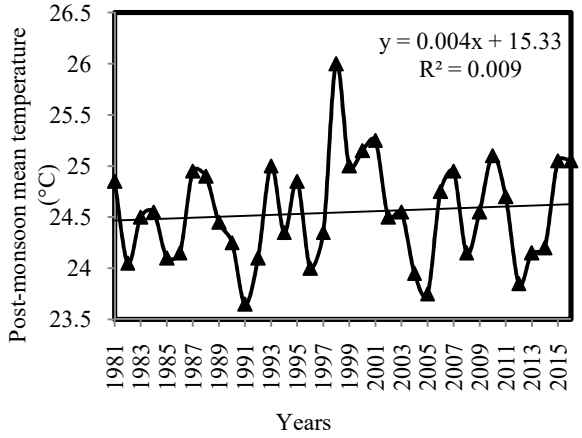

Figure 6: Temporal variation of mean temperature (ºC) at Rajshahi during the post-monsoon season of 1981-2016

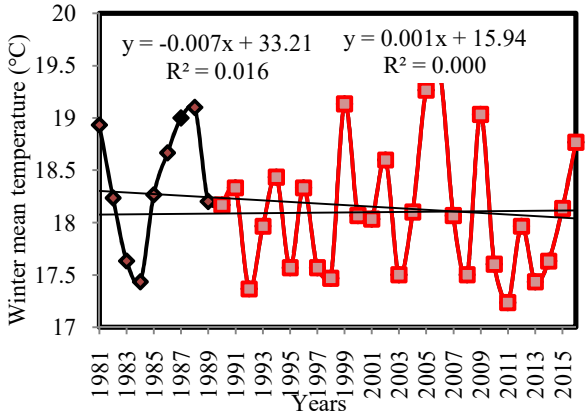

Figure 7: Temporal variation of mean temperature (ºC) at Rajshahi during the winter season of 1981-2016

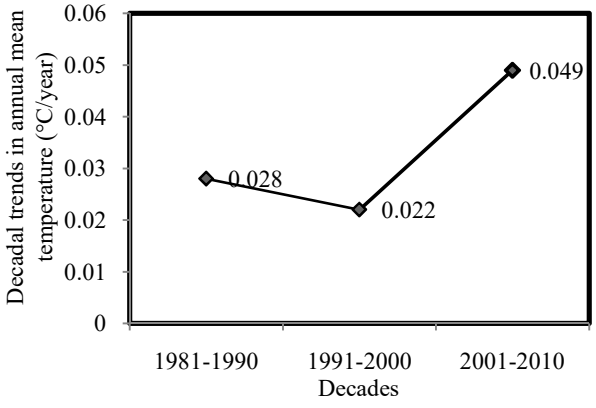

Figure 8: Decadal variability of annual temperature at Rajshahi

4.2 Frequency of Heat waves and Cold waves

4. 2.1 Frequency of minimum temperature <10°C

The frequency of minimum temperature less than 10°C (cold waves) over Rajshahi during 1981-2016 has been computed from the daily minimum temperature. Figure 9 shows that the frequency of minimum temperature <10°C

may vary from 7 to 39 days in a year at Rajshahi and it has increasing trend at 0.035 days/year, which means that the intensity of cold waves may increase in future if this trend continues.

4.2.2 Frequency of maximum temperature >36°C

The temporal variation of the annual frequency of days with maximum temperature >36°C at Rajshahi during 1981-2016 are shown in Figure 10. The figure shows inter-annual variation in the frequency of days with maximum temperature >36°C. It is found that the annual frequency of days with maximum temperature >36°C has increasing tendency at Rajshahi at 0.655 days/year during 1981-2016. If the current rate of increase in the annual frequency of days with maximum temperature >36°C would continue in future, the heat waves would have tremendous impacts on the agriculture sector and food security (crops, animals, etc.) in future and the situation would be more aggravated in Rajshahi.

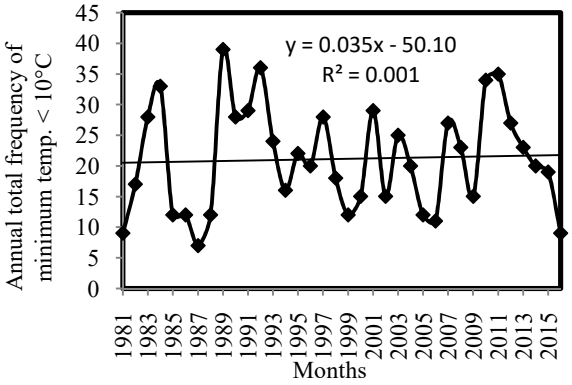

Figure 9: Temporal variation of annual total frequency of minimum temperature <10°C at Rajshahi during 1981-2016

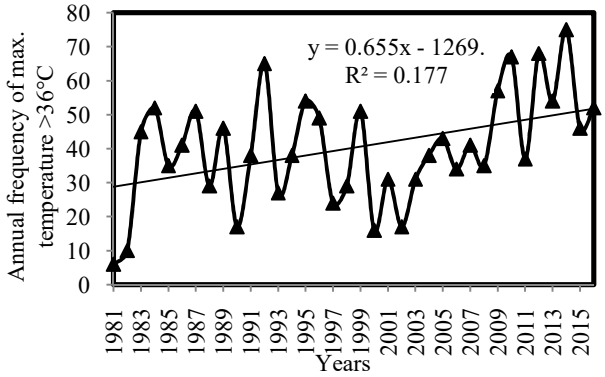

Figure 10: Temporal variation of annual frequency of maximum temperature >36°C at Rajshahi during 1981-2016

4.3 Trends in annual and seasonal rainfall at Rajshahi

The trends in the seasonal rainfall during pre-monsoon, monsoon, post-monsoon and winter seasons at Rajshahi during the period 1981-2016 are shown in Figures. 11-14 respectively. Figure 11 shows that the pre-monsoon rainfall at Rajshahi has increasing trend at a rate of 0.029 mm/year. The rainfall at Rajshahi has decreasing trends in other seasons. The rates of decrease are -6.788, -1.115 and -0.993 mm/year during the monsoon, post-monsoon and winter seasons respectively (Figures. 12-14). Of these, monsoon season has the maximum decreasing rate of -6.788 mm/year (Figure 12). This indicates that the drought condition is likely to increase at Rajshahi even in the monsoon season. The trend in annual rainfall at Rajshahi during the period 1981-2016 is shown in Figure 15. This figure shows that the annual rainfall at Rajshahi has also decreasing trend at a rate of -8.946 mm/year. This decreasing rate is alarming and is likely to cause drought at Rajshahi in future. Decadal trend in annual rainfall at Rajshahi during 1981-2010 is shown in Figure 16, indicating a prominent decreasing trend in annual rainfall (-56.07 mm/year) during the last decade i.e. 2001-2010, which is alarming for Rajshahi. The figure also shows that the decadal rainfall vary from one decade to another.

4.4 Perception of the community people on the impact of climate change in Rajshahi region

A workshop was organized in Rajshahi on the climate change and its impact by Environment & Population Research Centre (EPRC) and Global Applied Research Network (GARNET-SA) in collaboration with Basti Unnayan & Karmo Sangstha on 30 January 2013 and a number of participants were present. Open discussion and group discussion were held in the workshop. The results of the discussion are given below.

4.4.1 Open discussion on climate change

On the basis of the open discussion, the opinions of the participants are tabulated in Table 1. According to the participants, temperature increased much at Rajshahi during the last 30 years. Of these, 51.42% respondents mentioned that temperature rose much during last 5 years and 57.14% respondents replied that temperature increased much during last 30 years. About rainfall at Rajshahi, 51.42% respondents replied that rainfall decreased very much during the last 5 years whereas 62.85% respondents opined that rainfall decreased very much during the

last 30 years. Drought conditions increased much at Rajshahi during last 5 and 30 years as responded by 42.85% and 40,0 % participants respectively. Regarding flood, 85.71% respondents replied that flood frequency decreased much in the recent 5 years whereas 42.85% respondents replied that flood frequency was more in the last 30 years. About Kalbaishakhi storms and tornadoes, 42.85% respondents replied that these storms decreased very much in last 5 years and 45.71% respondents answered that Kalbaishakhi storms and tornadoes decreased much in the last 30 years at Rajshahi.

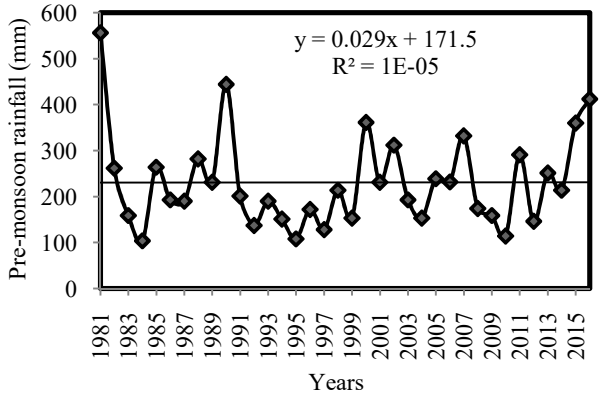

Figure 11: Temporal variation of rainfall during pre-monsoon season at Rajshahi during the period 1981-2016

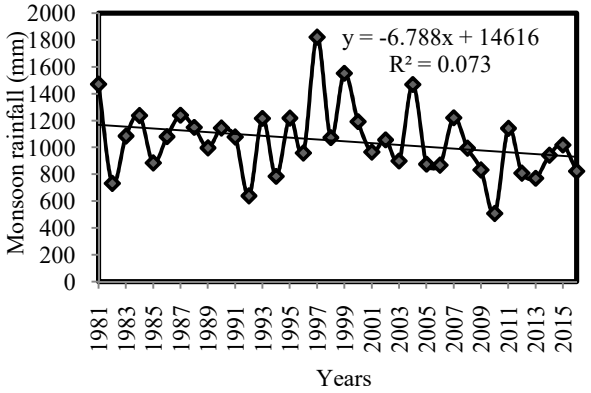

Figure 12: Temporal variation of rainfall during monsoon season at Rajshahi during the period 1981-2016

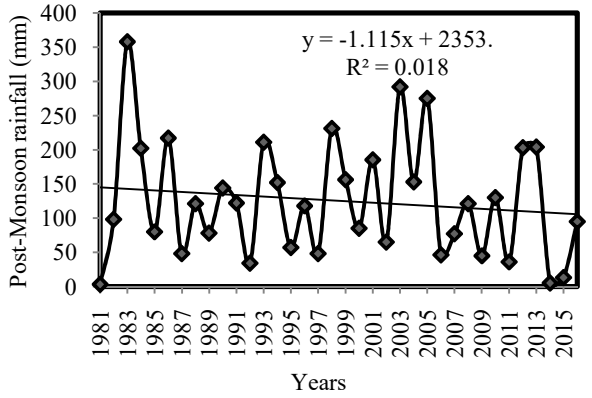

Figure 13: Temporal variation of rainfall during post-monsoon season at Rajshahi during the period 1981-2016

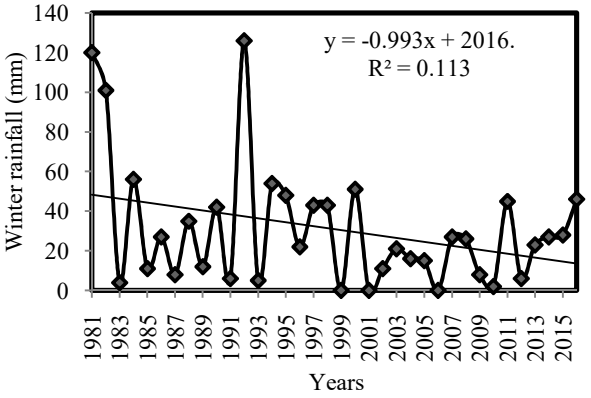

Figure 14: Temporal variation of rainfall during winter season at Rajshahi during the period 1981-2016

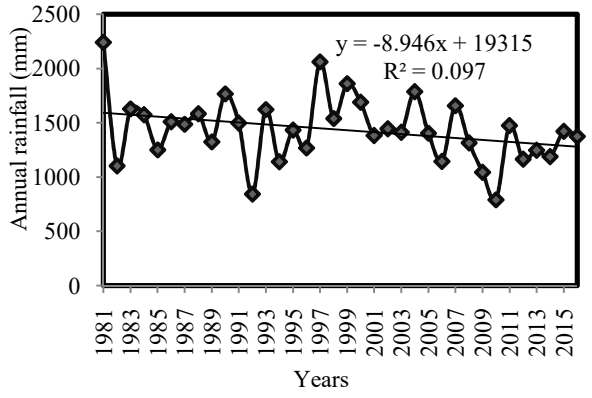

Figure 15: Temporal variation of annual rainfall at Rajshahi during the period 1981-2016

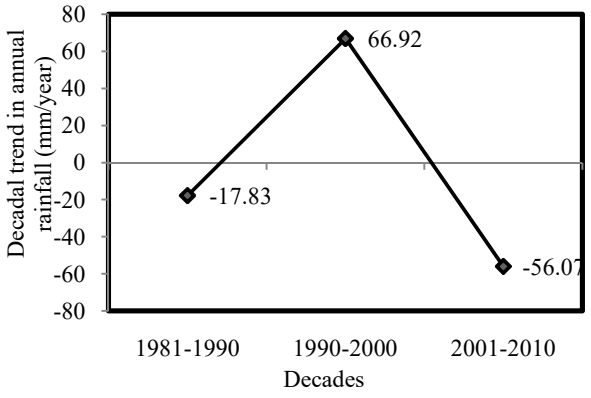

Figure 16: Decadal variability of annual rainfall at Rajshahi

According to the respondents, frequency of heat waves increased very much (57.14% respondents) in the last 5 years whereas it increased much in the last 30 years (22.85% respondents); frequency of cold waves also increased very

much (71.42% respondents) in the last 5 years and moderately increased (51.42% respondents) in the last 30 years. Therefore, climate change occurred at Rajshahi with the increase in temperature and decrease in rainfall as per the opinions of the participants and these changes are as per the presentation in the key-note paper in the workshop. The continuation of the decrease in rainfall is likely to enhance drought conditions at Rajshahi. The decrease in Kalbaishakhi/tornadoes also indicates that rainfall will be less during the pre-monsoon season thereby enhancing the drought situation at Rajshahi.

Table 1: Interview related to climate change at Rajshahi

Question on	Last 5 years			Last 30 years		
	No. of respondents (N=35)			No. of respondents (N=35)		
	Moderate	Much	Very much	Moderate	Much	Very much
Increase in temperature	1(2.85%)	18 (51.42%)		3 (8.57%)	20 (57.14%)	
Decrease in rainfall			18 (51.42%)			22 (62.85%)
Increase in drought conditions		15 (42.85%)			14 (40.00%)	
Decrease in floods		15 (42.85%)				
Increase in floods				2(5.71%)	15 (42.85%)	
Decrease in Kalbaishakhi /tornadoes			15 (42.85%)		16 (45.71%)	
Increase in heat waves/hotness			20 (57.14%)		8 (22.85%)	
Increase in cold waves/coldness			25 (71.42%)	18 (51.42%)		

According to the participants, drought is the most harmful in Rajshahi region and the intensity of drought increased during the last 5 years as compared to that during last 30 years. Rainfall intensity and duration also decreased in this region. As a result, the agriculture patterns, crop patterns and quality of water were being affected very much. The participants emphasized on the importance of climate change at Rajshahi sequentially as (i) drought conditions increased, (ii) temperature increased, (iii) rainfall decreased and (iv) cold waves/ coldness increased.

4.4.2 Group discussion on climate change

After the open discussion, the participants were divided into 2 groups namely (i) the "Barendra Group" and (ii) the "Padma Group". The two groups were given Flip charts with designed questionnaires to work on them and they were separated. They were given about 1 hour for discussion among themselves and requested to come up with the possible answers and appropriate recommendations. After 1 hour discussion, the two groups came back with their possible answers of the questionnaires. The leaders of the group were requested to present their opinions. The presentations are summarized and given in Tables 2-5 regarding the change in agricultural patterns, impact of climate change on the use of water, impact of climate change on health and impact of climate change on the types of agricultural crops respectively.

Because of climate change, there was much to very much changes in the irrigation sources at Rajshahi in the last 30 years as per 45.71%-51.42% respondents as can be seen from Table 2.

Table 2: Change in agricultural patterns

N=35	Change in last 30 years				
	Very little	Little	Moderate	Much	Very much
Change in irrigation source	0	0	0	45.71%	51.42%
Increase in the use of surface water	51.42%	0	0	45.71%	0
Increase in the use of ground water	0	0	0	0	97.14%
Change in the time of sowing seeds	0	17.14%	28.57%	51.42%	0
Decrease in the amount of crops	0	0	0	97.14%	0
Decrease in the quality of crops	0	5.71%	0	51.42%	0
Increase in the use of fertilizer	0	0	0	97.14%	0
Increase in the use of insecticides	0	0	0	97.14%	0

Use of ground water was increased very much (97.14% respondents), which is alarming. In agriculture, the time of sowing seeds was also changed to adapt with the climate change. About 97.14% respondents were of the opinion the

production of crops was reduced due to climate change at Rajshahi and at the same time the quality of crops was also decreased much. Use of fertilizer and insecticides was increased considerably (97.14% respondents). This use of fertilizer and insecticides should be reduced and organic fertilizer should be used for increasing the fertility and quality of land. Because of the reduction in the river flow, ground water is being used more now-a-days for irrigation and drinking purposes. Due to the more use of ground water, its layer is going down.

The sources of drinking and cooking water were also changed due to climate change during the last 30 years as can be seen from the Table 3. Before people used to drink river water, pond water and shallow tube well water and now they are drinking water from shallow tube well and deep tube well. Even the sources of bathing water were also changed much. People used to take bath in the river and ponds; now they bathe in shallow/deep tube well water mainly. Number of ponds has become less because ponds are now filled up and used for cultivation and habitation mostly. The river at Rajshahi has lost its flow conditions and its bed has risen up due to siltation and its capacity to accommodate much water has been reduced significantly. As a result, the distance of the water sources has increased considerably. The women are the key persons for maintaining household works; they are to fetch water from distant places for household works. The quantity of water is also reduced. They emphasized on the harvesting of rain water, which can be used for agriculture and household works.

Table 3: Impact of climate change on the use of water

N=35	Change in last 30 years		
	Moderate	Much	Very much
Change in the source of drinking water	45.71%	0	51.42%
Change in the source of cooking water	45.71%	45.71%	0
Change in the source of bathing water	28.57%	62.85%	0
Change in the source of irrigation water	0	45.71%	45.71%
Distance of the source water increased	80.0%	11.42%	0
Quality of drinking water decreased	45.71%	0	45.71%
Quantity of water decreased	45.71%	0	45.71%

Climate change has considerable impact on health especially the health of children and women as per the opinions of the participants in the workshop (Table 4). The male are more resistant to diseases. The children and women are affected by cold and cough, pneumonia, fever, cholera/diarrhea, jaundice/ hepatitis, asthma, etc. The children are suffering from lack of nutrition. As per the opinions of the participants, diseases increased more in Rajshahi region due to climate change. But the time of break out of diseases was not changed apparently. As a result the people are facing more financial loss and social problems due to climate change (45.71-51.42% respondents) as can be seen from Table 4.

Table 4: Impact of climate change on health

N=35	Change in last 30 years		
	Moderate	Much/more	Very much
Increase of deceases	0	34 (97.14%)	0
Time of diseases	0		0
Increase in labour	16 (45.71%)	18 (51.42%)	0
Increase in financial loss	0	16 (45.71%)	18 (51.42%)
Increase in social problem	0	18 (51.42%)	16 (45.71%)

Table 5: Impact of climate change on the types of agricultural crops

N=35	Change in last 30 years		
	Moderate	Much	Very much
Paddy	0	32 (91.42%)	0
Mango and Litchi	16 (45.71%)	16 (45.71%)	0
Fish	0	16 (45.71%)	16 (45.71%)
Vegetables	16 (45.71%)	16 (45.71%)	0
Wheat	16 (45.71%)	16 (45.71%)	0

Table 5 summarizes the opinions of the participants regarding the impact of climate change on the types of agricultural crops. Production of paddy, mango, litchi and vegetables and wheat are being hampered due to climate change. The “Challonbil” was a reservoir of huge quantity of water, lot of different species of fish and birds were available there before. Native species of paddy used to be grown there. Now, this Challonbil is dried up and the whole ecosystem was changed. Fishes and birds are not now available there. So, the people around the Challonbil are facing financial crisis. Agriculture production in the Rajshahi region has decreased due to climate change and

this decrease in crop production occurred mostly in last 30 years. Original species of paddy and fish are being lost due climate change and replace by artificial/breed species of fish. As a result, the people are suffering from malnutrition.

4.4.3 Effect of Farakka dam on climate change at Rajshahi

In the group discussion, the effects of Farakka dam on climate change, agriculture, health and water quality were discussed. The participants gave their opinions as follows:

i. The river flow has been reduced significantly.
ii. The river bed has filled up very much due to siltation for the reduction of the river flow. Some rivers already died. As a result less water in the river and ponds is available now-a-days.
iii. More underground water is being used for irrigation and drinking purposes.
iv. The water quality is being deteriorated, causing health hazards.
v. Because of the less availability of water, the climate is changing at Rajshahi. Temperature is increasing and rainfall is decreasing. Frequency of heat waves in summer and cold waves in winter are increasing. Production of agricultural crops is decreasing.
vi. It has great impact on Challonbil, which remains almost dry in the dry season. Different species of fish, which were available in the past, are no more in the Challonbil. Before many species of birds used to live in this Challonbil. Now, these birds are not there.

4.4.4 Recommendations in the workshop

i. Organic fertilizer should be used in agricultural land for crop production since chemical fertilizer reduces the fertility of land. Use of pesticides should be reduced.
ii. Climate change adapted crop patterns should be innovated so that crops can withstand the stresses due to rising trend of temperature and decreasing trend in rainfall at Rajshahi.
iii. Appropriate adaptation techniques should be developed for facing the challenges of climate impacts in long-term perspectives.
iv. It is necessary to develop and implement appropriate plans, strategies and programs to address the problems arising from arsenic contamination of water in local and national perspectives.
v. Use of ground water for agriculture should be reduced considerably and arrangements be made for harvesting of rain water.
vi. Native species of fish and crops should be grown instead of artificial crops and fishes.
vii. Water storage has to be increased by digging cannel and ponds so that more water would be accommodated. The rivers, cannel, ponds and 'Challonbil' should be re-excavated for storage of water coming through the Farakka Dam and rain water.
viii. Since building materials are good absorbers and emitters of heat, they increase the heat content in the earth's surface; the use of these materials should be restricted to inhibit the contribution to climate change.
ix The water flow of the Padma has been reduced due to Farakka Dam. For maintaining the navigability of the Padma/Ganges, the Water Treaty needs to be revised through bilateral negotiation.

5 CONCLUSIONS

On the basis of the present study, the following conclusions can be drawn:

i. The trend in annual mean temperature at Rajshahi has a sharp increasing trend at 0.013°C/year during the period 1981-2016. The seasonal mean temperature has increasing trends in pre-monsoon, monsoon and post-monsoon seasons during 1981-2016, having 0.021, 0.024 and 0.004°C/year respectively. The mean temperature in winter has decreasing trend at 0.007°C/year. It is interesting to note that the mean temperature during the winter season has a slight increasing trend during the period 1990-2016.
ii. The annual rainfall at Rajshahi during the period 1981-2016 is decreasing trend at 6.968 mm/year. This decreasing rate is alarming and is likely cause drought at Rajshahi in future. The seasonal rainfall during pre-monsoon monsoon at Rajshahi has increasing trend 0.723 mm/year. The seasonal rainfall at Rajshahi has decreasing trends in other seasons. The rates of decrease are -6.433, -0.669 and -0.532 mm/year during the monsoon, post-monsoon and winter seasons respectively. Of these, monsoon season has the maximum decreasing rate of -6.433 mm/year. This indicates that the drought condition is likely to increase at Rajshahi.

iii. The frequency of minimum temperature less than 10°C (cold waves) over Rajshahi during 1981-2016 varies from 7 to 39 days in a year at Rajshahi and it has increasing trend at 0.035 days/year. The annual frequency of days with maximum temperature >36°C has increasing tendency at Rajshahi at 0.655 days/year during 1981-2016.

iv. The continuation of the increase in the annual frequency of days with minimum temperature <10°C and maximum temperature >36°C i.e. cold waves and heat waves would have tremendous impacts on the agriculture sector and food security (crops, animals, etc.) in future and the situation would be more aggravated in Rajshahi.

v. Inter-annual and inter-decadal climate variability exists at Rajshahi. Rise in temperature at Rajshahi will have profound effect on agriculture.

vi. Climate change will affect the use of water and its quality at Rajshahi. Drought is likely to affect Rajshahi in the long run. Agricultural patterns are likely to change too.

vii. Because of the less availability of water, the climate is changing at Rajshahi. Temperature is increasing and rainfall is decreasing. Frequency of heat waves in summer and cold waves in winter are increasing. Production of agricultural crops is decreasing.

viii. Climate change adapted crop patterns should be innovated so that crops can withstand the stresses due to rising trend of temperature and decreasing trend in rainfall at Rajshahi. Appropriate adaptation techniques should be developed for facing the challenges of climate impacts in long-term perspectives.

ACKNOWLEDGEMENT

The Authors wish to thank the Director of Bangladesh meteorological Department (BMD) for supplying relevant meteorological data. Thanks are also due to the Executive Director of Environment and Population Research Centre (EPRC) for giving the opportunity for undertaking the study.

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