ISSN 1562-269X

SOCIAL SCIENCE REVIEW

The Dhaka University Studies, Part-D

Volume 29 • Number 1 • June 2012

Faculty of Social Sciences
University of Dhaka

Social Science Review [The Dhaka University Studies, Part-D], Vol. 29, No. 1, June 2012

Effects of Climate Change on Crop Production and Climate Adaptive Techniques for Agriculture in Bangladesh

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Abstract: *There have been a number of studies since the IPCC Fourth Assessment Report detailing impacts of climate change on agricultural production at global, regional and national levels, yet hardly any scientific attempts have been made in Bangladesh to suggest adaptive techniques to adapt to climate variability and change by way of looking at changing temperatures and rainfall patterns in different agro-ecological zones (AEZs). The current research was conducted in six AEZs in the three most vulnerable regions in Bangladesh: AEZs 2 and 7 in the Northwestern region, AEZs 4, 7 and 11 in the Central region and AEZs 10 and 12 in the Southern region of the country, analyisng changing patterns of temperature and rainfall for 33 years (1976-2008). It found that the changing pattern of temperature and rainfall in these selected three regions are significantly higher compared to IPCC prediction, stipulating the urgency and the immediacy of location specific sustainable practice of adaptation. The paper, thus, suggests some location appropriate and science-based sustainable adaptation measures in terms of management of seed, crop, and irrigation, following extensive consultations with the farmers of the study areas.*

Keywords: Adaptation, agriculture, Bangladesh, climate change, crop production

1. Introduction

Bangladesh is recognised as one of the most vulnerable countries to climate change because of its geographic exposure, and greater reliance on climate sensitive sectors, such as agriculture. The severity of such exposures has continued to worsen by lack of the mitigation responses necessary to contain the changes in the global atmosphere, mainly by the Annex - I countries and the availability of required levels of financial, technological and capacity-building resources that will allow countries such as Bangladesh to adapt with speed and effectiveness. Besides having been creating multiple stresses and adverse impacts on the maintenance of course of the development and the right to grow and to catch up in countries like Bangladesh

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4) summarises the scientific evidence on impacts up until 2006. The evidences demonstrate that composition of global atmosphere is changing, e.g. increasing atmospheric concentrations of greenhouse gases (GHG), such as carbon-di-oxide (379 ppm recorded in 2005), methane (1774 ppb recorded in 2005) and nitrous oxide (319 ppb

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recorded in 2005) (IPPC, 2007). The IPCC – AR4 predicts that global average temperature is expected to increase by 0.2°C per decade over the next two decades. If temperatures continue to increase at this rate, it adds, global average temperature increase (from 1905) will reach 1.5°C by 2050. It also points out that larger increases (0.3°C-0.4°C or greater per decade) are expected on cultivated land areas and large landmasses.

Since IPCC-AR4 scientific understanding of impacts of climate change has progressed significantly. These studies, amongst others, take advantage of developments in climate and scientific modeling to provide a more specific picture of current impacts and predicted changes over the next several decades. For example, Stanford researchers recently published analysis in *Nature* documenting that from 1980-2008, due to rising global temperatures, global maize and wheat production has already decreased by 3.8% and 5.5% respectively (Lobell et al., 2011).

Continuing emissions of greenhouse gases and other anthropogenic factors are likely to result in significant changes in mean climate and its intra-seasonal and inter-annual variability in the Asian region. Bangladesh, being in South Asia, is one of the most vulnerable countries regarding the impacts of climate change.

The variability of climate change has become a challenging issue for agriculture. Agricultural crops of Bangladesh are especially sensitive to the different variables of climate such as temperature, rainfall, humidity, day-length etc. as well as different natural disasters including floods, drought, salinity, storm surges etc.

Rainfall and tempertaure are two climatic variables that shape the structure of socio-ecological system. Any alternation of rainfall and temperature cycle, as a result of climate change, hampers agriculture production significantly. For example, rice plant has nine growth stages with its three distinct growth phases and every stage has an optimum temperature range for its proper development. The critical temperatures differ according to variety, duration of the critical temperature, diurnal changes and physiological status of the plant (Yoshida, 1981). High temperatures are a constraint to rice production and cause a significant yield reduction. Crop often respond negatively with a steep decline in net growth and yield, if temperatures exceed the optimal level of biological processes (Rosenzweig and Hillel, 1995). Basak *et al.* (2010) predicted significant reduction in yield of some varieties of boro rice due to climate change in Bangladesh. Yield reductions of over 20% and 50% have been predicted for the years 2050 and 2070, respectively. Another research, taking into account the IPCC 4th assessment report (2007) projected temperature rise (1.8 to 4^{0}C), shows that rice yield would be reduced by 10.41% and 22.87% due to increased maximum temperature at the level of 2^{0}C and 4^{0}C respectively in Bangladesh (Basak, 2009). Karim *et al.* (1996) argue that a significant yield reduction may have occurred for rice and wheat (35% and 31%, respectively) due to changing climatic conditions in Bangladesh.

Adaptive capacity is the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Goklany, 1995; Burton, 1997; Cohen *et al.* 1998; Klein, 1998; Rayner and Malone, 1998; Munasinghe, 2000; Smit *et al.*, 2000). Therefore, location-wise and scientifically based sustainable adaption practices are essential to cope up with the changing climatic conditions. Otherwise, it will be very difficult to make communities more resilient towards adverse impacts of climate change.

Bangladesh is divided into 30 AEZs. Geographically, Northwestern and central region are flood stricken area. Almost every year, these areas experience flood and consequent riverbank erosion. On the other hand, Southern regions witness salinity intrusion as a consequence of backwater effect due to climate change.

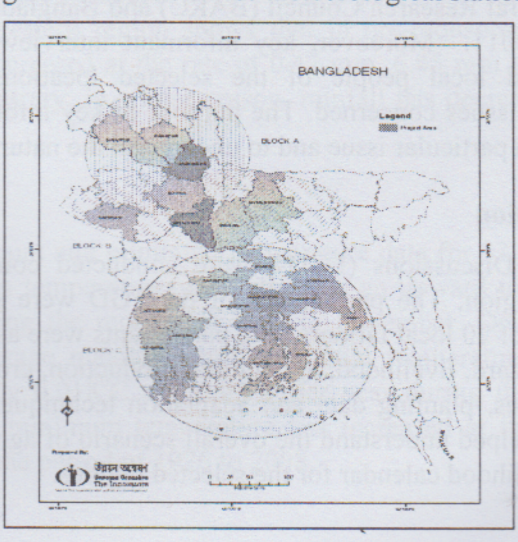
The main objective of the article is to suggest suitable adaptation techniques that have the potential to help farmers to adapt climate change. These include, amongst others, identification of suitable cropping patterns, choice of seeds, management of irrigation, and intensification of crop. Therefore, the research analyses the changing pattern of climatic parameters, mainly temperature (monthly and yearly average of maximum and minimum temperatures) and rainfall for the selected regions. It also focuses on the impacts of climatic variability (changing temperature and rainfall pattern) on crop production.

2. Methodology

2.1 Selection of locations

The reserach was conducted in the three most vulnerable regions in Bangladesh. They were Northwestern region (AEZs 2 and 7), Central region (AEZs 4, 7 and 11) and Southern region (AEZs 10 and 12). For these, Bogra, Dinajpur and Rangpur weather stations were selected for Northwestern region; Bogra, Mymensingh, Ishurdi and Rajshahi for Central region and Barisal, Bhola, Chandpur, Comilla, Dhaka, Faridpur, Feni, Jessore, Khulna, Madaripur, Patuakhali and Satkhira for Southern region (Figure 1).

Figure 1: Location wise meteorological stations



2.2 Climate data collection and data range

The data on temperature and rainfall of 18 weather stations in Bangladesh were collected from the Bangladesh Meteorological Department (BMD). The data on temperatures include monthly average and annual mean of maximum and minimum temperatures for the period of January 1976 through December 2008, and daily rainfall for the same period.

Monthly-average maximum temperature data have been used to assess the changes in maximum temperature. These data are 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 are assessed for each of the 18 stations. In each case, only linear trend is assessed for the period 1976-2008 and the nature (increasing or decreasing) and significance of trend is 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.

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 of "intense precipitation events" could not be made from the available data on precipitation.

2.3 Crop data collection

Crop related data such as crop varieties, irrigation methods, cropping pattern, plantation etc. are collected from Bangladesh Rice Research Institute (BRRI), Bangladesh Agriculture Research Institute (BARI), Bangladesh Jute Research Institute (BJRI), Bangladesh Agricultural Research Council (BARC) and Bangladesh Sugarcane Research Institute (BSRI) in 2011. Moreover, key informant interviews were conducted with resource persons and local people of the selected locations who have first-hand knowledge about the issues concerned. The purpose of key informant interviews was to collect information on particular issue and to understand the nature of problems.

2.4 Field data collection

Three Focus Group Discussions (FGDs) were conducted comprising both men and women from each region. The participants of the FGD were selected using snowball sampling, comprised of 20 local farmers. The participants were asked questions regarding the climate related hazard, livelihood, agricultural production, cropping pattern, irrigation methods, crop varieties, planting date and adaptation techniques applied in field level. The field level data helped understand the overall scenario of agriculture practices and to develop crop and livelihood calendar for the selected regions.

3. Changes in Maximum and Minimum Temperature and Rainfall

The rainfall variability and distribution, and changes in temperature may cause the most disruption to crop yields. Temperature, as noted earlier, is significant for physiological processes of a crop, particularly affecting phases such as pollination and grain filling, and basic photosynthesis. Accordingly, high temperatures, lasting over a series of days or an extreme spike of several hours, can have negative effect on these processes, with consequential implications on yields. The botanists state that extreme heat events of even short duration during flowering or pollination can severely reduce harvest (Araus et al., 2008; Semenov and Halford, 2009).

Yet the major models that have been developed to date to evaluate the impacts of climate changes on agriculture cannot factor in well the temperature dependency of these key variables and thus may lead to underestimation of the potential impacts of rising temperatures on agricultural production and yields (Stanford University, 2009). Moreover, some writers also call into question an "over-optimistic reliance" on the potential for increased CO2 concentrations to counter the yield-reducing effects of increasing temperatures (for example, see Long et al., 2005 and Long et al., 2006).

3.1 Northwestern region

The analysis of monthly average maximum and minimum temperature shows that monthly average maximum temperature have increased at the rate of 0.01^0C per year, whereas monthly average minimum temperature increased at a rate of 0.04^0C per year. Moreover, increasing trend is particularly significant for the month of May to December. On an average, the total change of monthly average maximum and minimum temperature for these particular months has increased about 1^0C during this period (Figure 2 and 3). Yearly average maximum and minimum temperature has increased at the rate of 0.03^0C and 0.01^0C, respectively. (Figure 4).

Rainfall data for winter, pre-monsoon, monsoon and post-monsoon during the period of 1976 - 2008 in Northwestern region shows that in pre-monsoon, monsoon and post-monsoon, rainfall has increased at the rate of 0.42 mm, 6.45 mm and 5.56 mm per year respectively. On the contrary, in winter season, rainfall has decreased at the rate of 0.2 mm per year (Figure 5).

3.2 Central region

Monthly average maximum and minimum temperature data for 33 years shows that both maximum and minimum temperatures are following an upward trend. Moreover, rising trend is significant during the months of May to December. On an average, the total change of monthly average maximum and minimum temperature for these particular months has increased by 0.018^0C and 0.02^0C per year during this period. The yearly average maximum and minimum temperature has increased at the rate of 0.02^0C and 0.01^0C respectively for the period of 1976 to 2008.

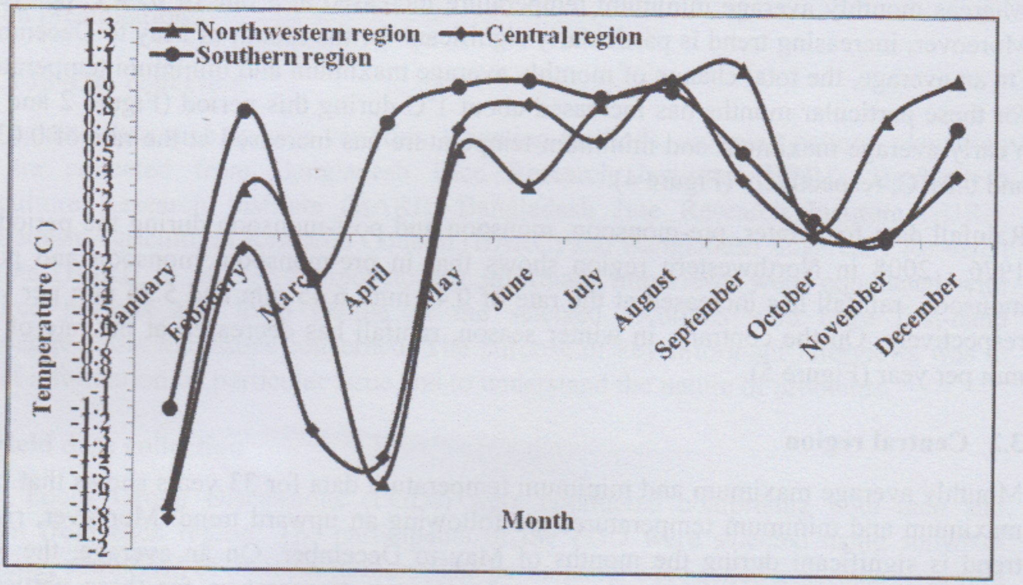
The rainfall has increased during monsoon and post-monsoon periods whereas decreasing trend is witnessed in winter and pre-monsoon seasons. The rainfall has increased by 2.1 mm and 3.04 mm in monsoon and post-monsoon seasons respectively in each year. On the other hand, it has decreased at the rate of 0.5 mm and 1.5 mm per year during winter and pre-monsoon periods respectively.

3.3 Southern region

The monthly average maximum temperature has increased at the rate of 0.015^0C per year. Moreover, increasing trend is particularly significant for the months between of April and December except November. On an average, the total change of monthly average maximum and minimum temperature for the particular months except November has increased by nearly about 1^0C during this period. The yearly average maximum and minimum temperature has increased at the rate of 0.02^0C and 0.014^0C respectively.

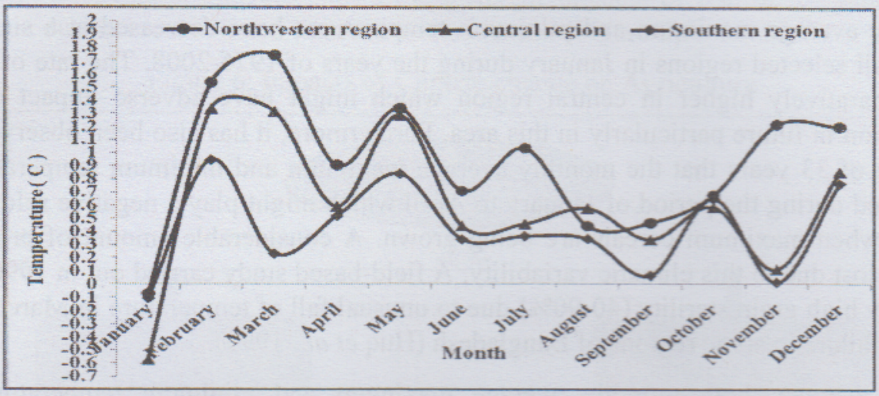
The rainfall during monsoon and post-monsoon seasons has increased whereas it decreased in winter and pre-monsoon seasons at southern region in Bangladesh. The changing pattern of rainfall in each year is found to increase by 5.47 mm and 2.90 mm in monsoon and post-monsoon season respectively. In winter and pre-monsoon periods, it has decreased at rate of 0.4 mm and 1.75 mm per year.

Figure 2: Changes in monthly average maximum temperature during 1976-2008



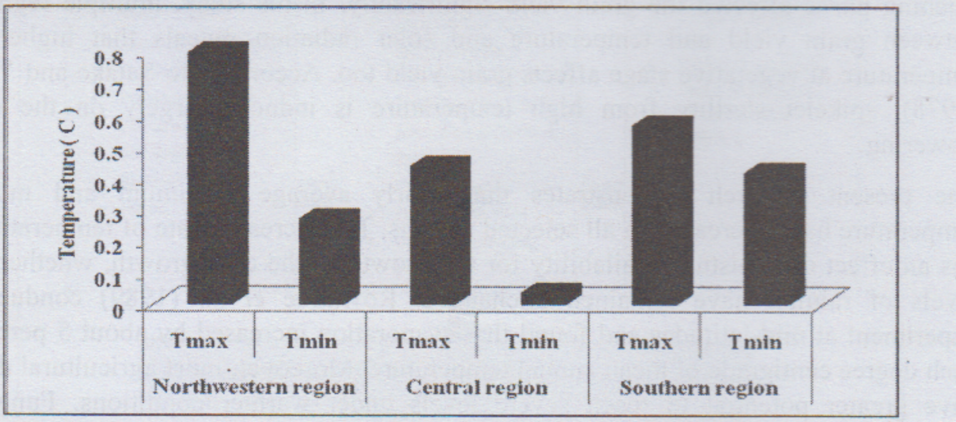
Source: Authors' calculation based on BMD, 2010

Figure 3: Changes in monthly average minimum temperature during 1976-2008



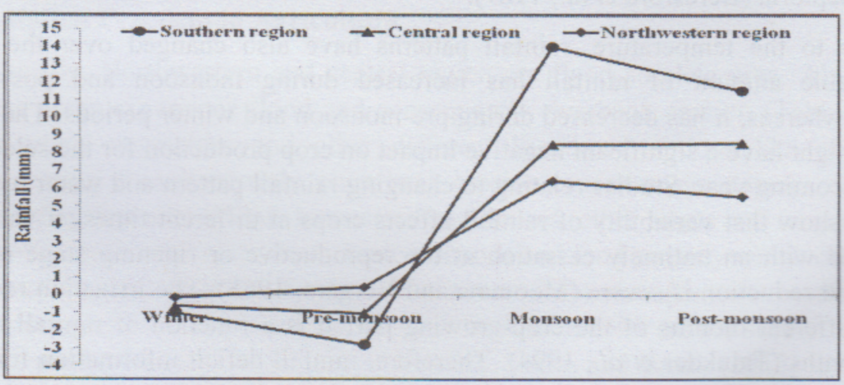
Source: Authors' calculation based on BMD, 2010

Figure 4: Changes in annual average maximum and minimum temperature during 1976-2008



Source: Authors' calculation based on BMD, 2010

Figure 5: Changing pattern of rainfall in selected regions during 1976-2008



Source: Authors' calculation based on BMD, 2010

3.4 Impacts of Changing Climatic Parameters on Crop Production

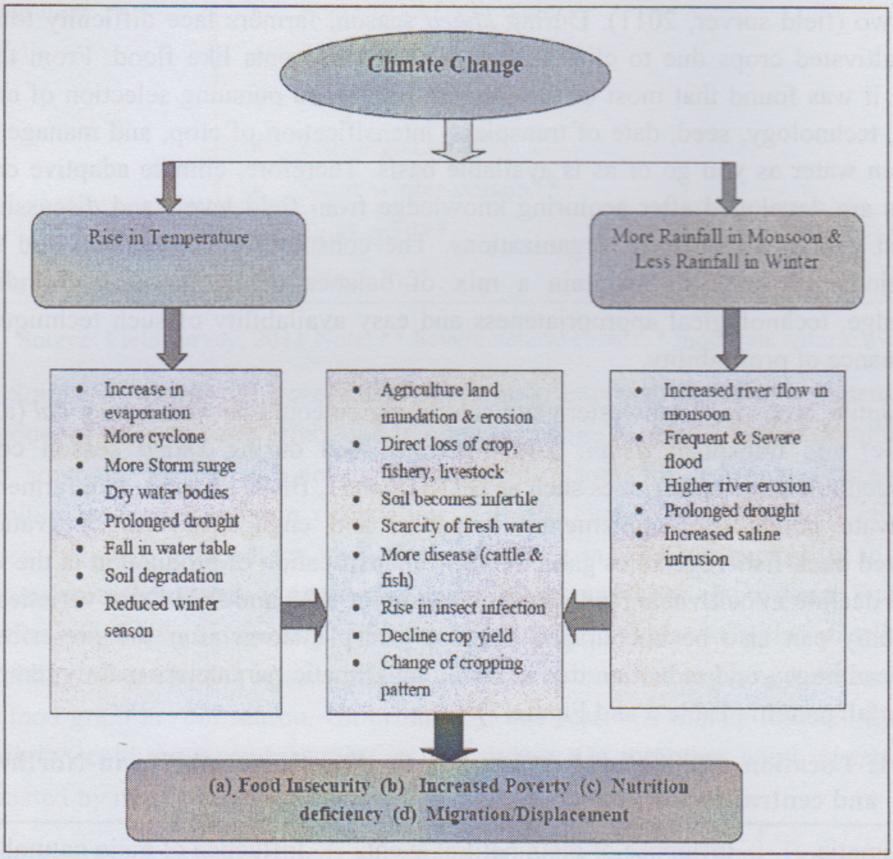
Monthly average maximum and minimum temperatures have decreased at a significant rate in all selected regions in January during the years of 1976-2008. The rate of change is comparatively higher in central region which might have adverse impact on crop production in future particularly in this area. Furthermore, it has also been observed from the data of 33 years that the monthly average maximum and minimum temperature has fluctuated during the period of January to April which might play a negative role on *robi* season when maximum cereals are being grown. A considerable amount of production may be lost due to this climatic variability. A field-based study carried out in 1990 shows that very high grain sterility (40-90%) due to unusual fall of temperature in March results in crop failure in some regions of Bangladesh (Huq *et al.*, 1999).

On an average, both monthly average maximum and minimum temperature have increased each year at a rate of 0.02^0C during May to October. The increased rate of temperature might have a significant negative impact on *kharif* crops and a part of *robi* crops in future. Islam (1995) shows that the higher minimum temperature during the ripening phase affected the grain yield significantly. In his study, multiple regressions between grain yield and temperature and solar radiation reveals that higher mean temperature at vegetative stage affects grain yield too. According to Satake and Yoshida (1978), spikelet sterility from high temperature is induced largely on the day of flowering.

The present research demonstrates that yearly average maximum and minimum temperature have increased in all selected regions. The increased rate of temperature also has an effect on moisture availability for the growth of the crop growth, whether or not levels of rainfall have remained unchanged. Rowntree *et al.* (1989) conducted an experiment at mid-latitudes and found that evaporation increased by about 5 percent for each degree centigrade of mean annual temperature. Moreover, most agricultural diseases have greater potential to reach severe levels under warmer conditions. Fungal and bacterial pathogens are likely to increase in severity in areas where precipitation increases. Under warmer and more humid conditions, cereals are more prone to diseases such as Septoria (Beresford *et al.*, 1989).

Similarly to the temperature, rainfall patterns have also changed over the years. A considerable amount of rainfall has increased during monsoon and post-monsoon seasons, whereas, it has decreased during pre-monsoon and winter periods. The changing pattern might have a significant negative impact on crop production for the selected areas in the upcoming year. Studies relating to changing rainfall pattern and water requirement of crops show that variability of rainfall affects crops at different times. If variability is associated with an untimely cessation at the reproductive or ripening stage of the rice crop, yield reduction is severe (Moomaw and Vergara, 1965). The irrigation requirement during different months of the crop-growing period is a function of rainfall deficits in those months (Talukder *et al.*, 1994). Therefore, rainfall deficit information for different areas and periods can greatly help determine water release from sources (ground or surface). A schematic diagram shows the different impacts of rise in temperature and more rain during monsoon and lesser in winter season (Figure 6).

Figure 6: Impacts of Climate change on Agriculture



Source: Field survey, 2011

4. Adaptation Practices in Agriculture

Geographically, Northwestern and central region are flood stricken area. Almost every year, these areas experience flood and consequently riverbank erosion (Table 1). Flood damages crops, vegetables and other different livelihood options like poultry and livestock rearing. Simultaneously, river bank erosion causes severe damage of standing crops including agriculture land, homestead and houses, other assets and trees and plants that altogether put severe stresses on the livelihoods and food security which often led the affected households in debt and consequential poverty. For example, two rounds of floods and devastating cyclone Sidr in 2007 and cyclone Aila in 2009 caused severe damages in agriculture production, especially rice production. Uddin and Basak (2012) revealed that on an average, 256.1 ha and 622.2 ha of agriculture land was eroded per year due to river bank erosion at Gaibandha and Sirajganj regions in Bangladesh respectively during the period of 1973-2009.

Most of the farmers of these locations are paddy producers and cropping intensity is near about two (field surver, 2011). During *kharif* season, farmers face difficulty to harvest their cultivated crops due to climate induced natural events like flood. From the field survey, it was found that most of the farmers have been pursuing selection of cropping pattern, technology, seed, date of transplant, intensification of crop, and management of irrigation water as you go or as is available basis. Therefore, climate adaptive cropping patterns are developed after acquiring knowledge from field levels and discussing with different experts of different organizations. The consultative process that led to such suggestions has tried to maintain a mix of balance of traditional and indigenous knowledge, technological appropriateness and easy availability of such techniques, and maintenance of profitability.

The adaptive crops in Northwestern and central region could be wheat, *mug dal* (a variety of pulse) and transplant *aman*. The preferred seed during *kharif* season could be submerged tolerant rice varieties such as BRRI *dhan51*, BRRI *dhan*52. The farmers could re-excavate ponds for supplemental irrigation and engage in fish cultivation and integrated duck-fish-vegetables gardening for intensification of production in the wake of gradual decline in cultivable land. Transplantation of BR3 and BR14 rice varieties before 15 January can also be encouraged because transplantation after the prescribed time might lead huge yield reduction due to changing climatic parameters mainly temperature and rainfall pattern (Table 3 and Figure 7).

Table 1: Location-wise natural events due to climatic variability in Northwestern and central region

Climatic parameters	Influence of main natural events in Northwestern region	Influence of main natural events in central region
Temperature Rainfall	• Flood** • River bank erosion** • Drought* • Prolonged heat** • Short winter season** • Cold spell** • Dense fog*	• Flood** • River bank erosion** • Drought* • Prolonged heat** • Short winter season** • Cold spell** • Dense fog*

Source: Field survey, 2011 **Note:** ** Severe natural events; * moderate natural events

Table 2: Location-wise natural events due to climatic variability in Southern region

Climatic parameters	Influence of main natural events in southern region
Temperature Rainfall	• Scarcity of fresh water** • Saline water intrusion** • Drought* • Prolonged heat** • Short winter season** • Cold spell** • Dense fog*

Source: Field survey, 2011 Note: ** Severe natural events; * moderate natural events

The Southern region is increasingly becoming exposed to salinity intrusion as a consequence of backwater effect due to climate change (Table 2). River dominated areas make southern region as one of the suitable places for artisanal fishing, besides agriculture as people's main occupation. Climate change has, however, changed the scenario. Climate induced sea level rise is resulting in accruing backwater to the rivers and consequently salinity is increasing in the rivers and agricultural land. Such salinity intrusion is not only hampering agriculture production but also affecting distribution and availability of native fish species. Usually, the farmers in the region produce majority of their food grain in *robi* season. Unfortunately, this season is mostly affected by intrusion of salinity, cold wave, and scarcity in fresh water. On the other hand, *kharif* season is dominated by rain-fed agriculture.

Some climate adaptive practices suggested in this location include Boro rice, T.aman rice and/or jute. Short duration and saline tolerant boro rice varieties like BRRI *dhan*47 and saline tolerant rice varieties such as BRRI *dhan*40, BRRI *dhan*41, BRRI *dhan*53, BRRI *dhan*54 can be introduced to the local farmers during *kharif* season. The supplemental irrigation can be maintained through excavation of mini ponds and harvesting of surface water. In such places, an integrated duck-fish-vegetables gardening could be introduced for intensification of crops and for addressing the scarcity of land. Transplant *aman* rice can also be cultivated before 1 June to minimise drop in yield (Table 4 and Figure 8).

Table 3: Adaptation options for Northwestern and central region

Management/Practices	Adaptation options
Cropping pattern	• Boro rice-T.aman • Wheat-Mug dal (Pulse)-T.aman • Chilli - T.aman • Maize -T.aman • Mustard-Mug dal (Pulse)-Jute • Mustard-Mug dal (Pulse)-T.aman • Sweet gourd-T.aman • Potato-Mug dal-T.aman
Seed	• Short duration boro rice varieties –BRRI *dhan*28 • Short duration and cold tolerant boro rice varieties-BRRI *dhan*36 • Submerged tolerant rice varieties during *kharif* season-BRRI *dhan* 51, BRRI *dhan*52 • Short duration rice varieties during *kharif* season-BRRI *dhan*39, BRRI *dhan*33 • Drought tolerant rice varieties during *kharif* season-BRRI *dhan*42, BRRI *dhan*43 • Low water requirement and short duration wheat varieties-Hashi • Short duration pulse varieties-BARI Mug-6 • Cold tolerant potato varieties-Diamond, Cardinal
Irrigation management	• Supplemental irrigation • Excavation of mini ponds and surface water harvesting for supplemental irrigation • Re-excavation of ponds for supplemental irrigation and fish cultivation • Dry seed bed preparation during *kharif* season for T.aman rice • Cultivation of wheat for water use efficiency
Crop intensification	• Integrated rice-fish cultivation • Integrated rice-fish-vegetables cultivation • Integrated duck-fish-vegetables gardening (GUK, 2011) • Homestead gardening over the years
Selection of suitable date for rice transplantation	• Before 15 January for boro rice transplantation • 1 June for T.aman rice transplantation

Source: Developed by authors through discussions with BRRI, BARI, BJRI, BSRI and BRRI Rich Farming division, and local farmers, 2011

Table 4: Adaptation options for Southern region

Management/Practices	Adaptation options
Cropping pattern	• Boro rice-T.aman rice/Jute • Wheat-Mug dal (Pulse)-T.aman/Jute • Chilli-T.aman/Jute • Maize-T.aman/Jute • Mustard-Mug dal (Pulse)-Jute • Mustard-Mug dal (Pulse)-T.aman • Sweet gourd-T.aman/Jute • Potato-Mug dal-T.aman/Jute
Seed	• Short duration boro rice varieties –BRRI *dhan*28 • Short duration and saline tolerant boro rice varieties-BRRI *dhan*47 • Saline tolerant rice varieties during *kharif* season-BRRI *dhan*40, BRRI *dhan*41, BRRI *dhan*53, BRRI *dhan*54 • Short duration rice varieties during *kharif* season-BRRI *dhan*39, BRRI *dhan*33 • Drought tolerant rice varieties during *kharif* season-BRRI *dhan*42, BRRI *dhan*43 • Saline tolerant jute varieties-CVL-1, HC-95 • Saline tolerant sugarcane varieties-ISWARDI-40 • Low water requirement and short duration wheat varieties-Hashi • Short duration pulse varieties-BARI Mug-6 • Cold tolerant potato varieties-Diamond, Cardinal
Irrigation management	• Supplemental irrigation • Excavation of mini ponds and surface water harvesting for supplemental irrigation • Dry seed bed preparation during *kharif* season for T.aman rice • Re-excavation of ponds for supplemental irrigation and fish cultivation • Cultivation of wheat for water use efficiency
Crop intensification	• Integrated rice-fish cultivation • Integrated rice-fish-vegetables cultivation • Integrated duck-fish-vegetables gardening (GUK, 2011) • Homestead gardening over the years
Selection of suitable date for rice transplantation	• Before 15 January for boro rice transplantation • 1 June for T.aman rice transplantation

Source: Developed by authors through discussions with BRRI, BARI, BJRI, BSRI and BRRI Rich Farming division and local farmers, and local farmers, 2011

Figure 7: Suggested Crop Calendar for Northwestern and central region

Month/Crops	January	February	March	April	May	June	July	August	September	October	November	December
	Poush	*Magh*	*Falgun*	*Choitro*	*Boishakh*	*Joishtho*	*Asharh*	*Srabon*	*Bhadro*	*Ashvin*	*Kartik*	*Ograhayon* *Poush*
Boro rice-T.aman	BRRI *dhan* 28				BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)						BRRI *dhan* 28	
Wheat-Mug dal-T.Aman	Wheat (Hashi developed by BARI)		Mug dal (BARI Mug 6)				T. Aman (BRRI *dhan* 39 and BRRI *dhan* 33)			Wheat (Hashi developed by BARI)		
Chilli-T.aman	Chilli				BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)					Chilli		
Maize-T.aman	Maize				BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)					Maize		
Mustard-Mug dal-Jute	Mustard		Mug dal (BARI Mug 6)		Jute					Mustard		
Mustard-Mug dal-T.aman	Mustard		Mug dal (BARI Mug 6)		BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)					Mustard		
Sweet gourd-Jute/T.aman	Sweet gourd				BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)/Jute					Sweet gourd		
Potato-Mug dal-Taman/Jute	Potato		Mug dal (BARI Mug 6)		BRRI *dhan* 51 and BRRI *dhan* 52 (Submerged Tolerant)/Jute					Potato (Diamond/Cardinal variety)		

Source: Developed by authors following detailed discussions with BRRI, BARI, BJRI and BRRI Rich Farming division, and local farmers, 2011

Figure 8: Suggested Crop Calendar for Southern region

Month/Crops	January	February	March	April	May	June	July	August	September	October	November	December
	Poush	*Magh*	*Falgun*	*Choitro*	*Boishakh*	*Joishtho*	*Asharh*	*Srabon*	*Bhadro*	*Ashvin*	*Kartik*	*Ograhayon* *Poush*
Boro rice-T.aman	BRRI *dhan* 47 (Salinity Tolerant-12-14 ds/m)				BRRI *dhan* 40 and BRRI *dhan* 41 (Salinity Tolerant-8 ds/m)						BRRI *dhan* 47	
Wheat-Mug dal-T.Aman	Wheat (Hashi developed by BARI)		Mug dal (BARI Mug 6)				BRRI *dhan* 40 (Salinity Tolerant-8 ds/m)			Wheat (Hashi developed by BARI)		
Chilli-T.aman	BRRI *dhan* 47 (Salinity Tolerant-12-14 ds/m)				Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)					BRRI *dhan* 47		
Maize-T.aman	Maize				BRRI *dhan* 40 and BRRI *dhan* 41 (Salinity Tolerant-8 ds/m)/ Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)					Maize		
Mustard-Mug dal-Jute	Mustard		Mug dal (BARI Mug)		BRRI *dhan* 40 and BRRI *dhan* 41 (Salinity Tolerant-8 ds/m)/ Jute (CVL-1 and HC-95) (Salinity Tolerant-8 ds/m)					Mustard		
Mustard-Mug dal-T.aman	Sugarcane (ISWARDI-40)											

Source: Developed by authors after detailed discussions with BRRI, BARI, BJRI, BSRI and BRRI Rich Farming division, and local farmers, 2011

Table 5: Relative tolerance of some crops to salinity

Tolerant(8-12dS/m)	Medium tolerant(6-8 dS/m)	Medium Sensitive(4-6 dS/m)	Sensitive(0-4 dS/m)
Data Shak	Soybean	Rice, paddy	Bean
Sugar beet	Beet	Tomato	Onion
Barley	Wheat	Corn	Carrot
Cotton	*Dhiancha*	Potato	Mungbean

Source: Developed by authors through discussion with BRRI, BARI, BJRI, BSRI and BRRI Rich Farming division, and local farmers, 2011

4. Conclusion

In Bangladesh, different climate change induced events such as recurring floods, riverbank erosion, drought in dry season, salinity intuition have been augmenting vulnerability in many regions and leaving impacts on the yields of crops. Contextual analysis suggests that unless urgent actions are taken, climate change will undermine efforts to ensure food security.

The research finds that the changing pattern of temperature and rainfall for the selected three regions are significantly higher compared to IPCC prediction over the world in last 100 years, which have considerable negative impacts on crop production. Therefore, location-wise and scientifically based sustainable adaption practices are essential to cope up with the changing climatic conditions. Otherwise, it would be very difficult to make communities more resilient towards adverse impacts of climate change and ensuring food security.

From the field study, it is observed that most of the farmers of these locations pursue as is available cropping patterns. During *kharif* season, they have been particularly facing difficulties in harvesting their cultivated crops due to climate induced natural events. The study has shown that there has been changing pattern of temperature and rainfall in 33 years (1976 to 2008) in all 18 metrological stations surrounding the selected three locations and the change of those climatic parameters are significant during this period.

Considering the main climate induced natural events, adaptation practices in terms of cropping pattern, choice of seed, management of irrigation, intensification of crops and selection of suitable date for transplantation have been suggested to help farmers adapt to climate change. However, it is difficult to confirm a crop as adaptive to climate change situations unless at least three years of experimentation is carried out. The selected crop varieties, irrigation management, cropping pattern, crop intensification and selection of suitable date for rice transplantation for both *robi* and *kharif* season are needed to be confirmed by trails.

Acknowledgement

The research is conducted as a part of the programme titled Regenerative Agriculture and Sustainable Livelihood for Vulnerable Ecosystems (RESOLVE), implemented by GUK in Gaibandha, SDS in Shariatpur and GKS in Sirajganj, with technical assistance from Unnayan Onneshan and financial support from Oxfam Novib. Acknowledgement goes to local farmers who helped a lot by providing valuable opinion and information. The Authors also acknowledges comments and supports of Mr. Palash Kanti Das and Mr. Mohammed Abdul Baten of Unnayan Onneshan and Dr. Md. Abdur Rashid, Dr. Jiban Krishna Biswas, Dr. Abhijit Shaha, Md. Abdus Salam and Md. Khairul Kayesh of Bangladesh Rice Research Institute (BRRI), Gazipur.

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